Meso-superstructured Hybrid Solar Cells (MESO)

Grant agreement no: 604032

Use and dissemination of foreground

Section A

This section should describe the dissemination measures, including any scientific publications relating to foreground. Its content will be made available in the public domain thus demonstrating the added-value and positive impact of the project on the European Union.

All MESO partners have benefited considerably from the MESO project. Below we give some specific examples of how each partner has benefited, followed by a list of all the scientific publications.

UOXF (1): All research in Oxford is not focused on perovskite optoelectronics. Primarily photovoltaics but also on light emitting applications. In total, since MESO UOXF has raised ~12 million EUR in grant funding, which includes a 3.5M Euro cluster deposition facility for advanced thin film perovskite device fabrication. The perovskite area of research and general growth of the filed has significantly assisted in H. J. Snaith establishing himself as a leader in this area. On the back of citations for their articles on perovskite solar cells, Snaith was deemed to be #2 "most influential scientific mind" in all sciences for publishing the 2nd most number of highly cited papers over the last 2 years. The MESO project and consortium has been central to this progress. UOXF have licenced the "buffer layer patent" to OxfordPV Ltd, and this patent is now entering the PCT phase.

EPFL (2): Md K Nazeeruddin and M. Graetzel have benefited enormously from the perovskite technology and the MESO project. Specifically Md K Nazeeruddin has been made a full professor and set up his own independent research facility at Sion in Switzerland, as an EPFL, Vallais campus. Both Nazeeruddin and Gratzel were in the top 19 Authors in the world, for publishing the highest number of highly cited articles over the last 2 years. In addition to a number of further grants, EPFL have formed a consortium which is applying for a 100 million USD grant. MKN envisages the Indian Market for perovskite solar cells and will attempt to raise funding to establish an Indian manufacturing company based on the low cost printable "triple layer" perovskite solar cell.

CNR (5): Filippo De Angelis: Acquired Italian national funds and personally has become an editor of ACS energy letters due to the perovskite work and the MESO project.

IIT (3): Alex Barker/Annamaria Petrozza have been granted 3 new projects, all on light-emitting perovskite applications. AP has established herself as one of the leading authorities on fundamental aspects of perovskite optoelectronics.

HZB (7): Before the start of MESO, HZB had no background in perovskite (or dye sensitized/organic) solar cells. Therefore, in the set-up phase of the project, it was planned that HZB's main contribution should be to provide know how on high efficiency silicon solar cells to the fabrication of perovskite/silicon tandem cells, i.e. to provide the silicon cells and work on device integration with the perovskite top cell, to be manufactured by project partners EPFL and UOXF.

However, HZB's involvement in the MESO project, the know-how gained in the field of perovskite-based PV over the course of the project and the fruitful collaboration with MESO partners has led to developments that go far beyond this initial, limited scope. MESO has stimulated and/or influenced funding for multitude of new perovskite cell related projects:

- MESO has stimulated strong activities in materials characterization of perovskites in HZB's new Energy Materials In-Situ Lab (EMIL), which provides a close integration of deposition tools with synchrotron-based X-ray analytics (https://www.helmholtz-

berlin.de/projects/emil/index_en.html). First results from a collaboration between H. Snaith's group/U Oxford and M. Bär/HZB have been published recently, e.g. [Starr, D. E., Sadoughi, G., Handick, E., Wilks, R. G., Alsmeier, J. H., Köhler, L., ... & Bär, M. (2015). Direct observation of an inhomogeneous chlorine distribution in CH 3 NH 3 PbI 3− x Cl x layers: surface depletion and interface enrichment. *Energy & Environmental Science*, *8*(5), 1609-1615.]

- Triggered by MESO, an activity on perovskite materials and solar cells development was integrated into the German national project HI ERN (Helmholtz-Institute Erlangen-Nürnberg for Renewable Energy), a collaboration between Forschungszentrum Jülich, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) and Helmholtz-Zentrum Berlin (HZB). (http://www.hi-ern.de)
- MESO had a strong influence on the project planning, evaluation and acquisition of funding for the Helmholtz Innovation Lab HySPRINT (Hybrid Silicon Perovskite Research, Integration & Novel Technologies) (https://www.helmholtz-berlin.de/quellen/corelabs/hysprint_en.html), which has the objective to develop new material combinations and processes for energy applications.
- The set-up, positive evaluation and funding of the German national Project Persist (2015-2018) with project partners HZB, Fraunhofer ISE, and industrial partners Merck and Heraeus, funded by the German ministry of economy (BMWi), was strongly influenced by the results of HZB's collaboration with MESO partners.

Furthermore,

- At HZB, two Helmholtz Young Investigator Groups on perovskite/silicon tandem cells (led by Steve Albrecht) and on perovskite printing/upscaling (led by Eva Unger) could be acquired. Especially for the acquisition of the former group, it was essential to demonstrate that key know-how had been developed in fruitful collaborations with MESO partners EPFL and UOXF, as shown by joint publications [e.g. Albrecht, S.; Saliba, M.; Baena, J. P. C.; Lang, F.; Kegelmann, L.; Mews, M.; Steier, L.; Abate, A.; Rappich, J.; Korte, L., Monolithic perovskite/silicon-heterojunction tandem solar cells processed at low temperature. *Energy & Environmental Science*, 2016, 9, 81.].
- The graduate school HyPerCells on perovskite solar cells with ~10 enrolled graduate students was set up as a joint activity between HZB and University of Potsdam (http://www.uni-potsdam.de/perovskites/index.html).

We estimate the perovskite- and/or silicon/perovskite-tandem-related 3rd party funding acquired for HZB in these activities to ~ 3.8 million €. It is safe to say that MESO was the nucleus and provided a strong initial momentum to the setup and acquisition of these projects.

KTU (4): The main project benefits for KTU were the new know-how gained in the fields of photovoltaics and materials design from cooperation with the leaders in these fields. The project activities also enlarged and strengthened our network of research and industrial partners. Foreground of the project has greatly benefited KTU research group in identifying the most promising groups of organic molecules for the perovskite solar cells and understanding the causes why certain groups of molecules function better than the others. Foreground obtained during the project allowed us to identify the most promising directions of research and groups of materials for the perovskite solar cells and better understand the reasons why certain groups of molecules function better than the others. We plan to

consolidate our efforts and concentrate on investigating in the identified directions so that more efficient and cost-effective solutions for the perovskite solar cells could be identified and developed.

Two new national projects employing 3 researchers have been started as a direct result of the MESO project:

- Grant of the Research Council of Lithuania (No. MIP-105/2015) “Synthesis of Compounds with Trȍger Base Moiety in the Center of the Molecules for the Efficient Solar Cells”. Budget: 100 000 Eur.
- Grant of the Research Council of Lithuania (No. LAT07/16) “Metal organic perovskite photodetectors”. Budget: 300 000 Eur.

Trials of the new HTMs patented within MESO are now underway at Oxford PV Ltd, with a view to licence the technology if the materials prove to outperform the existing commercial HTMs in OXPVs devices.

OXPV (6): Oxford PV is the MESO projects commercial partner and hence can make the most commercial benefit from the MESO foreground. The outputs from the MESO project have helped considerably on OXPVs route to market with the perovskite PV technology.

List of Publications

Order Nº	Nº	D.O.I.	Title	Author(s)	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Date of publication	Relevant pages	Open access is/will be provided to this publication	Status	Actions
	1	10.1039/c4cp00569d	Structural and electronic properties of organo-halide lead perovskites: a combined IR-spectroscopy and ab initio molecular dynamics investigation	Edoardo Mosconi , Claudio Quarti , Tanja Ivanovska , Giampiero Ruani , Filippo De Angelis	Physical Chemistry Chemical Physics	Vol. 16/Issue 30	Royal Society of Chemistry	United Kingdom	01/01/2014	16137	No	VALIDATED	
	2	10.1021/jz402589q	The Raman Spectrum of the CH	Claudio Quarti , Giulia Grancini , Edoardo Mosconi , Paola Bruno , James M. Ball , Michael M. Lee , Henry J. Snaith , Annamaria Petrozza , Filippo De Angelis	Journal of Physical Chemistry Letters	Vol. 5/Issue 2	American Chemical Society	United States	16/01/2014	279-284	No	VALIDATED	
	3	10.1038/srep04467	Relativistic GW calculations on CH3NH3PbI3 and CH3NH3SnI3 Perovskites for Solar Cell Applications	Paolo Umari , Edoardo Mosconi , Filippo De Angelis	Scientific Reports	Vol. 4	Nature Publishing Group	United Kingdom	26/03/2014	4467	No	VALIDATED	
	4	10.1038/ncomms4586	Excitons versus free charges in organo-lead tri-halide perovskites	Valerio D'Innocenzo,Giulia Grancini,Marcelo J. P. Alcocer,Ajay Ram Srimath Kandada,Samuel D. Stranks,Michael M. Lee,Guglielmo Lanzani,Henry J. Snaith& Annamaria Petrozza	Nature Communications	5	Nature Publishing Group		08/04/2014	3586	Yes	VALIDATED	
	5	10.1021/nl500627x	Supramolecular Halogen Bond Passivation of Organic–Inorganic Halide Perovskite Solar Cells	Antonio Abate †, Michael Saliba †, Derek J. Hollman †, Samuel D. Stranks †, Konrad Wojciechowski †, Roberto Avolio ‡, Giulia Grancini §, Annamaria Petrozza §, and Henry J. Snaith *†	Nano Letters	Nano Lett., 2014, 14 (6)	American Chemical Society		01/05/2014	3247–3254		VALIDATED	
	6	10.1021/nl5012992	Cation-Induced Band-Gap Tuning in Organohalide Perovskites: Interplay of Spin–Orbit Coupling and Octahedra Tilting	Anna Amat †, Edoardo Mosconi *†, Enrico Ronca †‡, Claudio Quarti †, Paolo Umari §∥, Md. K. Nazeeruddin ⊥, Michael Grätzel ⊥, and Filippo De Angelis *†	Nano Letters	2014, 14 (6)	American Chemical Society		05/05/2014	3608–3616	Yes	VALIDATED	
	7	10.1063/1.4889845	Role of the crystallization substrate on the photoluminescence properties of organo-lead mixed halides perovskites	Michele De Bastiani1,2,a), Valerio D'Innocenzo1,3,a), Samuel D. Stranks4, Henry J. Snaith4 and Annamaria Petrozza1,b)	AIP Advances	081509 (2014)	AIP		28/07/2014	081509 (2014)	Yes	VALIDATED	
	8	10.1021/jz501127k	First-Principles Investigation of the TiO	Edoardo Mosconi , Enrico Ronca , Filippo De Angelis	Journal of Physical Chemistry Letters	Vol. 5/Issue 15	American Chemical Society	United States	07/08/2014	2619-2625	No	VALIDATED	
	9	10.1021/jz501869f	Elusive Presence of Chloride in Mixed Halide Perovskite Solar Cells	Silvia Colella , Edoardo Mosconi , Giovanna Pellegrino , Alessandra Alberti , Valentino L. P. Guerra , Sofia Masi , Andrea Listorti , Aurora Rizzo , Guglielmo Guido Condorelli , Filippo De Angelis , Giuseppe Gigli	Journal of Physical Chemistry Letters	Vol. 5/Issue 20	American Chemical Society	United States	16/10/2014	3532-3538	No	VALIDATED	
	10	10.1021/cm5032046	Interplay of Orientational Order and Electronic Structure in Methylammonium Lead Iodide: Implications for Solar Cell Operation	Claudio Quarti , Edoardo Mosconi , Filippo De Angelis	Chemistry of Materials	Vol. 26/Issue 22	American Chemical Society	United States	25/11/2014	6557-6569		VALIDATED	
	11	10.1021/ja511198f	Tuning the Light Emission Properties by Band Gap Engineering in Hybrid Lead Halide Perovskite	Valerio D'Innocenzo †‡, Ajay Ram Srimath Kandada *†, Michele De Bastiani †§, Marina Gandini †, and Annamaria Petrozza *†	ACS Applied Materials and Interfaces	2014, 136 (51)	American Chemical Society		03/12/2014	17730		VALIDATED	
	12	10.1039/C4TA06230B	Electronic and optical properties of mixed Sn–Pb organohalide perovskites: a first principles investigation	Edoardo Mosconi,Paolo Umaribc and Filippo De Angelis	Journal of Materials Chemistry A	2015	Royal Society of Chemistry		23/12/2014	-		VALIDATED	

13	10.1039/C5EE02608C	Highly efficient planar perovskite solar cells through band alignment engineering	Juan Pablo Correa Baena , Ludmilla Steier , Wolfgang Tress , Michael Saliba , Stefanie Neutzner , Taisuke Matsui , Fabrizio Giordano , T. Jesper Jacobsson , Ajay Ram Srimath Kandada , Shaik M. Zakeeruddin , Annamaria Petrozza , Antonio Abate , Mohammad Khaja Nazeeruddin , Michael Grätzel , Anders Hagfeldt	Energy and Environmental Science	Vol. 8/Issue 10	Royal Society of Chemistry	United Kingdom	01/01/2015	2928-2934		VALIDATED
14	10.1039/C5SC02542G	CH 3 NH 3 PbI 3 perovskite single crystals: surface photophysics and their interaction with the environment	G. Grancini , V. D'Innocenzo , E. R. Dohner , N. Martino , A. R. Srimath Kandada , E. Mosconi , F. De Angelis , H. I. Karunadasa , E. T. Hoke , A. Petrozza	Chemical Science	Vol. 6/Issue 12	Royal Society of Chemistry	United Kingdom	01/01/2015	7305-7310	Yes	VALIDATED
15	10.1039/C5EE01265A	Defect migration in methylammonium lead iodide and its role in perovskite solar cell operation	Jon M. Azpiroz , Edoardo Mosconi , Juan Bisquert , Filippo De Angelis	Energy and Environmental Science	Vol. 8/Issue 7	Royal Society of Chemistry	United Kingdom	01/01/2015	2118-2127	Yes	VALIDATED
16	10.1021/jz502703p	Improving the Long-Term Stability of Perovskite Solar Cells with a Porous Al	Simone Guarnera , Antonio Abate , Wei Zhang , Jamie M. Foster , Giles Richardson , Annamaria Petrozza , Henry J. Snaith	Journal of Physical Chemistry Letters	Vol. 6/Issue 3	American Chemical Society	United States	05/02/2015	432-437	No	VALIDATED
17	10.1021/acs.jpclett.5b00542	Ferroelectric Polarization of CH 3 NH 3 PbI 3 : A Detailed Study Based on Density Functional Theory and Symmetry Mode Analysis	Alessandro Stroppa , Claudio Quarti , Filippo De Angelis , Silvia Picozzi	Journal of Physical Chemistry Letters	Vol. 6/Issue 12	American Chemical Society	United States	18/06/2015	2223-2231	Yes	VALIDATED
18	10.1021/acsami.5b02237	Observation and Mediation of the Presence of Metallic Lead in Organic–Inorganic Perovskite Films	Golnaz Sadoughi , David E. Starr , Evelyn Handick , Samuel D. Stranks , Mihaela Gorgoi , Regan G. Wilks , Marcus Bär , Henry J. Snaith	ACS Applied Materials and Interfaces	Vol. 7/Issue 24	American Chemical Society	United States	24/06/2015	13440-13444	Yes	VALIDATED
19	10.1021/acs.chemmater.5b01991	Ab Initio Molecular Dynamics Simulations of Methylammonium Lead Iodide Perovskite Degradation by Water	Edoardo Mosconi , Jon M. Azpiroz , Filippo De Angelis	Chemistry of Materials	Vol. 27/Issue 13	American Chemical Society	United States	14/07/2015	4885-4892	Yes	VALIDATED
20	10.1021/acs.jpclett.5b01177	Perovskite Solar Cells with Large-Area CVD-Graphene for Tandem Solar Cells	Felix Lang , Marc A. Gluba , Steve Albrecht , Jörg Rappich , Lars Korte , Bernd Rech , Norbert H. Nickel	Journal of Physical Chemistry Letters	Vol. 6/Issue 14	American Chemical Society	United States	16/07/2015	2745-2750		VALIDATED
21	10.1038/nphoton.2015.151	Role of microstructure in the electron–hole interaction of hybrid lead halide perovskites	Giulia Grancini , Ajay Ram Srimath Kandada , Jarvist M. Frost , Alex J. Barker , Michele De Bastiani , Marina Gandini , Sergio Marras , Guglielmo Lanzani , Aron Walsh , Annamaria Petrozza	Nature Photonics	Vol. 9/Issue 10	Nature Publishing Group	United Kingdom	17/08/2015	695-701		VALIDATED
22	10.1002/anie.201504666	A Methoxydiphenylamine-Substituted Carbazole Twin Derivative: An Efficient Hole-Transporting Material for Perovskite Solar Cells	Paul Gratia , Artiom Magomedov , Tadas Malinauskas , Maryte Daskeviciene , Antonio Abate , Shahzada Ahmad , Michael Grätzel , Vytautas Getautis , Mohammad Khaja Nazeeruddin	Angewandte Chemie - International Edition	Vol. 54/Issue 39	John Wiley and Sons Ltd	United Kingdom	21/09/2015	11409-11413	No	VALIDATED
23	10.1021/acsnano.5b03626	The Importance of Moisture in Hybrid Lead Halide Perovskite Thin Film Fabrication	Giles E. Eperon , Severin N. Habisreutinger , Tomas Leijtens , Bardo J. Bruijnaers , Jacobus J. van Franeker , Dane W. deQuilettes , Sandeep Pathak , Rebecca J. Sutton , Giulia Grancini , David S. Ginger , Rene A. J. Janssen , Annamaria Petrozza , Henry J. Snaith	ACS Nano	Vol. 9/Issue 9	American Chemical Society	United States	22/09/2015	9380-9393		VALIDATED
24	10.1002/aenm.201500962	Mapping Electric Field-Induced Switchable Poling and Structural Degradation in Hybrid Lead Halide Perovskite Thin Films	Tomas Leijtens , Eric T. Hoke , Giulia Grancini , Daniel J. Slotcavage , Giles E. Eperon , James M. Ball , Michele De Bastiani , Andrea R. Bowring , Nicola Martino , Konrad Wojciechowski , Michael D. McGehee , Henry J. Snaith , Annamaria Petrozza	Advanced Energy Materials	Vol. 5/Issue 20	Wiley	United States	01/10/2015	1500962		VALIDATED
25	10.1021/acs.chemmater.5b03769	Perovskite Crystals for Tunable White Light Emission	Sandeep Pathak , Nobuya Sakai , Florencia Wisnivesky Rocca Rivarola , Samuel D. Stranks , Jiewei Liu , Giles E. Eperon , Caterina Ducati , Konrad Wojciechowski , James T. Griffiths , Amir Abbas Haghighirad , Alba Pellaroque , Richard H. Friend , Henry J. Snaith	Chemistry of Materials	Vol. 27/Issue 23	American Chemical Society	United States	08/12/2015	8066-8075	Yes	VALIDATED

26	10.1021/jacs.5b09085	Modulating the Electron–Hole Interaction in a Hybrid Lead Halide Perovskite with an Electric Field	Tomas Leijtens , Ajay Ram Srimath Kandada , Giles E. Eperon , Giulia Grancini , Valerio D'Innocenzo , James M. Ball , Samuel D. Stranks , Henry J. Snaith , Annamaria Petrozza	Journal of the American Chemical Society	Vol. 137/Issue 49	American Chemical Society	United States	16/12/2015	15451-15459	Yes	VALIDATED	
27	10.1039/C5EE03911H	Branched methoxydiphenylamine-substituted fluorene derivatives as hole transporting materials for high-performance perovskite solar cells	Tadas Malinauskas , Michael Saliba , Taisuke Matsui , Maryte Daskeviciene , Simona Urnikaite , Paul Gratia , Robert Send , Henrike Wonneberger , Ingmar Bruder , Michael Graetzel , Vytautas Getautis , Mohammad Khaja Nazeeruddin	Energy and Environmental Science	Vol. 9/Issue 5	Royal Society of Chemistry	United Kingdom	01/01/2016	1681-1686	No	VALIDATED	
28	10.1039/C6RA09878A	Molecular engineering of the hole-transporting material spiro-OMeTAD via manipulation of alkyl groups	D. Tomkute-Luksiene , M. Daskeviciene , T. Malinauskas , V. Jankauskas , R. Degutyte , R. Send , N. G. Pschirer , H. Wonneberger , I. Bruder , V. Getautis	RSC Advances	Vol. 6/Issue 65	RSC	United Kingdom	01/01/2016	60587-60594	No	VALIDATED	
29	10.1039/C6TA01087C	The mechanism of toluene-assisted crystallization of organic–inorganic perovskites for highly efficient solar cells	Nobuya Sakai , Sandeep Pathak , Hsin-Wei Chen , Amir A. Haghighirad , Samuel D. Stranks , Tsutomu Miyasaka , Henry J. Snaith	Journal of Materials Chemistry A	Vol. 4/Issue 12	Royal Society of Chemistry	United Kingdom	01/01/2016	4464-4471	Yes	VALIDATED	
30	10.1039/C5RA24211H	"Click-chemistry" inspired synthesis of hydrazone-based molecular glasses	A. Magomedov , S. Urnikaite , O. Paliulis , V. Jankauskas , V. Getautis	RSC Advances	Vol. 6/Issue 11	RSC	United Kingdom	01/01/2016	8701-8704	No	VALIDATED	
31	10.1039/C6EE01504B	Light-induced annihilation of Frenkel defects in organo-lead halide perovskites	Edoardo Mosconi , Daniele Meggiolaro , Henry J. Snaith , Samuel D. Stranks , Filippo De Angelis	Energy and Environmental Science	Vol. 9/Issue 10	Royal Society of Chemistry	United Kingdom	01/01/2016	3180-3187	No	VALIDATED	
32	10.1039/C6CP03969C	Electronic and optical properties of MAPbX 3 perovskites (X = I, Br, Cl): a unified DFT and GW theoretical analysis	Edoardo Mosconi , Paolo Umari , Filippo De Angelis	Physical Chemistry Chemical Physics	Vol. 18/Issue 39	Royal Society of Chemistry	United Kingdom	01/01/2016	27158-27164	No	VALIDATED	
33	10.1039/C5EE02925B	Structural and optical properties of methylammonium lead iodide across the tetragonal to cubic phase transition: implications for perovskite solar cells	Claudio Quarti , Edoardo Mosconi , James M. Ball , Valerio D'Innocenzo , Chen Tao , Sandeep Pathak , Henry J. Snaith , Annamaria Petrozza , Filippo De Angelis	Energy and Environmental Science	Vol. 9/Issue 1	Royal Society of Chemistry	United Kingdom	01/01/2016	155-163	Yes	VALIDATED	
34	10.1039/C6NR01275B	Efficiency enhancement of perovskite solar cells via incorporation of phenylethenyl side arms into indolocarbazole-based hole transporting materials	Ieva Petrikyte , Iwan Zimmermann , Kasparas Rakstys , Maryte Daskeviciene , Tadas Malinauskas , Vygintas Jankauskas , Vytautas Getautis , Mohammad Khaja Nazeeruddin	Nanoscale	Vol. 8/Issue 16	RSC Publishing	United Kingdom	01/01/2016	8530-8535	No	VALIDATED	
35	10.1039/C5EE02965A	Monolithic perovskite/silicon-heterojunction tandem solar cells processed at low temperature	Steve Albrecht , Michael Saliba , Juan Pablo Correa Baena , Felix Lang , Lukas Kegelmann , Mathias Mews , Ludmilla Steier , Antonio Abate , Jörg Rappich , Lars Korte , Rutger Schlatmann , Mohammad Khaja Nazeeruddin , Anders Hagfeldt , Michael Grätzel , Bernd Rech	Energy and Environmental Science	Vol. 9/Issue 1	Royal Society of Chemistry	United Kingdom	01/01/2016	81-88		VALIDATED	
36	10.1126/science.aad5845	A mixed-cation lead mixed-halide perovskite absorber for tandem solar cells	D. P. McMeekin , G. Sadoughi , W. Rehman , G. E. Eperon , M. Saliba , M. T. Horantner , A. Haghighirad , N. Sakai , L. Korte , B. Rech , M. B. Johnston , L. M. Herz , H. J. Snaith	Science	Vol. 351/Issue 6269	American Association for the Advancement of Science	United States	08/01/2016	151-155		VALIDATED	
37	10.1038/NENERGY.2015.17	A molecularly engineered hole-transporting material for efficient perovskite solar cells	Michael Saliba , Simonetta Orlandi , Taisuke Matsui , Sadig Aghazada , Marco Cavazzini , Juan-Pablo Correa-Baena , Peng Gao , Rosario Scopelliti , Edoardo Mosconi , Klaus-Hermann Dahmen , Filippo De Angelis , Antonio Abate , Anders Hagfeldt , Gianluca Pozzi , Michael Graetzel , Mohammad Khaja Nazeeruddin	Nature Energy	Vol. 1/Issue 2	Nature Publishing Group (NPG)	United Kingdom	18/01/2016	15017	Yes	VALIDATED	
38	10.1021/jacs.5b12124	Solution Synthesis Approach to Colloidal Cesium Lead Halide Perovskite Nanoplatelets with Monolayer-Level Thickness Control	Quinten A. Akkerman , Silvia Genaro Motti , Ajay Ram Srimath Kandada , Edoardo Mosconi , Valerio D'Innocenzo , Giovanni Bertoni , Sergio Marras , Brett A. Kamino , Laura Miranda , Filippo De Angelis , Annamaria	Journal of the American Chemical Society	Vol. 138/Issue 3	American Chemical Society	United States	27/01/2016	1010-1016	Yes	VALIDATED	

39	10.1021/acs.accounts.5b00464	Photophysics of Hybrid Lead Halide Perovskites: The Role of Microstructure	Ajay Ram Srimath Kandada , Annamaria Petrozza	Accounts of Chemical Research	Vol. 49/Issue 3	American Chemical Society	United States	15/03/2016	536-544		VALIDATED
40	10.1002/aenm.201502458	Bandgap-Tunable Cesium Lead Halide Perovskites with High Thermal Stability for Efficient Solar Cells	Rebecca J. Sutton , Giles E. Eperon , Laura Miranda , Elizabeth S. Parrott , Brett A. Kamino , Jay B. Patel , Maximilian T. Hörantner , Michael B. Johnston , Amir Abbas Haghighirad , David T. Moore , Henry J. Snaith	Advanced Energy Materials	Vol. 6/Issue 8	Wiley	United States	01/04/2016	1502458		VALIDATED
41	10.1021/acs.jpclett.6b00564	Dynamical Origin of the Rashba Effect in Organohalide Lead Perovskites: A Key to Suppressed Carrier Recombination in Perovskite Solar Cells?	Thibaud Etienne , Edoardo Mosconi , Filippo De Angelis	Journal of Physical Chemistry Letters	Vol. 7/Issue 9	American Chemical Society	United States	05/05/2016	1638-1645	Yes	VALIDATED
42	10.1088/2040-8978/18/6/064012	Towards optical optimization of planar monolithic perovskite/silicon-heterojunction tandem solar cells	Steve Albrecht , Michael Saliba , Juan-Pablo Correa-Baena , Klaus Jäger , Lars Korte , Anders Hagfeldt , Michael Grätzel , Bernd Rech	Journal of Optics	Vol. 18/Issue 6	Institute of Physics Publishing	United Kingdom	01/06/2016	064012		VALIDATED
43	10.1021/acs.chemmater.6b00779	Enhanced TiO 2 /MAPbI 3 Electronic Coupling by Interface Modification with PbI 2	Edoardo Mosconi , Giulia Grancini , Cristina Roldán-Carmona , Paul Gratia , Iwan Zimmermann , Mohammad Khaja Nazeeruddin , Filippo De Angelis	Chemistry of Materials	Vol. 28/Issue 11	American Chemical Society	United States	14/06/2016	3612-3615	Yes	VALIDATED
44	10.1002/pssa.201532944	In situ graphene doping as a route toward efficient perovskite tandem solar cells	Felix Lang , Marc A. Gluba , Steve Albrecht , Oleksandra Shargaieva , Jörg Rappich , Lars Korte , Bernd Rech , Norbert H. Nickel	Physica Status Solidi (A) Applications and Materials	Vol. 213/Issue 7	Wiley-VCH Verlag	Germany	01/07/2016	1989-1996		VALIDATED
45	10.1021/acsenergylett.6b00108	Mobile Ions in Organohalide Perovskites: Interplay of Electronic Structure and Dynamics	Edoardo Mosconi , Filippo De Angelis	Journal of the American Chemical Society	Vol. 1/Issue 1	American Chemical Society		08/07/2016	182-188	Yes	VALIDATED
46	10.1021/acsenergylett.6b00077	High Open-Circuit Voltage: Fabrication of Formamidinium Lead Bromide Perovskite Solar Cells Using Fluorene–Dithiophene Derivatives as Hole-Transporting Materials	Neha Arora , Simonetta Orlandi , M. Ibrahim Dar , Sadig Aghazada , Gwénolé Jacopin , Marco Cavazzini , Edoardo Mosconi , Paul Gratia , Filippo De Angelis , Gianluca Pozzi , Michael Graetzel , Mohammad Khaja Nazeeruddin	ACS Sustainable Chemistry & Engineering	Vol. 1/Issue 1	ACS		08/07/2016	107-112	Yes	VALIDATED
47	10.1002/asia.201600474	Synthesis and Investigation of the V-shaped Tröger's Base Derivatives as Hole-transporting Materials	Titas Braukyla , Nobuya Sakai , Maryte Daskeviciene , Vygintas Jankauskas , Egidijus Kamarauskas , Tadas Malinauskas , Henry J. Snaith , Vytautas Getautis	Chemistry - An Asian Journal	Vol. 11/Issue 14	John Wiley and Sons Ltd	United Kingdom	20/07/2016	2049-2056	Yes	VALIDATED
48	10.1002/cssc.201600762	Additive-Free Transparent Triarylamine-Based Polymeric Hole-Transport Materials for Stable Perovskite Solar Cells	Taisuke Matsui , Ieva Petrikyte , Tadas Malinauskas , Konrad Domanski , Maryte Daskeviciene , Matas Steponaitis , Paul Gratia , Wolfgang Tress , Juan-Pablo Correa-Baena , Antonio Abate , Anders Hagfeldt , Michael Grätzel , Mohammad Khaja Nazeeruddin , Vytautas Getautis , Michael Saliba	ChemSusChem		Wiley-VCH Verlag	Germany	01/08/2016		No	VALIDATED
49	10.1002/adma.201603326	Radiation Hardness and Self-Healing of Perovskite Solar Cells	Felix Lang , Norbert H. Nickel , Jürgen Bundesmann , Sophie Seidel , Aandrea Denker , Steve Albrecht , Victor V. Brus , Jörg Rappich , Bernd Rech , Giovanni Landi , Heinrich C. Neitzert	Advanced Materials		Wiley-VCH Verlag	Germany	01/08/2016			VALIDATED
50	10.1021/acs.inorgchem.6b01681	Chlorine Incorporation in the CH 3 NH 3 PbI 3 Perovskite: Small Concentration, Big Effect	Claudio Quarti , Edoardo Mosconi , Paolo Umari , Filippo De Angelis	Inorganic Chemistry		American Chemical Society	United States	26/09/2016		No	VALIDATED

Section B

This section should specify the exploitable foreground and provide the plans for exploitation. All these data can be public or confidential; the report must clearly mark non-publishable (confidential) parts that will be treated as such by the Commission. Information under Section B that is not marked as confidential will be made available in the public domain thus demonstrating the added-value and positive impact of the project on the European Union.

Intellectual Property

All inventive steps which have **commercial potential have been patent protected and exploited** through the technology transfer offices at the respective institutions and commercial partners. To ensure exploitation of the advances, the MESO project is based on the appropriate participation of the research and industrial partner. In particular, **Oxford Photovoltaics Ltd**, is in an appropriate positions in the PV value chain to work effectively with the broader materials supply chain, and Manufacturing industry. This guarantees efficient, effective technology transfer and direct exploitation of the new knowledge from Europe.

Application reference (s) (eg EP123456)	Subject or title of application	WP	Partners and applicant (s) as on the application
EP15157217.9.	"Organic Hole transporting Materials for Opto Electronic Applications"	WP1	KTU and EPFL Paul Gratia, Mohammad Khaja Nazeeruddin, Michael Graerzel, Vytautas Getautis, Maryte Daskeviciene, Tadas Malinauskas, Artiom Magomedov
PCT/IB2016/051115	“Small Molecule Hole Transporting Material for Optoelectronic and Photoelectrochemical Devices”	WP1	KTU and EPFL: Paul Gratia, Mohammad Khaja Nazeeruddin, Michael Graerzel, Vytautas Getautis, Maryte Daskeviciene, Tadas Malinauskas, Artiom Magomedov
LT2016515	“Hole Transporting Organic Molecules Possessing Enamine Groups for Optoelectronic and Photoelectroch	WP1	KTU and EPFL: Vytautas Getautis, Maryte Daskeviciene, Tadas Malinauskas, Mohammad Khaja Nazeeruddin, Sanghyun Paek, Kasparas Rakstys

	emical Devices”		
GB1410542.3	“Perovskite buffer layer with hybrid solar cell”	WP2	UOXF, IIT Henry Snaith (UOXF), Antonio Abate (UOXF), Sandeep Pathak(UOXF), Simone Guarnera (IIT Millan) , Annamaria Petrozza (IIT Millan)

[THE REPORT BELOW IS CONFIDENTIAL] This report below summarises the OxPV plans for commercial exploitation and dissemination of foreground arising from the MESO project technical development, including target product, timeline, business model and route to market.

The target product for Oxford PV at the outset of the MESO project was solar power glazing for building-integrated PV application. Oxford PV is now focused on introducing a 2-terminal, monolithically-integrated perovskite-on-silicon tandem technology into the volume production market. This approach takes advantage of the existing manufacturing infrastructure of the silicon PV industry and a focus on high absolute efficiency to make the most of the fixed cost component of PV installations (Figure 1,Figure 2).

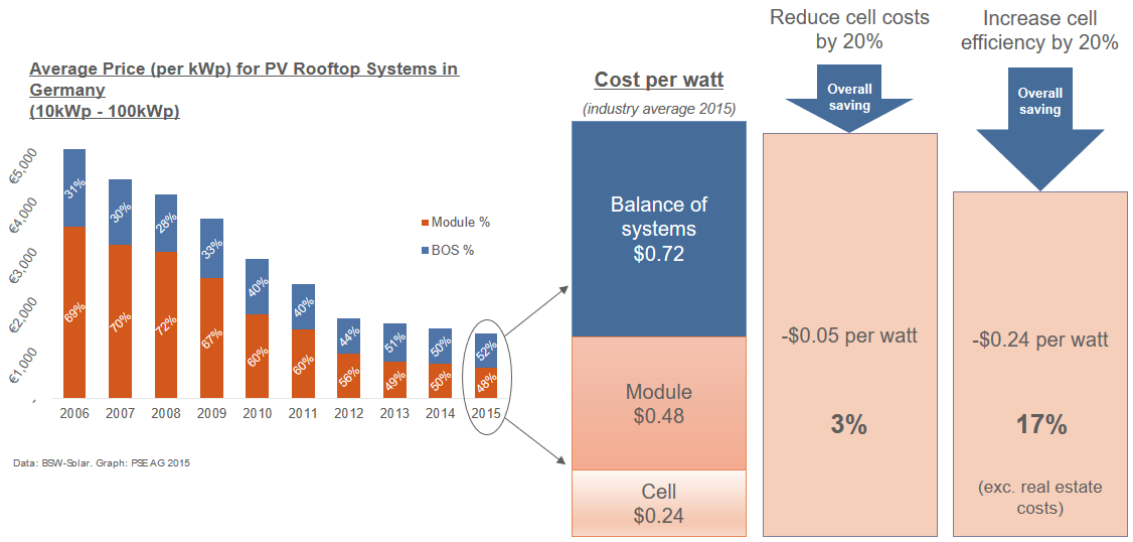

Figure 1: Cell efficiency improvements from perovskite-on-Si tandem technology offers greater potential for reduction in cost per installed Watt.

For 100MW of existing capacity upgraded to perovskite:

	Volume production setup	Pilot production setup
Capital expenditure	$16.5m	$25.5m
Added production cost per cell:		
Materials	$0.11	$0.11
Equipment amortisation (inc. depreciation, labour & overhead)	$0.11	$0.15
Total	$0.22	$0.26

Assumptions:
- 7-year asset life
- 80% materials utilisation
- 90% equipment utilisation

Figure 2:Verification of predicted cost-added for the 2T perovskite-on-silicon tandem product modelled on a 100MW PV fab using industry standard 'Factory Commander' model of Wright, Williams and Kelly.

The market opportunities for the perovskite-on-Si tandem product are:

- Increasing the efficiency of crystalline silicon PV cells, which account for circa 90% of the market.
- This is a $25bn market (at cell level) growing at a rate of 20%+ per year.
- Long-term the deployment of a perovskite-only thin film PV solution will open further future business opportunities for Oxford PV.

Business Model

The company has a lean business model which, instead of building capital-intensive manufacturing facilities, will offer the tandem technology to companies with existing manufacturing facilities via a licencing model. This allows Oxford PV to have a highly scalable, capital-efficient business model based on:

The technology will be scaled up to 156x156mm commercial wafer size at OXPVs new demonstration line facility in Germany (please see recent press release: http://www.oxfordpv.com/News/20161114-Oxford-PV-acquires-thin-film-development-line-for-perovskite-scale-up) , thoroughly tested, validated and qualified by industrial partners.

- Oxford PV aims to provide license-based solution to PV cell manufacturers. The solution package for customers will include the technology license and process know-how.

The capital-light business model allows for quick ramp-up:

- Oxford PV needs to invest only in technology / product development and sales.
- Customers of Oxford PV can upgrade their existing production lines with limited additional capital expenditures.
- Oxford PV can quickly scale its technology deployment once it is proven in commercial scale production.

Timeline and Route to Market

New Product-Demonstration Line

In order to provide a technology evaluation platform to partners and licenses, Oxford PV will be commissioning a demonstration line in Germany. This line will include manufacturing-compatible process tools that can produce the Oxford PV perovskite top cell on full size (156 x 156 mm) silicon bottom cells. With the opportunity to assemble cells into mini-modules and modules, customers will have the necessary tools to fully validate and qualify our technology. The demonstration facility will be equipped with a full-size test and reliability suite which can complement customer and industry qualification needs.

Timeline

Scaling to full-size wafers along with completing the necessary reliability tests is expected to take between 9 and 12 months. A further 6 months would be required to qualify customer product. Extrapolating forward, early conforming prototypes may be available some time in 2018.

Partnership with Si manufacturer

Oxford PV intends to finalise development with one or more key manufacturing partners to ensure compatibility with customer PV production lines and ensure seamless technology transfer.