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Supporting Information

Vapor Phase Deposition of Perovskite Photovoltaics: Short Track to Commercialization?

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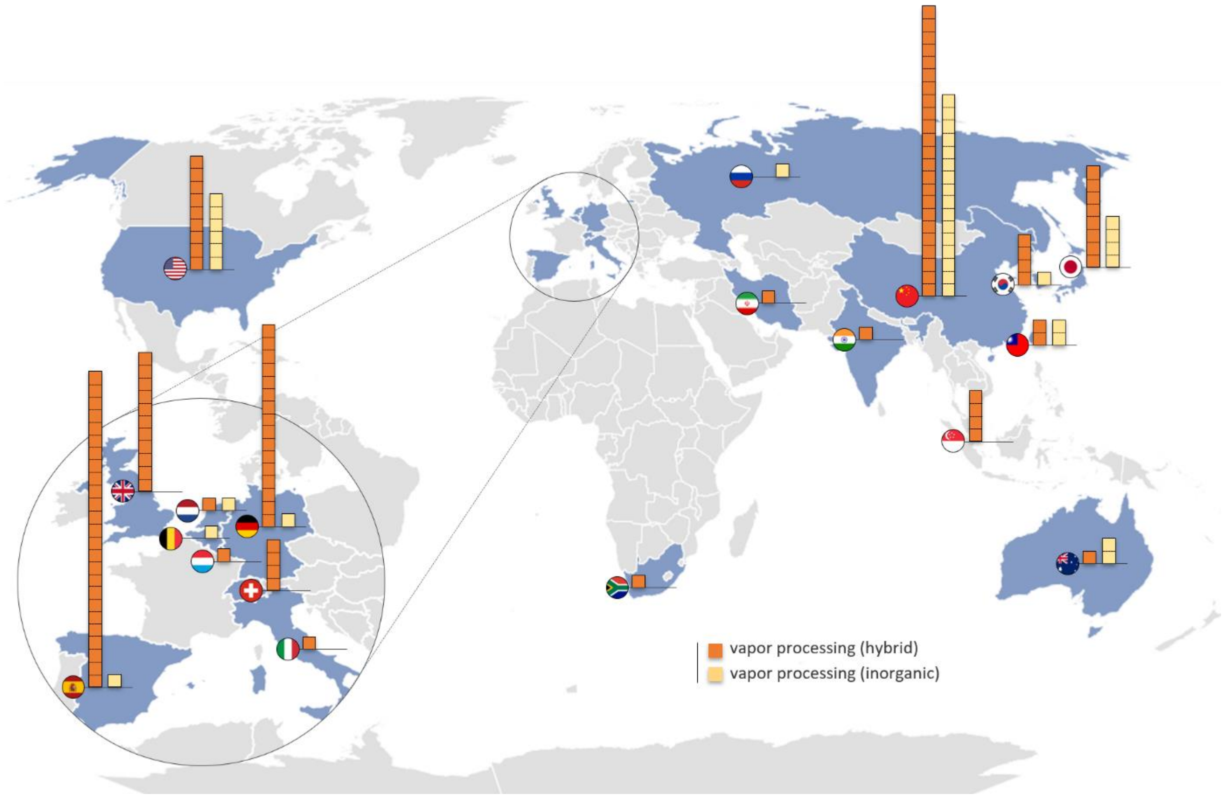

Fig. S1 | Global academic activities in the field of vapor-processed perovskite PV. Geographical distribution of authors of research articles with a focus on the fabrication of vapor processed hybrid (orange) and inorganic (yellow) perovskite materials for solar cell applications. The country of origin is defined based on the main affiliation of the first author each publication. A summary of the considered research studies is provided in Table S3 and Table S4 in the Supporting Information.

Methodology of Techno-Economic Analysis

This section describes the logic of our bottom-up techno-economic analysis of manufacturing costs for the vapor processed absorber layer of perovskite photovoltaics at industrial scale. A realistic cost-of-ownership model was created by one of the involved industrial partners of this work. The model calculated an annual cost for six categories: equipment, building and facilities, maintenance, utilities, labor, and materials and consumables. Unit costs ($\$ m^{-2}$, $\$ W^{-1}$, \$ per module) were calculated based on annual tool and factory throughput. The final device was assumed to have a perovskite absorber layer thickness of 500 nm, a power conversion efficiency of 16%, and was fabricated with an annual production capacity of 2 GW. We note that the assumed efficiency is considered low compared to recent record devices reported in literature. As a consequence, the total costs calculated here are rather conservative. Deposition profiles from vapor sources were based on vapor flux modeling results. Deposition tool assumptions (e.g., capital costs, footprints, utility demands) were collected from interviews with tooling manufacturers and engineers with experience in tool design and operations. Deposition tool uptime was assumed to be 92% after accounting for routine maintenance and servicing on a bi-weekly cadence and 400 hours of unplanned downtime per year. Tool throughput was calculated based on deposition rate, the number of modules ran in parallel on the same tool, and the number of deposition sources installed serially. Material unit costs were assumed to decrease in a non-linear fashion with the increasing scale of consumption, with a 50% reduction in cost achieved with each order of magnitude increase. The starting material unit costs were collected from quotes from commercial vendors. Facilities, utilities, and labor costs were collected from surveys of real-world examples for production facilities in Grant County, Washington, USA. Capital equipment costs were assumed to depreciate over seven years. A summary of the employed variables and their sources can be found in **Table S1**. It needs to be noted that there are several unknowns in the original report of NREL used to estimate the production costs of solution processing, which add uncertainties to the cost comparison between solution and vapor processing. However, we note that most assumptions are rather conservative to avoid an over-optimistic viewpoint on vapor phase deposition. The key assumptions are:

Production yield: The yield used for the case of solution processing is 96%, which the original report by NREL notes is hypothetical as there are no commercial solution-based manufacturers in full production to establish this metric. According to the employed survey performed in this work, typical yields for vapor processes are 90% at a minimum and typically rather above 96% depending on the complexity of the process. So far, there are no reports the authors are aware of that boast yields for large area deposition for solution processed perovskites to values above 90%. This item alone can increase the production costs for solution deposition dramatically as there is a direct relationship between yield and production costs.

Material usage: Material costs include both the precursor materials and solvents and are assumed to be equal for solution- and vapor processing in this work. This is considered a rather conservative estimation for vapor processing as there are no solvent employed and the material usage can, theoretically, be near 100% for certain processes based on the herein performed survey. Additionally, the use of solvents adds additional safety related disadvantages that can increase production costs of solution processing.

Annealing processes: Typical annealing processes for solution processed films are 20-60 minutes long, which would require multiple, parallel drying lines for each deposition line or a single, very long drying stage which is typically impractical as they negatively impact production costs. For certain vapor deposition processes (e.g., co-evaporation processes), post-annealing procedures are often reported to be irrelevant or only very short annealing processes (< 5 min) employed, potentially creating an additional cost benefit of vapor processing.

Service life and recycling: Although there are reports purporting vapor deposited films and devices as being more stable, the evidence is found to be limited as well as the total lifetimes far from commercial relevance. As such, differences in projected service life for the both methods have not been considered. In terms of recycling, only the active layer is with all other layers and processes being equivalent considered in this discussion. Therefore, the recycling of modules for either method should also be equivalent.

Tab. S1 | Employed variables for the bottom-up techno-economic analysis of manufacturing costs for a vapor-processed perovskite absorber layer. The table summarizes the key variables and the respective source used for the calculation of the production costs and capital expenditure (CAPEX) of a vapor-processed perovskite absorber as described in the main manuscript.

variable	**base assumption**	**source**
absorber thickness	500 nm	common device data
capital cost for deposition tool	$7,500,000	expert interviews
source nozzle diameter	5 mm	vapor flux modeling
throw distance	100 mm	vapor flux modeling
nozzle spacing	30 mm	vapor flux modeling
module width	1 m	common device data
module length	2 m	common device data
Module efficiency	16%	common device data

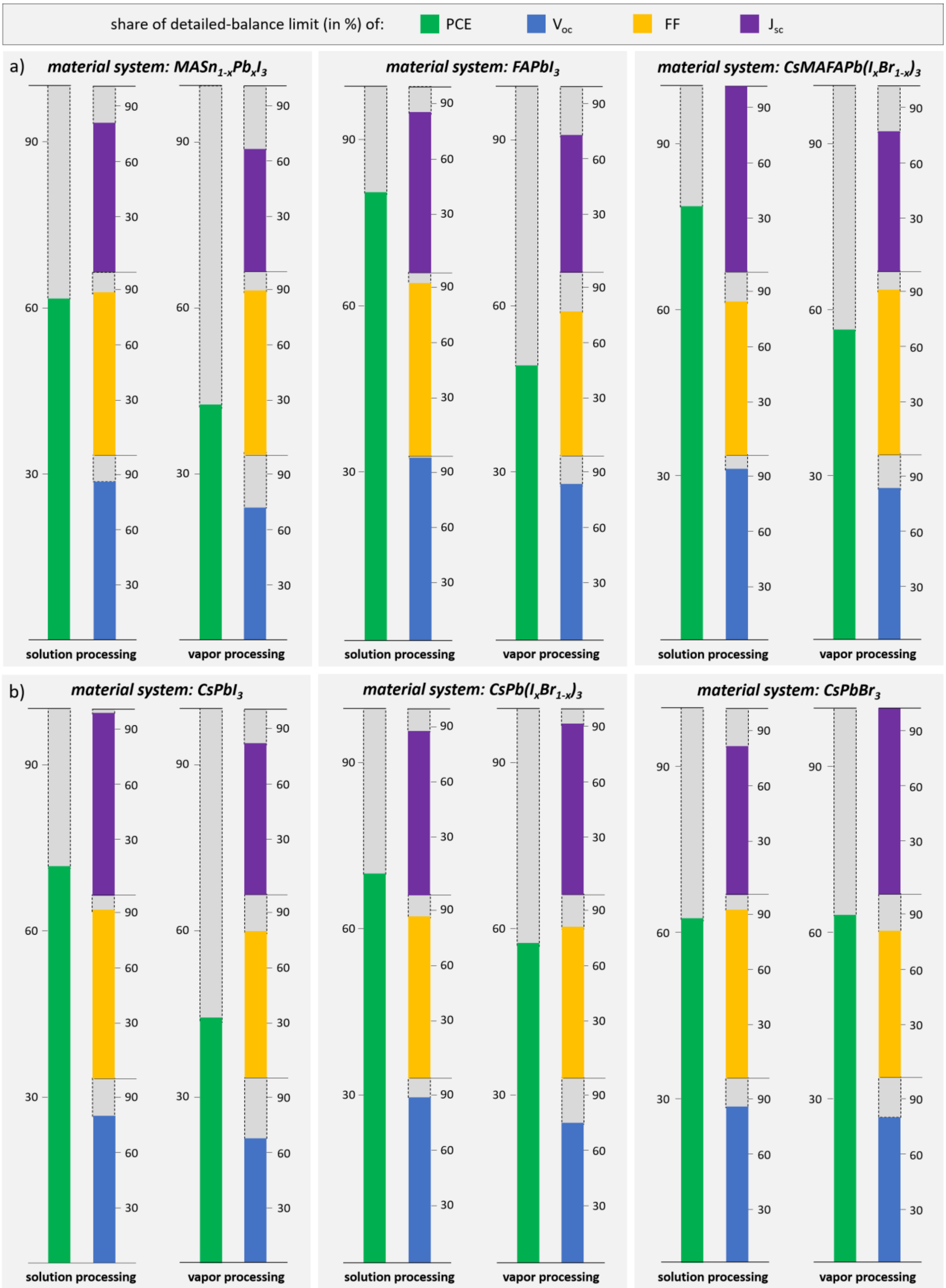

Fig. S2 | Solar cell parameters of state-of-the-art vapor-processed perovskite-based solar cells. Comparison of champion solar cells employing various hybrid (a) and inorganic (b) perovskite absorbers prepared by either solution- (left) or vapor-based (right) approaches with respect to the theoretical detailed balance of the individual solar cell parameters

Tab. S2 | Literature overview of state-of-the-art vapor- and solution-processed perovskite-based solar cells. This table summarizes the solar cell parameters of state-of-the-art vapor- and solution-processed perovskite solar cells used for the direct comparison in Figure 2 in the main manuscript and Figure S1 in the Supporting Information. Solar cell parameters shown here represent values extracted from the reverse *J-V* scan.

authors	year	absorber type	absorber composition	deposition approach	E_g (eV)	PCE (%)	FF (%)	V_{oc} (V)	J_{sc} (mA cm^{-2})	reference
Li *et al.*	2020	hybrid	$Cs_{0.05}MA_{0.1}FA_{0.85}Sn_{0.5}Pb_{0.5}I_3$	solution-based	1.28	20.4	79.1	0.86	29.8	[1]
Igual-Muñoz *et al.*	2020	hybrid	$FAPb_{0.5}Sn_{0.5}I_3$	vapor-based	1.28	14.0	79.3	0.72	24.5	[2]
Li *et al.*	2022	hybrid	$MAPbI_3$	solution-based	1.55	22.1	81.8	1.13	24.0	[3]
Pérez-del-Rey *et al.*	2018	hybrid	$MAPbI_3$	vapor-based	1.55	20.8	82.1	1.16	21.9	[4]
Min *et al.*	2021	hybrid	$FAPbI_3$	solution-based	1.48	25.8	84.9	1.18	25.8	[5,6]
Borchert *et al.*	2017	hybrid	$FAPbI_3$	vapor-based	1.48	15.8	70.8	1.01	22.1	[7]
Gharibzadeh *et al.*	2021	hybrid	$Cs_{0.18}FA_{0.82}PbI_3$	solution-based	1.57	22.7	83.2	1.16	23.5	[8]
Li *et al.*	2022	hybrid	$Cs_{0.05}FA_{0.95}Pb(I_{1-x}Cl_x)_3$	vapor-based	1.57	24.4	81.8	1.15	25.9	[9]
Xu *et al.*	2022	hybrid	$Cs_{0.22}FA_{0.78}Pb(I_{0.85}Br_{0.15})_3$	solution-based	1.68	19.5	78.7	1.20	20.7	[10]
Chiang *et al.*	2023	hybrid	$Cs_{0.30}FA_{0.7}Pb(I_{0.76}Br_{0.24})_3$	vapor-based	1.71	17.7	78.4	1.18	19.1	[11]
Lou *et al.*	2021	hybrid	$Cs_{0.05}MA_{0.15}FA_{0.80}Pb(I_{0.85}Br_{0.15})_3$	solution-based	1.65	23.1	76.1	1.25	24.2	[12]
Gil-Escrig *et al.*	2018	hybrid	$Cs_{0.5}MA_{0.1}FA_{0.4}Pb(I_{0.83}Br_{0.17})_3$	vapor-based	1.70	16.0	82.0	1.15	17.0	[13]
Wang *et al.*	2023	inorganic	$CsPbI_3$	solution-based	1.73	20.2	84.0	1.13	21.4	[14]
Becker *et al.*	2019	inorganic	$CsPbI_3$	vapor-based	1.73	12.5	73.0	0.96	17.8	[15]

authors	year	absorber type	absorber composition	deposition approach	E_g (eV)	PCE (%)	FF (%)	V_{oc} (V)	J_{sc} (mA cm^{-2})	reference
Guo *et al.*	2022	inorganic	$CsPb(I_{0.67}Br_{0.33})_3$	solution-based	1.91	17.4	81.3	1.42	15.0	[16]
Abzieher *et al.*	2023	inorganic	$CsPb(I_{0.83}Br_{0.17})_3$	vapor-based	1.84	14.9	76.0	1.17	16.8	[17]
Duan *et al.*	2019	inorganic	$CsPbBr_3$	solution-based	2.25	10.8	85.5	1.62	7.8	[18]
Tong *et al.*	2019	inorganic	$CsPbBr_3$	vapor-based	2.25	10.9	74.5	1.50	9.8	[19]

Tab. S3 | Solar cell parameters and deposition rates of vapor-processed hybrid perovskite solar cells. Only the champion device of the respective references is provided. The table only shows devices with accessible deposition rates. Solar cell parameters shown here represent values extracted from the reverse *J-V* scan. Data is presented visually in Figure 3 in the main manuscript.

authors	year	absorber composition	deposition approach	deposition rate (nm min^{-1})	source of rate	PCE (%)	FF (%)	V_{oc} (V)	J_{sc} (mA cm^{-2})	reference
Liu et al.	2013	$MAPb(I_{1-x}Cl_x)_3$	co-evaporation	2.6	in article	15.4	67.0	1.07	21.5	[20]
Leyden *et al.*	2014	$MAPb(I_{1-x}Cl_x)_3$	CVD	2.4	in article	11.8	n/a	n/a	n/a	[21]
Chen *et al.*	2014	$MAPb(I_{1-x}Cl_x)_3$	layer-by-layer	4.1	from authors	15.4	72.2	1.02	20.9	[22]
Ono *et al.*	2014	$MAPb(I_{1-x}Cl_x)_3$	co-evaporation	4.2	in article	9.9	53.5	1.09	17.0	[23]
Roldán-Carmona *et al.*	2014	$MAPbI_3$	co-evaporation	4.3	from authors	7.0	47.0	1.04	14.3	[24]
Momblona *et al.*	2014	$MAPbI_3$	co-evaporation	4.8	from authors	12.7	63.0	1.07	18.8	[25]
Malinkiewicz *et al.*	2014	$MAPbI_3$	co-evaporation	4.8	from authors	12.0	67.0	1.05	16.1	[26]
Malinkiewicz *et al.*	2014	$MAPbI_3$	co-evaporation	5.0	from authors	14.8	75.0	1.09	18.2	[27]
Polander *et al.*	2014	$MAPb(I_{1-x}Cl_x)_3$	co-evaporation	5.6	from authors	10.9	70.0	0.97	16.1	[28]
Ng *et al.*	2014	$MAPb(I_{1-x}Cl_x)_3$	co-evaporation	6.8	from authors	6.1	60.0	0.82	12.5	[29]
Subbiah *et al.*	2014	$MAPb(I_{1-x}Cl_x)_3$	co-evaporation	10.4	in article	7.3	75.0	0.94	14.9	[30]
Hu *et al.*	2014	$MAPbI_3$	layer-by-layer	11.7	in article	5.4	50.0	0.80	13.6	[31]
Gao *et al.*	2015	$MAPb(I_{1-x}Cl_x)_3$	co-evaporation	n/a	n/a	10.3	63.0	0.97	17.3	[32]
Ke *et al.*	2015	$MAPbI_3$	co-evaporation	n/a	n/a	15.4	77.5	1.04	19.1	[33]
Lin *et al.*	2015	$MAPbI_3$	co-evaporation	n/a	n/a	16.5	72.0	1.05	21.9	[34]
Abbas *et al.*	2015	$MAPbI_3$	layer-by-layer	1.9	in article	13.7	65.3	0.96	21.8	[35]
Teuscher *et al.*	2015	$MAPbI_3$	co-evaporation	1.9	in article	12.5	n/a	n/a	n/a	[36]

authors	year	absorber composition	deposition approach	deposition rate (nm min^{-1})	source of rate	PCE (%)	FF (%)	V_{oc} (V)	J_{sc} (mA cm^{-2})	reference
Wang *et al.*	2015	$MAPbI_3$	layer-by-layer	2.0	in article	11.5	52.4	1.10	19.9	[37]
Tavakoli *et al.*	2015	$MAPbI_3$	CVD	3.0	in article	9.2	61.0	0.95	15.9	[38]
Leyden *et al.*	2015	$FAPb(I_{1-x}Cl_x)_3$	CVD	3.3	in article	12.5	59.0	0.98	21.5	[39]
Luo *et al.*	2015	$MAPbI_3$	CVD	3.7	in article	12.7	64.5	0.91	21.7	[40]
Tavakoli *et al.*	2015	$MAPb(I_{1-x}Cl_x)_3$	CVD	5.0	in article	11.1	64.0	0.97	18.0	[38]
Kim *et al.*	2015	$MAPbI_3$	co-evaporation	5.3	from authors	13.7	67.6	1.12	18.1	[41]
Yang *et al.*	2015	$MAPb(I_{1-x}Cl_x)_3$	layer-by-layer	6.8	from authors	16.0	72.0	1.00	22.3	[42]
Ng *et al.*	2015	$MAPbI_3$	layer-by-layer	15.8	from authors	12.5	60.0	0.96	21.8	[43]
Longo *et al.*	2015	$MAPbI_3$	single-source evaporation†	1,000.0	from authors	12.2	68.0	1.07	18.0	[44]
Yu *et al.*	2016	$MASnI_3$	co-evaporation	n/a	n/a	1.7	36.6	0.38	12.1	[45]
Zhao *et al.*	2016	$MAPbI_3$	co-evaporation	n/a	n/a	15.7	75.4	1.10	18.9	[46]
Leyden *et al.*	2016	$MAPbI_3$	CVD	3.4	in article	15.6	68.0	1.06	21.7	[47]
Leyden *et al.*	2016	$FAPbI_3$	CVD	3.4	in article	10.4	53.0	1.02	19.5	[47]
Hsiao *et al.*	2016	$MAPbI_3$	co-evaporation	4.0	in article	17.6	73.2	1.06	22.7	[48]
Kim *et al.*	2016	$MAPbI_3$	co-evaporation	4.7	in article	14.5	72.0	1.00	20.1	[49]
Momblona *et al.*	2016	$MAPbI_3$	co-evaporation	4.8	from authors	20.3	80.5	1.14	22.1	[50]
Fan *et al.*	2016	$MAPbI_3$	single-source evaporation	133.3	in article	10.8	60.0	0.93	19.4	[51]
Xu *et al.*	2016	$MAPbI_3$	single-source evaporation†	2,500.0	in article	10.0	64.0	0.99	15.8	[52]
Borchert *et al.*	2017	$FAPbI_3$	co-evaporation	3.1	from authors	15.8	70.8	1.01	22.1	[7]

authors	year	absorber composition	deposition approach	deposition rate (nm min^{-1})	source of rate	PCE (%)	FF (%)	V_{oc} (V)	J_{sc} (mA cm^{-2})	reference
Forgács *et al.*	2017	$MAPbI_3$	co-evaporation	4.5	from authors	19.1	81.6	1.07	21.8	[53]
Forgács *et al.*	2017	$Cs_{0.15}FA_{0.85}Pb(I_{0.3}Br_{0.7})_3$	co-evaporation	4.5	from authors	10.7	77.8	1.20	11.4	[53]
Patel *et al.*	2017	$MAPbI_3$	co-evaporation	4.9	in article	15.8	75.0	1.04	20.2	[54]
Zhu *et al.*	2017	$Cs_{0.23}MA_{0.77}PbI_3$	co-evaporation	10.0	from authors	20.1	79.0	1.10	23.2	[55]
Tavakoli *et al.*	2017	$MAPbI_3$	layer-by-layer	17.5	in article	15.9	83.0	0.96	20.1	[56]
Cojocaru *et al.*	2018	$MAPbI_3$	co-evaporation	4.2	in article	17.1	75.0	1.01	21.3	[57]
Longo *et al.*	2018	$MAPbI_3$	co-evaporation	5.0	from authors	17.4	81.2	1.09	19.6	[58]
Longo *et al.*	2018	$MAPb(I_{0.8}Br_{0.2})_3$	co-evaporation	5.0	from authors	15.6	81.9	1.10	17.3	[58]
Pérez-del-Rey *et al.*	2018	$MAPbI_3$	co-evaporation	5.9	from authors	20.8	82.1	1.16	21.9	[4]
Gil-Escrig *et al.*	2018	$Cs_{0.5}FA_{0.4}MA_{0.1}Pb(I_{0.83}Br_{0.17})_3$	co-evaporation	6.2	from authors	16.0	82.0	1.15	17.0	[13]
Gil-Escrig *et al.*	2018	$Cs_{0.5}FA_{0.5}Pb(I_{0.83}Br_{0.17})_3$	co-evaporation	6.2	from authors	8.5	57.0	0.85	17.6	[13]
Luo *et al.*	2018	$Cs_{0.24}FA_{0.76}Pb(I_{1-x}Br_x)_3$	layer-by-layer	15.7	from authors	17.3	71.0	1.07	22.9	[59]
Luo *et al.*	2018	$FAPb(I_{1-x}Br_x)_3$	layer-by-layer	25.0	from authors	11.3	65.0	1.00	17.4	[59]
Tai *et al.*	2018	$MAPbI_3$	single-source evaporation†	3,000.0	from authors	16.8	75.0	0.98	23.1	[60]
Abzieher *et al.*	2019	$MAPbI_3$	co-evaporation	2.3	from authors	15.6	72.0	1.06	20.3	[61]
Abzieher *et al.*	2019	$MAPbI_3$	co-evaporation	2.4	from authors	16.8	79.0	1.03	20.7	[62]
Borchert *et al.*	2019	$MAPbI_3$	co-evaporation	2.5	in article	15.0	n/a	n/a	n/a	[63]
Qiu *et al.*	2019	$Cs_{0.1}FA_{0.9}Pb(I_{0.97}Br_{0.03})_3$	layer-by-layer	2.5	from authors	13.3	73.2	0.90	20.2	[64]
La-Placa *et al.*	2019	$MAPbI_3$	co-evaporation	4.5	from authors	18.9	78.5	1.06	22.7	[65]

authors	year	absorber composition	deposition approach	deposition rate (nm min^{-1})	source of rate	PCE (%)	FF (%)	V_{oc} (V)	J_{sc} (mA cm^{-2})	reference
Kottokkaran *et al.*	2019	$MAPbI_3$	co-evaporation	4.7	from authors	17.4	77.0	1.03	22.0	[66]
Ball *et al.*	2019	$Cs_{1-x}FA_xPb_{1-y}Sn_yI_3$	co-evaporation	5.1	in article	11.5	74.0	0.78	20.3	[67]
Pérez-del-Rey *et al.*	2019	$MAPbI_3$	co-evaporation	5.9	from authors	19.3	79.3	1.10	22.0	[68]
Palazon *et al.*	2019	$MAPbI_3$	co-evaporation	6.6	from authors	19.7	81.2	1.16	20.8	[69]
Kiermasch *et al.*	2019	MAPbI3	co-evaporation	6.8	from authors	18.2	72.0	1.11	22.7	[70]
Lin *et al.*	2019	$MAPbI_3$	layer-by-layer	9.1	in article	17.3	72.4	1.01	23.7	[71]
Hoerantner *et al.*	2019	$MAPbI_3$	layer-by-layer	13.5	in article	6.9	48.0	1.01	14.2	[72]
Arivazhagan *et al.*	2019	$MAPbI_3$	co-evaporation	17.5	in article	15.7	66.8	1.08	21.8	[73]
Tavakoli *et al.*	2019	$FA_{1-x}MA_xPb(I_{1-y}Cl_y)_3$	layer-by-layer	24.5	in article	17.7	75.0	1.04	22.7	[74]
Peng *et al.*	2019	$MAPbI_3$	single-source evaporation	36.0	in article	2.6	34.0	0.77	10.0	[75]
Zheng *et al.*	2019	$BA_2MA_3Pb_4I_{13}$	single-source evaporation	400.0	from authors	2.5	45.8	0.85	6.5	[76]
Momblona *et al.*	2020	$MABiI_3$	co-evaporation	n/a	n/a	0.1	43.0	0.67	0.13	[77]
Qiu *et al.*	2020	$Cs_{1-x}FA_xPbI_3$	CVD	1.6	in article	7.6	42.1	0.96	19.0	[78]
Ngqoloda *et al.*	2020	$MAPbI_3$	CVD	1.8	in article	11.7	59.5	0.88	22.4	[79]
Hellmann *et al.*	2020	$MAPbI_3$	co-evaporation	2.1	from authors	13.7	n/a	1.03	19.4	[80]
Patel *et al.*	2020	$MAPbI_3$	co-evaporation	2.5	in article	17.0	77.0	1.02	21.8	[81]
Harding *et al.*	2020	$MAPbI_3$	layer-by-layer	2.6	in article	12.1	56.6	0.98	21.9	[82]
Lohmann *et al.*	2020	$MAPbI_3$	co-evaporation	2.9	in article	18.3	77.8	1.08	21.7	[83]
Suwa *et al.*	2020	$MAPbI_3$	co-evaporation	4.2	from authors	8.1	46.0	0.97	18.2	[84]

authors	year	absorber composition	deposition approach	deposition rate (nm min^{-1})	source of rate	PCE (%)	FF (%)	V_{oc} (V)	J_{sc} (mA cm^{-2})	reference
Li *et al.*	2020	$MAPbI_3$	co-evaporation	4.3	from authors	19.1	76.4	1.12	22.3	[85]
Roß *et al.*	2020	$MAPbI_3$	co-evaporation	5.0	in article	20.3	79.0	1.15	22.4	[86]
Gil-Escrig *et al.*	2020	$FA_{1-x}MA_xPbI_3$	co-evaporation	5.6	from authors	18.8	76.0	1.09	22.6	[87]
Babaei *et al.*	2020	$MAPb(I_{1-x}Cl_x)_3$	co-evaporation	5.6	from authors	16.1	73.0	1.13	19.5	[88]
Kim *et al.*	2020	$MAPbI_3$	co-evaporation	5.6	from authors	18.7	n/a	n/a	n/a	[89]
Li *et al.*	2020	$MAPbI_3$	co-evaporation	5.8	in article	20.3	77.7	1.12	23.3	[90]
Zanoni *et al.*	2020	$MAPbI_3$	co-evaporation	6.6	from authors	18.0	78.3	1.12	20.3	[91]
Babaei *et al.*	2020	$MAPbI_3$	co-evaporation	6.7	from authors	18.4	n/a	n/a	n/a	[92]
Igual-Muñoz *et al.*	2020	$FAPb_{0.5}Sn_{0.5}I_3$	co-evaporation	7.6	from authors	14.0	79.3	0.72	24.5	[2]
Chiang *et al.*	2020	$Cs_{0.3}FA_{0.7}Pb(I_{0.9}Br_{0.1})_3$	co-evaporation	8.2	from authors	18.1	74.6	1.06	23.0	[93]
Ji *et al.*	2020	$Cs_{0.1}FA_{0.9}Pb(I_{0.97}Br_{0.03})_3$	co-evaporation	10.0	from authors	16.6	79.7	1.07	19.5	[94]
Lei *et al.*	2020	$MAPbI_3$	layer-by-layer	11.4	in article	19.2	80.9	1.06	22.4	[95]
Qiu *et al.*	2020	$Cs_{1-x}FA_xPbI_3$	CVD	37.0	in article	15.5	70.2	0.99	22.3	[78]
Tavakoli *et al.*	2021	$MAPbI_3$	co-evaporation	n/a	n/a	19.4	77.0	1.09	23.1	[96]
Tavakoli *et al.*	2021	$MAPbI_3$	co-evaporation	n/a	n/a	20.3	78.5	1.11	23.3	[97]
Smecca *et al.*	2021	$MAPbI_3$	layer-by-layer	1.7	in article	17.5	75.4	1.07	21.6	[98]
Heinze *et al.*	2021	$MAPbI_3$	co-evaporation	1.7	from authors	14.3	74.5	0.96	20.0	[99]
Sahli *et al.*	2021	$MAPbI_3$	CVD	2.0	in article	12.3	n/a	n/a	n/a	[100]
Choi *et al.*	2021	$MAPbI_3$	layer-by-layer	3.8	from authors	18.5	79.0	1.07	21.9	[101]

authors	year	absorber composition	deposition approach	deposition rate (nm min^{-1})	source of rate	PCE (%)	FF (%)	V_{oc} (V)	J_{sc} (mA cm^{-2})	reference
Li *et al.*	2021	$MAPbI_3$	co-evaporation	4.2	from authors	20.6	82.4	1.12	22.3	[102]
Li *et al.*	2021	$MAPbI_3$	co-evaporation	4.2	in article	20.6	82.4	1.12	22.3	[102]
Li *et al.*	2021	MAPbI3	co-evaporation	4.2	in article	19.3	80.3	1.11	21.7	[102]
Dewi *et al.*	2021	$MAPbI_3$	co-evaporation	4.6	in article	17.2	74.6	1.06	21.7	[103]
Paliwal *et al.*	2021	$MAPbI_3$	co-evaporation	4.9	from authors	13.0	76.5	1.12	15.2	[104]
Susic *et al.*	2021	$MAPbI_3$	co-evaporation	5.0	from authors	18.3	76.0	1.1	21.9	[105]
Gil-Escrig *et al.*	2021	$MAPbI_3$	co-evaporation	5.6	from authors	18.2	78.0	1.12	20.9	[106]
Klipfel *et al.*	2021	$MAPbI_3$	co-evaporation	5.6	in article	15.2	77.4	0.98	19.9	[107]
Gallet *et al.*	2021	$MAPbI_3$	co-evaporation	5.6	from authors	14.7	77.0	1.05	18.2	[108]
Roß *et al.*	2021	$FA_{0.53}MA_{0.47}PbI_3$	co-evaporation	6.3	in article	20.4	75.9	1.05	25.7	[109]
Roß *et al.*	2021	$FAPbI_3$	co-evaporation	6.5	in article	15.8	n/a	n/a	n/a	[109]
Kaya *et al.*	2021	$MAPbI_3$	co-evaporation	6.7	from authors	19.2	79.7	1.09	22.1	[110]
Feng *et al.*	2021	$Cs_{1-x}FA_xPbI_3$	layer-by-layer	6.8	from authors	21.3	77.2	1.11	24.9	[111]
Gil-Escrig *et al.*	2021	$Cs_{0.35}FA_{0.65}Pb(I_{0.73}Br_{0.27})_3$	co-evaporation	7.7	from authors	16.8	79.0	1.18	18.0	[112]
Abzieher *et al.*	2021	$MAPbI_3$	co-evaporation	9.3	from authors	19.5	83.0	1.08	21.6	[113]
Ritzer *et al.*	2021	$MAPbI_3$	co-evaporation	9.3	from authors	19.2	82.0	1.08	21.6	[114]
Lin *et al.*	2021	$AL_{1-x}MA_xPbI_3$	layer-by-layer	14.3	from authors	18.2	74.8	1.08	22.6	[115]
Lin *et al.*	2021	$MAPbI_3$	layer-by-layer	14.3	from authors	17.2	72.7	1.05	22.6	[115]
Gao *et al.*	2021	$MAPb(I_{1-x}Cl_x)_3$	single-source evaporation	96.7	in article	15.2	71.0	0.93	23.0	[116]

authors	year	absorber composition	deposition approach	deposition rate (nm min^{-1})	source of rate	PCE (%)	FF (%)	V_{oc} (V)	J_{sc} (mA cm^{-2})	reference
Susic *et al.*	2022	$CsMAFAGAPb(I_{1-x}Br_x)_3$	co-evaporation	n/a	n/a	16.1	81.3	1.15	17.3	[117]
Susic *et al.*	2022	$Cs_{1-y-z}MA_yFA_zPb(I_{1-x}Br_x)_3$	co-evaporation	n/a	n/a	16.4	n/a	n/a	n/a	[117]
Lohmann *et al.*	2022	$Cs_{0.17}FA_{0.83}Pb(I_{1-x}Cl_x)_3$	co-evaporation	3.1	from authors	19.3	79.0	1.06	23.0	[118]
Kim *et al.*	2022	$MAPbI_3$	co-evaporation	5.6	from authors	18.1	75.0	1.10	21.9	[119]
Kroll *et al.*	2022	$Cs_{1-x}FA_xPb(I_{1-y}Br_y)_3$	co-evaporation	6.0	in article	15.6	76.6	1.09	18.7	[120]
Li *et al.*	2022	$Cs_{0.05}FA_{0.95}Pb(I_{1-x}Cl_x)_3$	layer-by-layer	11.2	from authors	24.4	81.8	1.15	25.9	[9]
Choi *et al.*	2022	$MASnI_3$	single-source evaporation	57.1	in article	1.7	39.0	0.32	13.8	[121]
Chiang *et al.*	2023	$Cs_{0.3}FA_{0.7}Pb(I_{0.76}Br_{0.24})_3$	co-evaporation	n/a	n/a	17.7	78.4	1.18	19.1	[11]
Chiang *et al.*	2023	$Cs_{0.3}FA_{0.7}Pb(I_{0.9}Br_{0.1})_3$	co-evaporation	n/a	n/a	20.0	78.7	1.11	23.0	[11]
Yuan *et al.*	2023	$Cs_{0.17}FA_{0.83}PbI_3$	co-evaporation	3.2	from authors	13.9	72.0	0.93	19.9	[122]
Li *et al.*	2023	$Cs_{0.1}FA_{0.9}(I_{0.74}Cl_{0.19}Br_{0.07})_3$	layer-by-layer	8.9	in article	24.4	82.2	1.16	25.5	[123]
Soto-Montero *et al.*	2023	$FA_{0.45}MA_{0.55}PbI_3$	single-source evaporation	10.0	from authors	14.0	70.5	1.00	19.9	[124]
Soto-Montero *et al.*	2023	$FA_{0.55}MA_{0.45}Pb(I_{1-x}Cl_x)3$	single-source evaporation	7.0	from authors	19.7	79.4	1.15	21.6	[125]

† processes are batch processes that rely on solution-based fabrication steps,
MA: methylammonium ($CH_3NH_3^+$), FA: formamidinium ($CH(NH_2)_2^+$), BA: butylammonium ($C_4H_{12}N^+$), AL: anilinium ($C_6H_5NH_3^+$), GA: guanidinium ($CH_6N_3^+$)

Tab. S4 | Solar cell parameters and deposition rates of vapor-processed inorganic perovskite solar cells. Only the champion device of the respective references is provided. The table only shows devices with accessible deposition rates. Solar cell parameters shown here represent values extracted from the reverse *J-V* scan. Data is presented visually in Figure 3 in the main manuscript.

authors	year	absorber composition	deposition approach	deposition rate (nm min^{-1})	source of rate	PCE (%)	FF (%)	V_{oc} (V)	J_{sc} (mA cm^{-2})	reference
Frolova *et al.*	2016	$CsPbI_3$	co-evaporation	n/a	n/a	10.5	71.6	1.06	13.8	[126]
Ma *et al.*	2016	$CsPbIBr_2$	co-evaporation	2.2	from authors	4.7	56.0	0.96	8.7	[127]
Moghe *et al.*	2016	$CsSn(Br_{1-x}F_x)_3$	layer-by-layer	2.8	in article	0.6	n/a	n/a	n/a	[128]
Yonezawa *et al.*	2017	$CsPbI_3$	layer-by-layer	n/a	n/a	5.7	67.0	0.71	12.1	[129]
Ma *et al.*	2017	$CsPbI_2Br$	co-evaporation	1.5	from authors	7.7	67.0	1.01	11.5	[130]
Shahiduzzaman *et al.*	2017	$CsPbI_3$	layer-by-layer	2.4	in article	6.8	72.0	0.79	12.1	[131]
Hutter *et al.*	2017	$CsPbI_3$	layer-by-layer	5.2	from authors	8.8	68.0	1.00	13.0	[132]
Chen *et al.*	2017	$CsPbI_2Br$	co-evaporation	11.4	from authors	11.8	68.0	1.13	15.2	[133]
Chen *et al.*	2017	$CsPbI_3$	co-evaporation	12.0	from authors	9.4	56.0	0.98	17.3	[133]
Chen *et al.*	2018	Cs_2TiBr_6	layer-by-layer	0.3	in article	3.3	56.0	1.02	5.7	[134]
Lei *et al.*	2018	$CsPbBr_3$	co-evaporation	5.0	from authors	7.0	78.5	1.27	7.0	[135]
Kottokkaran *et al.*	2018	$CsPbI_3$	layer-by-layer	5.3	from authors	9.5	65.0	0.95	14.9	[136]
Li *et al.*	2018	$CsPbBr_3$	layer-by-layer	5.7	in article	8.3	75.9	1.30	8.5	[137]
Park *et al.*	2018	$CsPbI_2Br$	co-evaporation	14.8	in article	5.7	49.0	1.10	10.9	[138]
Chen *et al.*	2018	$CsPbBr_3$	co-evaporation	22.5	from authors	7.8	77.1	1.44	7.0	[139]
Fan *et al.*	2019	$Cs_2AgBiBr_6$	single-source evaporation	1.9	in article	0.7	65.0	0.87	1.2	[140]
Tong *et al.*	2019	$CsPbBr_3$	layer-by-layer	3.0	in article	10.9	74.5	1.50	9.8	[19]

authors	year	absorber composition	deposition approach	deposition rate (nm min^{-1})	source of rate	PCE (%)	FF (%)	V_{oc} (V)	J_{sc} (mA cm^{-2})	reference
Chen *et al.*	2019	$CsPbBr_3$	layer-by-layer	3.0	from authors	9.0	73.1	1.44	8.5	[141]
Lin *et al.*	2019	$CsPbI_2Br$	layer-by-layer	6.7	in article	13.0	74.0	1.13	15.6	[142]
Becker *et al.*	2019	$CsPbI_3$	co-evaporation	7.3	from authors	12.5	73.0	0.96	17.8	[15]
Liu *et al.*	2019	$CsPbBr_3$	layer-by-layer	33.3	in article	7.6	75.2	1.33	7.6	[143]
Zhang *et al.*	2019	$CsPbBr_3$	layer-by-layer	36.5	from authors	8.9	80.4	1.52	7.2	[144]
Tai *et al.*	2019	$CsPbI_2Br$	single-source evaporation†	2,500.0	from authors	12.2	72.0	1.10	15.4	[145]
Murata *et al.*	2020	$CsPbBr_3$	layer-by-layer	n/a	n/a	6.6	68.8	1.47	6.6	[146]
Li *et al.*	2020	$CsPbBr_3$	single-source evaporation	3.6	in article	8.7	81.0	1.37	7.8	[147]
Gaonkar *et al.*	2020	$CsPb(I_{1-x}Br_x)_3$	layer-by-layer	5.7	from authors	11.8	n/a	n/a	n/a	[148]
Mi *et al.*	2020	$CsPbBr_3$	layer-by-layer	6.3	in article	7.1	73.0	1.36	7.2	[149]
Igual-Muñoz *et al.*	2020	$CsPbI_2Br$	co-evaporation	11.9	in article	10.0	73.1	0.96	14.3	[150]
Xiang *et al.*	2020	$CsPbBr_3$	layer-by-layer	30.0	from authors	9.4	82.2	1.55	7.4	[151]
Hua *et al.*	2020	$CsPbBr_3$	layer-by-layer	30.0	from authors	7.2	79.0	1.42	6.5	[152]
Monroy *et al.*	2021	$CsPbI_3$	co-evaporation	n/a	n/a	8.8	68.0	0.93	14.3	[153]
Abib *et al.*	2021	$Cs(Sn_{1-x}Pb_x)Br_3$	single-source evaporation	3.0	in article	9.0	71.0	1.36	9.3	[154]
Duan *et al.*	2021	$CsPbBr_3$	co-evaporation	5.9	from authors	9.4	71.3	1.35	9.8	[155]
Zhu *et al.*	2022	$CsPbBr_3$	layer-by-layer	n/a	n/a	7.9	71.0	1.64	6.7	[156]
Liao *et al.*	2022	$CsPbI_2Br$	layer-by-layer	7.1	in article	10.0	76.0	1.05	12.3	[157]
Liu *et al.*	2022	$CsPbBr_3$	single-source evaporation	31.0	in article	7.8	80.0	1.43	6.8	[158]

authors	year	absorber composition	deposition approach	deposition rate (nm min^{-1})	source of rate	PCE (%)	FF (%)	V_{oc} (V)	J_{sc} (mA cm^{-2})	reference
Abzieher *et al.*	2022	$CsPb(I_{0.83}Br_{0.17})_3$	single-source evaporation	84.4	In article	14.9	76.0	1.17	16.8	[17]
Abzieher *et al.*	2022	$CsPb(I_{0.83}Br_{0.17})_3$	single-source evaporation	134.3	In article	13.4	72.1	1.14	16.3	[17]

† processes are batch processes that rely on solution-based fabrication steps

Tab. S5 | Industry survey – List of companies working in the field of perovskite-based photovoltaics. This table summarizes all companies that were identified by the authors to actively work in the field of perovskite-based photovoltaics. The last column highlights whether the data of the industry outlook in the main manuscript is based on a reply provided by the respective companies to the survey or collected via publicly accessible sources (e.g., webpages, press releases, job openings, or similar). Early-stage companies are defined as companies that have been founded with the goal to commercialize the perovskite technology (or have switched to the field soon after foundation), while established companies have a longer tradition in the field and typically worked on other technologies before.

company	country	industry sector	company type	start of activities	source of information
Greatcell Energy Pty. Ltd.	Australia	Materials, Solar Modules	early stage	2012	company
Halocell	Australia	Solar Modules	early stage	2019	public information
Angstrom Engineering Inc.	Canada	Machinery	established	2008	company
Solaires Enterprises Inc.	Canada	Materials	early stage	2020	company
BOE Technology Group Co. Ltd.	China	Solar Modules	established	2023	public information
Borun New Material Technology Ltd.	China	Materials	established	n/a	public information
BYD Co. Ltd.	China	Solar Modules	established	2023	public information
Fangsheng Optoelectronics Equipment & Technology Co. Ltd.	China	Machinery	established	n/a	public information
GCL Nano Co. Ltd.	China	Solar Modules	established	2016	company
Hangzhou Zhongneng Photoelectricity Technology Co. Ltd.	China	Machinery, Solar Modules	early stage	2015	company
Hubei Wonder Solar LLC.	China	Materials, Solar Modules	early stage	2012	company
Infi-Solar	China	Solar Modules	early stage	2022	public information
JinkoSolar	China	Solar Modules	established	n/a	company

company	country	industry sector	company type	start of activities	source of information
LONGi Green Energy Technology Co. Ltd.	China	Solar Modules	established	2020	company
Microquanta Semiconductor Co. Ltd.	China	Solar Modules	early stage	2015	company
Renshine Solar Co. Ltd.	China	Solar Modules	early stage	2021	public information
Shengcheng Solar Equipment Co. Ltd.	China	Machinery	established	2021	public information
Tongwei Solar	China	Solar Modules	established	n/a	public information
Trina Solar Co. Ltd.	China	Solar Modules	established	n/a	company
Wuxi UtmoLight Technology	China	Solar Modules	early stage	2020	company
Yingli Energy Company Ltd.	China	Solar Modules	established	2018	company
FOM Technologies	Denmark	Machinery	early stage	2014	company
infinityPV ApS	Denmark	Materials, Machinery	early stage	n/a	public information
Riber	France	Machinery	established	n/a	public information
VOLTEC Solar	France	Solar Modules	established	n/a	public information
APEVA SE	Germany	Machinery	early stage	2018	company
CreaPhys GmbH	Germany	Materials, Machinery	established	2013	company
Dr. Eberl MBE-Komponenten GmbH	Germany	Machinery	established	n/a	company
Heraeus	Germany	Materials	established	2010	company
Leybold GmbH	Germany	Machinery	established	n/a	company
MBRAUN GmbH	Germany	Machinery	established	2014	company
PEROSOL	Germany	Machinery, Solar Modules	early stage	2021	company

company	country	industry sector	company type	start of activities	source of information
SCIPRIOS GmbH	Germany	Machinery	early stage	2020	company
SINGULUS TECHNOLOGIES AG	Germany	Machinery	established	n/a	company
TubeSolar AG	Germany	Solar Modules	established	2021	company
VON ARDENNE GmbH	Germany	Machinery	established	2017	company
P3C Technology and Solutions Pvt. Ltd.	India	Solar Modules	early stage	2018	company
KiMia Solar	Iran	Materials, Machinery, Solar Modules	early stage	2015	company
3GSolar Photovoltaics Ltd.	Israel	Solar Modules	early stage	n/a	public information
Enel Green Power S.p.A.	Italy	Solar Modules	established	2019	company
AISIN SEIKI Co. Ltd.	Japan	Solar Modules	established	n/a	public information
EneCoat Technologies Co. Ltd.	Japan	Materials, Solar Modules	early stage	2019	company
Kaneka Corporation	Japan	Solar Modules	established	2014	company
Mitsubishi Chemical Corporation	Japan	Materials	established	n/a	public information
Panasonic Corporation	Japan	Solar Modules	established	n/a	company
Sekisui Chemical Co. Ltd.	Japan	Solar Modules	established	n/a	public information
Sharp Energy Solutions Corp.	Japan	Solar Modules	established	n/a	public information
Tokyo Chemical Industry Co. Ltd.	Japan	Materials	established	2014	company
Toray Engineering Co. Ltd.	Japan	Machinery	established	2015	company
Toshiba Corporation	Japan	Solar Modules	established	n/a	public information
Renewable Energy Corporation	Norway	Solar Modules	established	2023	public information

company	country	industry sector	company type	start of activities	source of information
Saule Technologies S.A.	Poland	Solar Modules	early stage	2014	company
Hanwha Q CELLS Co. Ltd.	South Korea	Solar Module	established	n/a	public information
SELCOS Co. Ltd.	South Korea	Machinery	established	2019	company
Sunic System Co. Ltd.	South Korea	Machinery	established	n/a	public information
ULTECH CO. Ltd.	South Korea	Machinery	established	2018	company
UniTest Inc.	South Korea	Solar Modules	established	2015	public information
Dyenamo AB	Sweden	Materials	established	2013	company
EVOLAR AB	Sweden	Machinery	early stage	2019	company
Meyer Burger Technology AG	Switzerland	Machinery, Solar Modules	established	2019	company
Perovskia SA	Switzerland	Solar Modules	early stage	2021	company
Solaronix SA	Switzerland	Materials, Solar Modules	early stage	2013	company
FrontMaterials Co. Ltd.	Taiwan	Materials	early stage	n/a	public information
Kingyoup Optoelectronics Co. Ltd.	Taiwan	Machinery	established	n/a	public information
Luminescence Technology Corp.	Taiwan	Materials	established	2010	company
Taiwan Perovskite Solar Corp.	Taiwan	Solar Modules	early stage	2021	public information
SMIT Thermal Solutions B.V.	The Netherlands	Machinery	established	2016	company
TSST	The Netherlands	Machinery	established	2018	company
PeroSolar	Turkey	Solar Modules	early stage	2018	company
G24 Power Limited	UK	Solar Modules	early stage	n/a	public information

company	country	industry sector	company type	start of activities	source of information
Ossila Ltd.	UK	Materials	established	2013	company
Power Roll Ltd	UK	Solar Modules	early stage	2015	company
Oxford PV	UK, Germany	Solar Modules	early stage	2012	company
American Perovskites	USA	Materials	early stage	n/a	public information
Ascent Solar Technologies Inc.	USA	Solar Modules	established	n/a	public information
Beyond Silicon	USA	Solar Modules	early stage	2021	company
BlueDot Photonics Inc.	USA	Materials, Solar Modules	early stage	2020	company
Caelux Corporation	USA	Solar Modules	early stage	2017	company
CubicPV Technologies Inc.	USA	Solar Modules	early stage	2013	company
Energy Materials Corp.	USA	Solar Modules	early stage	n/a	public information
First Solar Inc.	USA	Solar Modules	established	n/a	public information
FUJIFILM Wako Pure Chemical Corporation	USA	Materials	established	n/a	public information
Kurt J. Lesker Company	USA	Machinery	established	2014	company
MujiElectric	USA	Solar Modules	early stage	n/a	public information
nTact	USA	Machinery	established	n/a	company
PEROTECH Inc.	USA	Solar Modules	early stage	2018	company
Swift Solar Inc.	USA	Solar Modules	early stage	2018	company
TandemPV Inc.	USA	Solar Modules	early stage	2016	company
Verde Technologies	USA	Solar Modules	early stage	2021	public information

Collection of Industry Information from Publicly Available Sources

The following section gives an overview on how information about activities in the perovskite field as well as employed deposition methods have been collected for companies that did not respond to or decided not to participate in the industry survey.

Halocell (Australia): The company homepage of Halocell states activities in the field of perovskite PV.[159] The company is active in the fabrication of solar modules for internet-of-things applications and was founded in 2019 according to its LinkedIn profile.[160] No information about the employed deposition technique is disclosed. However, the fact that most employees of Helocell seem to have been transferred from Greatcell Energy Pty. Ltd. indicates a primary focus on solution-based methods.

BOE Technology Group Co. Ltd. (China): The company has announced in 2023 to start working on the development of perovskite solar cells. No further information could be collected.

Borun New Material Technology Ltd. (China): The homepage of the company indicates activities in the manufacturing of materials for perovskite-based solar cells.[161] No further information could be collected. The fact that the company acts as a materials supplier indicates a focus on no specific deposition method.

BYD Co. Ltd. (China): The company has announced in 2023 to start working on the development of perovskite solar cells.[162] No further information could be collected.

Fangsheng Optoelectronics Equipment & Technology Co. Ltd. (China): The company presented at the "5th Perovskite, Heterojunction & Tandem Cell Forum 2023" in Changzhou and disclosed working on the development of vapor equipment for perovskite-based materials.

Infi-Solar (China): The company presented at the "5th Perovskite, Heterojunction & Tandem Cell Forum 2023" in Changzhou and disclosed working on the development of perovskite solar modules employing vapor- and solution-based methods since 2022.

Renshine Solar Co. Ltd. (China): The company presented at the "34th International Photovoltaic Science and Engineering Conference (PVSEC)" in Shenzhen and disclosed working on the development of solution-processed perovskite solar cells since 2021.

Shengcheng Solar Equipment Co. Ltd. (China): The company presented at the “5th Perovskite, Heterojunction & Tandem Cell Forum 2023” in Changzhou and disclosed working on the development of vapor equipment for perovskite-based materials since 2021.

Tongwei Solar (China): The company presented at the “5th Perovskite, Heterojunction & Tandem Cell Forum 2023” in Changzhou and disclosed working on the development of perovskite solar modules employing vapor- and solution-based methods.

infinityPV ApS (Denmark): The company is advertising deposition equipment and inks for organic and perovskite PV on its homepage. The focus is on solution-based roll-to-roll deposition.[163] No further information could be collected.

Riber (France): The homepage of the company states activities in the field of perovskite-based materials.[164] Its focus is on the development of equipment for the vapor phase deposition.

VOLTEC Solar (France): In a press release in 2022, VOLTEC Solar and the Institut Photovoltaïque d’Île-de-France (IPVF) announced to work jointly on the development of perovskite-based tandem solar cells.[165] No additional information could be collected.

3GSolar Photovoltaics Ltd. (Israel): According to its homepage, the company is specialized on the development of solar modules for internet-of-things applications and works on dye-sensitized and perovskite solar cells.[166] A project with the Nokia Corporation highlights the focus of the company on solution-based deposition.[167]

AISIN SEIKI Co. Ltd. (Japan): Annual business reports of the company state activities in the field of perovskite-based PV.[168] A conference contribution at the “nanoGe Conference” in Kyoto in 2019 indicates that the company is working on the solution-based deposition of perovskite solar modules.[169]

Mitsubishi Chemical Corporation (Japan): The company is involved in a Green Innovation Fund project to commercialize perovskite-based solar cells.[170] The company is focused on the supply of materials in this project that appears to be focused on solution-processed perovskite solar cells given the involvement of the project partner EneCoat Technologies Co. Ltd. that has a background in solution-based fabrication methods.

Sekisui Chemical Co. Ltd. (Japan): The company announced to work on the development of roll-to-roll fabricated perovskite solar cells.[171] Published images and videos of process equipment indicate a focus on solution-based methods.[172]

Sharp Energy Solutions Corporation (Japan): In recent press release, the company announced to be working on perovskite-based solar cells.[173] No additional information could be collected.

Toshiba Corporation (Japan): In a press release, the company announced to work on solution processed perovskite solar cells.[174]

Renewable Energy Corporation (Norway): In a very recent press release, the company announced to work on perovskite-based photovoltaics.[175] No additional information could be collected given the recent nature of the company's decision.

Hanwha Q CELLS Co. Ltd. (South Korea): The company is the key industrial partner in a European research project with the goal to establish a pilot production line for the fabrication of perovskite-based tandem solar cells.[176] The research project involves partners with a focus on solution- and vapor-based deposition methods indicating a tendency of the company to explore both methods.

Sunic System Co. Ltd. (South Korea): A recent job posting of the company indicates that it is expanding its experience in the direction of perovskite-based materials.[177] According to the homepage of the company, its general focus is on the development of vapor deposition equipment for thin-film technologies, indicating a focus on vapor processing also for perovskite materials.[178]

UniTest Inc. (South Korea): A press release states that the company is licensing technologies for the fabrication of perovskite-based tandem solar cells from the Korean Research Institute of Chemical Technology (KRICT) in 2015.[179] The latter has a nearly exclusive focus on solution-based deposition methods, indicating that the company is looking into these methods too. Furthermore, a recent job posting of the company is looking for candidate for the development of vapor processes for the deposition of perovskite absorbers.[180] Therefore, the company is believed to pursue both methods.

FrontMaterials Co. Ltd. (Taiwan): The homepage of the company indicates activities in the manufacturing of materials for perovskite-based solar cells.[181] No further information could be collected. The fact that the company acts as a materials supplier indicates a focus on no specific deposition method.

Kingyoup Optoelectronics Co. Ltd. (Taiwan): The homepage of the partner company Taiwan Perovskite Solar Corp. indicates activities in the manufacturing of vacuum equipment for the fabrication of perovskite-based solar cells.[182] No further information could be collected.

Taiwan Perovskite Solar Corp. (Taiwan): The homepage of the company, which was founded in 2021, indicates activities in the manufacturing of perovskite-based solar cells.[182] The homepage highlights the development of non-toxic perovskite precursor solution pointing into the direction of solution processing of perovskite materials. No further information could be collected.

G24 Power Limited (United Kingdom): A research publication from 2016 states that the company is working on the commercialization of perovskite solar cells with a focus on solution-based fabrication methods.[183] No further information about the company could be collected.

American Perovskites (United States): The early-stage company distributes materials for both vapor and solution processing.[162] No further information about the company could be collected.

Ascent Solar Technologies Inc. (United States): The company recently announced to establish the "Ascent Solar Perovskites Center of Excellence" for the commercialization of perovskite solar cells in the United States.[184] The historic background of the company is mostly on vapor phase deposition and also for perovskite materials the published images of the production facilities indicate a focus on vapor phase deposition.

Energy Materials Corp. (United States): The homepage of the company mentions its activities in the field of perovskite materials as well as its focus on solution-based coating methods.[185] The company is employing printing methods and equipment originally developed by the Eastman Kodak Company.[186]

First Solar Inc. (United States): The company recently acquired the Swedish manufacturer for vapor deposition equipment EVOLAR AB, proofing its activities in the perovskite field and the strong focus on vapor phase deposition.[187] Furthermore, the company owns patents on vapor phase deposition of perovskite materials.[188] Nevertheless, it cannot be excluded that the company also works on solution processing of perovskite materials. Several recent job postings (not available online anymore) highlighted the search for candidates with experience in solution processing and the close connection between the company and the National Renewable Energy laboratory (NREL) with its focus on solution processing indicates that solution processing is at least explored in parallel.[189,190]

FUJIFILM Wako Pure Chemical Corporation (United States): The homepage of the company states activities in the supply of materials for perovskite-based solar cells.[191] No further information could be collected. The fact that the company acts as a materials supplier indicates a focus on no specific deposition method.

MujiElectric (United States): An award application of the company states its activities in the development of perovskite solar cells as well as the licensing of technology developed by the National Renewable Energy Laboratory (NREL).[192] Given the fact that, to the author's best knowledge, NREL does not have any publications on vapor processing, the licensing is likely relying on solution processing and the company therefore believed to work exclusively on this method.

Verde Technologies (United States): The homepage of the company states its activities in the development of perovskite solar cells since 2021.[193] The images of solution deposition equipment on the homepage indicate an exclusive focus on these methods.

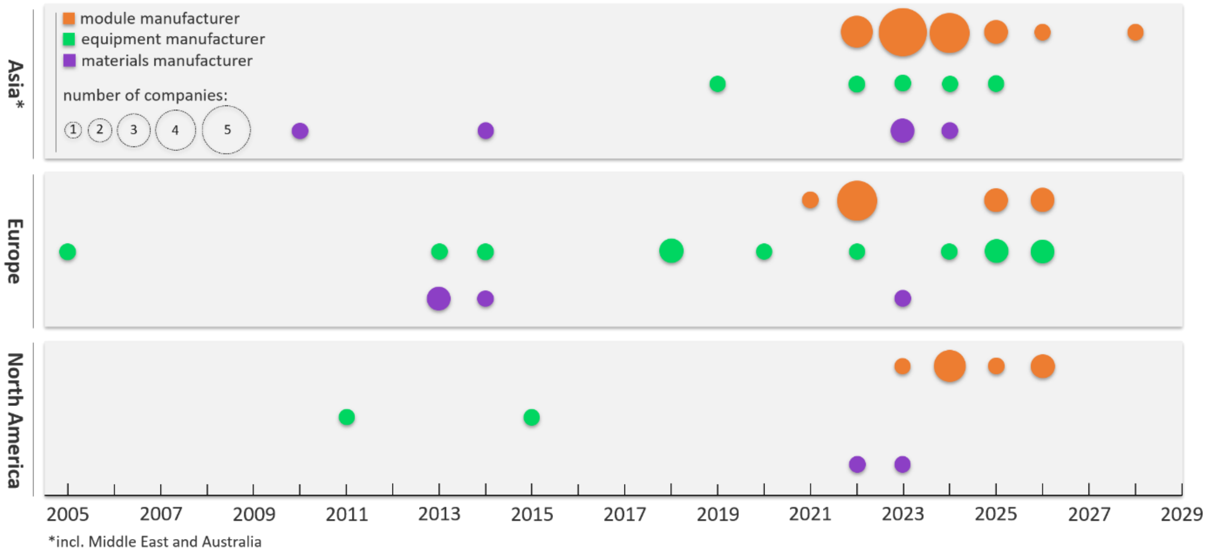

Fig. S3 | Anticipated commercialization dates of industrial manufacturing of perovskite PV and related business sectors. Listed are only the commercialization dates that have been disclosed by companies that participated in the industry survey (see Table S5 in the Supporting Information). The industry survey was performed between 2021 and 2023.

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