IEA INTERNATIONAL ENERGY AGENCY

BIPV research teams & BIPV R&D facilities

An international mapping, second version

PVPS

PHOTOVOLTAIC
POWER SYSTEMS
PROGRAMME

Report IEA-PVPS T15-05: 2018

INTERNATIONAL ENERGY AGENCY
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BIPV research teams & BIPV R&D facilities
An international mapping, second version

IEA PVPS Task 15, Subtask E
Report IEA-PVPS T15-05: 2018
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Authors:
Gabriele Eder (OFI, Austria)
Peter Illich (UAS-Technikum Vienna, Austria)
Lukas Maul (UAS-Technikum Vienna, Austria)
Wiep Folkerts (SEAC, Netherlands)

With contribution of:
Karl Berger (AIT, Austria), Philipp Rechberger (UAS Wels, Austria), Michael Grobbauer (UAS Salzburg, Austria), Veronique Delisle (NRCan, Canada), Konstantinos Kapsis (NRCan, Canada), Karin Kappel (Solarcity, Denmark), Kenn H. B. Frederiksen (Kenergy, Denmark), Ya-Brigitte Assoa (CEA, France), Simon Boddaert (CSTB, France), Valentine Moreau (Cycleco, France), Dimitris Karamanis (University of Patras, Greece), Francesca Tilli (GSE, Italy), Alessandra Scognamiglio (ENEA, Italy), Laura Maturi (EURAC, Italy), Stefano Avesani (EURAC, Italy), Hiroko Saito (PVTec, Japan), Hisashi Ishii (LIXIL, Japan), Seiji Inoue (AGC, Japan), Jun-Tae Kim (Kongju National University, Korea), Jae-Yong Eom (EAGON, Korea), Juras Ulbikas (Pro Technology, Lithuania), Souad Lalami (Capital Consulting, Morocco), Michiel Ritzen (ZUYD, Netherlands), Martje van Horrik (SMRT, Netherlands), Roland Valckenborg (SEAC, Netherlands), Alex Masolin (ZUYD, Netherlands), Zeger Vroon (ZUYD, Netherlands), Angèle Reinders (University of Twente, Netherlands), Thomas Reindl (NUS, Singapore), Lu Zhao (SERIS, Singapore), Veronika Shabunko (SERIS, Singapore), Ines Apraiz (Tecnalia, Spain), Eduardo Roman (Tecnalia, Spain), Maider Machado (Tecnalia, Spain), Nuria Martin Chivelet (CIEMAT, Spain), Faustino Chenlo (CIEMAT, Spain), Peter Kovacs (Rise, Sweden), Ricardo Bernardo (Lund University, Sweden), Francesco Frontini (SUPSI, Switzerland), Pierluigi Bonomo (SUPSI, Switzerland), Stephen Koopman (CSIR, South Africa), Silke Krawietz (SETA Network, United Kingdom), Nebosja Jakica (CSU, USA)

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Contents

1 Foreword

The International Energy Agency (IEA), founded in November 1974, is an autonomous body within the framework of the Organization for Economic Co-operation and Development (OECD) which carries out a comprehensive programme of energy co-operation among its member countries.

The IEA Photovoltaic Power Systems Programme (PVPS) is one of the technological collaboration programmes (TCP's) on research and development within the International Energy Agency (IEA). IEA PVPS has been established in 1993, and participants in the programme have been conducting a variety of joint projects regarding applications of photovoltaic (PV) conversion of solar energy into electricity.

The mission of the PVPS is *"…to enhance the international collaboration efforts which accelerate the development and deployment of photovoltaic solar energy as a significant and sustainable renewable energy option…"*. The underlying assumption is that the market for PV systems is gradually expanding from the niche-markets of remote applications and consumer products to rapidly growing ones for building-integrated and centralised PV generation systems.

Building Integrated PV (BIPV) is seen as one of the five major tracks for large market penetration of PV, and IEA PVPS Task 15 focuses on the international collaboration to create an enabling framework to accelerate the penetration of BIPV products in the global market of renewables.

To reach this objective, an approach based on 6 key developments has been developed, focussed on growth from prototypes to large-scale producible and applicable products. The key developments are dissemination, business modelling, regulatory issues, environmental aspects, and applied research and development for the implementation of BIPV.

This Task contributes to the ambition of realizing zero energy buildings and built environments. The scope of this Task covers new and existing buildings, different PV technologies, different applications, as well as scale difference from 1-family dwellings to large-scale BIPV application in offices and utility buildings.

The current members of IEA PVPS Task 15 include: Australia, Austria, Belgium, Canada, China, Denmark, France, Germany, Italy, Japan, Korea, The Netherlands, Norway, Singapore, Spain, Sweden and Switzerland.

Further information on the activities and results of the Task can be found at www.iea-pvps.org.

Michiel Ritzen, operating agent IEA PVPS Task 15,

January 2019

2 Executive summary

Building Integrated PV (BIPV) is seen as one of the five major tracks for large market penetration of PV, besides price decrease, efficiency improvement, lifespan, and electricity storage. IEA PVPS Task 15 focuses on the international collaboration to create an enabling framework to accelerate the penetration of BIPV products in the global market of renewables and building components. One of the key developments necessary for this acceleration is applied research and development of BIPV.

BIPV research teams around the globe have taken on the challenge of generating knowledge and providing solutions related to the integration of photovoltaic technologies in buildings. These research teams are in contact with each other on a regular basis e.g. though conferences, international consortia and in the IEA PVPS Task 15 community. However, a clear overview of the activities and the infrastructure of the different research facilities were still to be developed.
The scope of the report is to map the research and development teams and test facilities active in BIPV. It focuses on 17 country members of IEA PVPS Task 15 and thus, this report does not provide an exhaustive list of all research teams and facilities around the globe.

To collect the necessary information and allow for an additional in-depth-analysis of the research facilities, the first publication of this report (published in January 2018) used two questionnaires, developed before the publication of the first BIPV standard, “EN 50583: Photovoltaics in buildings”. Thus, the report included all research facilities interpreted as BIPV by the respondents and not necessarily fulfilling the requirements stated in EN 50583. In this edition, Appendix C is included. It provides further information on the testing facilities and measurement capabilities based on the classifications given in standard EN 50583.
The report is split into four main sections: Chapter 4 gives a general overview of the international BIPV-related research teams and facilities. Chapter 5 provides an overview of BIPV research capabilities and workforce for each country. Chapter 6 comprises information regarding BIPV outdoor testing facilities dedicated to BIPV and their testing capabilities. Finally, Chapter 7 presents a listing of additional relevant PV/BIPV R&D facilities.

The present report shows the BIPV related research topics undertaken by the interviewed research teams, covering market studies product development and technical design, indoor testing against building and PV norms, outdoor testing, architectural and aesthetic aspects, social aspects, economical aspects, electrical system solutions for BIPV, and other research topics related to BIPV.

It also presents the latest state of the art on BIPV testing facilities, providing relevant input for BIPV developers on site selection for their BIPV product development and testing, and increases the collaboration and international agreement on BIPV testing procedures. The international collaboration is embedded in a proceeding activity of a round robin BIPV test bench testing.

Finally, this second edition of the report provides further information on the testing facilities specific product testing and measurement capabilities taking into consideration the classifications given in standard EN 50583 and the development of other related BIPV standards.
This report can be downloaded from the IEA-PVPS website: www.iea-pvps.org.

3 Acknowledgements

This paper received valuable contributions from several IEA PVPS Task 15 members and other international experts. We want to acknowledge all participants in IEA PVPS Task 15 for their helpful inputs and reviews.

4 BIPV-Research Teams and Facilities

To be able to collect the necessary information and perform additional in-depth-analysis on the test facilities, two questionnaires were developed (Appendix A and B) and submitted to Task members for completion. In addition, the present second edition of the report provides further information on the testing facilities specific product testing and measurement capabilities taking into consideration the classifications given in standard EN 50583 and the development of other related BIPV standards. To be able to collect these additional information, a third questionnaire was developed (Appendix C) and submitted to Task members for completion.

4.1 R&D teams on BIPV per country

This section presents an overview and a detailed description of the R&D teams (listed alphabetically per country). Figure 1 illustrates the research institutions per country as blue dots on the world map. The following 17 countries responded to the questionnaires or provided high-level information related to their BIPV research:

- Australia
- Austria
- Belgium
- Canada
- Denmark
- France
- Germany
- Italy
- Japan
- Morocco
- Netherlands
- Norway
- Singapore
- South Korea
- Spain
- Sweden
- Switzerland

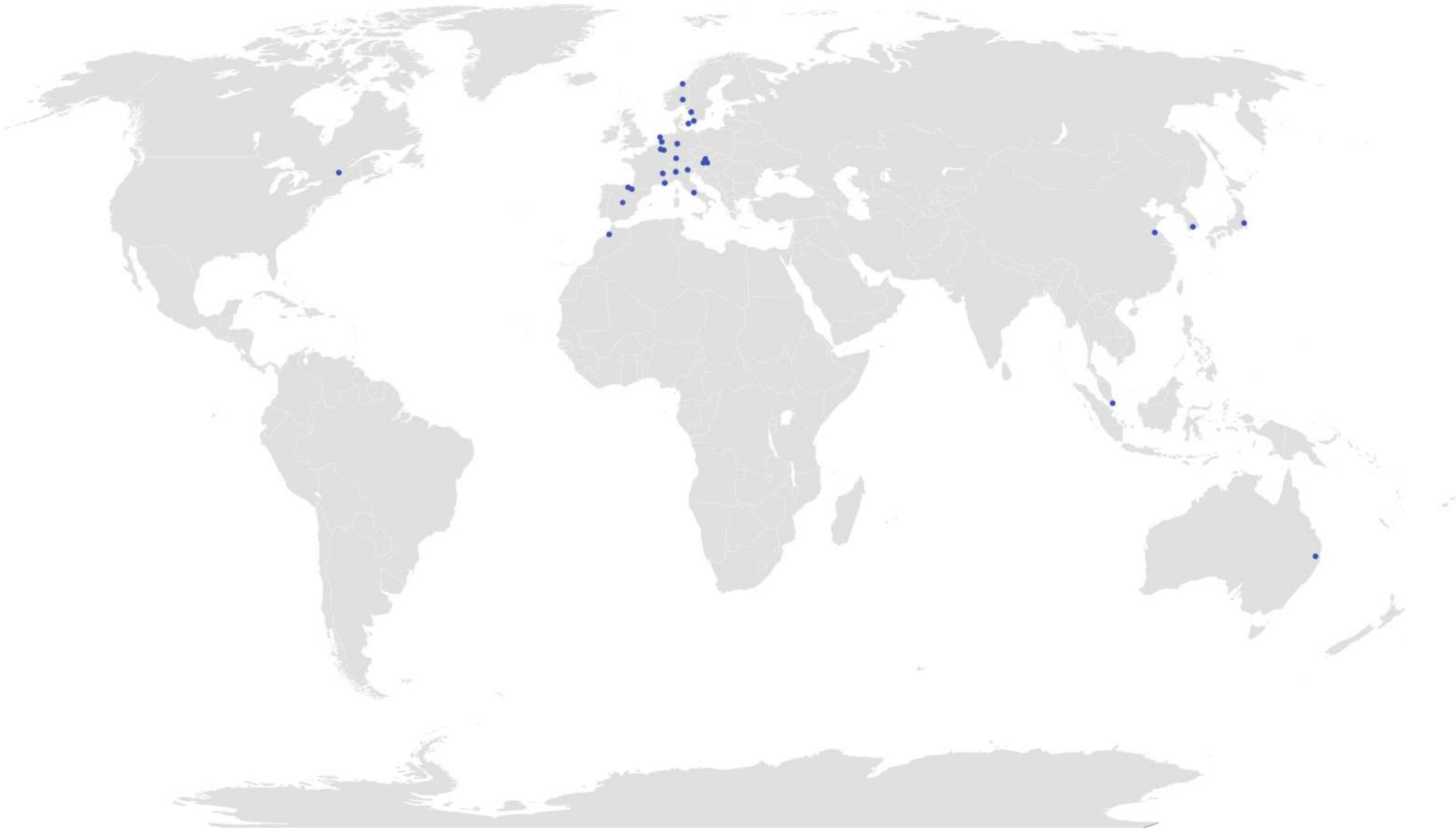


Figure 1: World map of BIPV Research institutes and teams covered in this report (marked in blue)

4.2 Australia

4.2.1 University of New South Wales

The faculty of the Built Environment is active in BIPV.
Main contact persons: Marc Snow, Alistair Sproul and Deo Prasad.

4.3 Austria

4.3.1 University of Applied Science Technikum Vienna

Basic information on the institution	
Research group	Institute of Renewable Energy – IEE
Team Leader	FH Prof. DI Hubert Fechner, MAs, MSc
Number of researchers in the team	12
Number of researchers on BIPV	4
Number of FTE (Full Time Equivalent) on BIPV	2

As the IEE is a research institute closely connected to the University of Applied Sciences, the BIPV research does not only focus on innovation but also on education in terms of renewable energy / BIPV. The Institute is responsible for the annual market analysis for PV in Austria. In addition, the institute has a strong background in electrical engineering (smart grid laboratory, storage technologies, small wind, etc.). Therefore, the conducted tests also focus on power quality (harmonics, etc.), inverter testing and system performance analysis.

BIPV related research projects:

- ShapePV - The shape of BIPV to come (national project);
- DEM4BIPV: Development of innovative educational material for building-integrated photovoltaics (EU Erasmus+ project);
- Infinity - Climate sensitive long-time reliability of photovoltaics (national flag-ship project); and,
- Several PV related product tests

References:

- Momir Tabakovic, Hubert Fechner, Wilfried van Sark, Atse Louwen, George Georghiou, George Makridesc. Eliza Loucaidou, Monica Ioannidou, Ingrid Weiss, Sofia Arancon, & Stephanie Betz: Status and outlook for building integrated photovoltaics (BIPV) in relation to

educational needs in the BIPV sector, 8th International Conference on Sustainability in Energy and Buildings, SEB-16, 11-13, Turin, ITALY. (2016)

- Shokufeh Zamini, Astrid Schneider, Marcus Rennhofer, Christoph Mayr, Karl A. Berger, Tim Selke, Barbara Beigelböck, Momir Tabacovic, Hubert Fechner, Georg Reinberg, & Gernot Becker: BIPV-Potential and State of the Art in Austria: High Future BIPV-Demand for 100% Renewables -Low Actual Share, EU PV SEC 2016, Munich. (2016)
- Fechner, Mayr, Peharz et al.: Photovoltaik Technologie Roadmap für Österreich, Bundesministerium für Verkehr, Innovation und Technologie. (2016)
- H. Fechner: Solar technologies for energy plus buildings and the impacts on the electricity grid in high penetration scenarios. (2011)
- Annual Report: Innovative Energietechnologien in Österreich – Marktentwicklung: Biomasse, Photovoltaik, Solarthermie und Wärmepumpen / Berichte aus Energie- und Umweltforschung, Wien, Vienna. (2017)
- H. Fechner & C. Mayr: High Penetration Photovoltaics in Electricity Grids, Invited lecture at 45th IEEE-International Conference on Microelectronics, Devices and Materials / 10th September 2009 / Postojna (Slovenia) (2009)
- H. Fechner: Gebäudeintegration von Photovoltaik ist ein internationales Thema Architektur Wettbewerbe / April 2009 (2009)
- H. Fechner: Solare Gebäude, die Kraftwerke von morgen Architektur Wettbewerbe / February 2009, (2009)

4.3.2 Austrian Institute of Technology (AIT)

Basic information on the institution	
Research group	Energy Department (PV related groups: Business Unit Photovoltaic Systems, Smart Buildings & Cities, Electric Energy Systems, Thermal Energy System, Water)
Team Leader	Dr. Brigitte Bach (PV-Unit: Christoph Mayr)
Number of researchers in the department	150
Number of researchers on BIPV	10
Number of FTE on BIPV	5

BIPV related research projects / fields:

- PV-Technology Roadmap Austria (Potential of BIPV in Austria, Technology Outlook);
- BIPV-Technology Research and Development Outlook
- Analysis of BIPV in the built environment of Vienna (Potential in certain areas or use cases, Acceptance, Business models)
- Optimization of BIPV-Simulation

- BIPV as a major energy source of Buildings, Cities, Smart Grids, National Energy System, Mobility Infrastructure - including energy for heat and mobility
- BIPV-Facade element development
- BIPV-element for double use: electricity and heat
- BIPV-element Testing and PV-Certification
- PV-Cell developments (thin film) for BIPV
- BIPV-design questions
- BIPV-Standards (member of IEC as representative of Austria and of national standardization committees)

References:

- Y. Abawi, M. Rennhofer, K. Berger, H. Wascher, & M. Aichinger: COMPARISON OF THEORETICAL AND REAL ENERGY YIELD OF DIRECT DC-POWER USAGE OF A PHOTOVOLTAIC FAÇADE SYSTEM; In Renewable Energy; 89; p 616-626 (2016)
- M. Rennhofer, K. Berger, R. Leidl, & Y. Abawi: integration of photovoltaic applications in multifunctional building skins, in: mppf - The multifunctional plug&play approach in facade technology, Verlag d. Technischen Universität Graz, Graz, 2015, ISBN: 978-3851253801, S. 35 - 46
- S. Gosztonyi, M. Rennhofer, Ch. Zauner, & B. Windholz: ARCHITECTURAL BENEFITS OF VIRTUAL AND EXPERIMENTAL ASSESSMENTS OF ACTIVE COMPONENTS IN MULTIFUNCTIONAL FAÇADES, Proceedings to the Energy Forum on Advanced Building Skins, 05-06 November, 2013 Bressanone, Italy, p 29-33 (2013)
- Ch. Zauner, B. Windholz, H. Schranzhofer, K. Lutschounig, M. Rennhofer, M. Müller, & W. Streicher: PHOTOVOLTAIC AND SOLAR THERMAL ENERGY CONVERSION IN A MULTIFUNCTIONAL FAÇADE, Proceedings at the 24th International Conference on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems, ECOS 2011, Novi Sad, Serbia July 4–7, 2011, p3450-3460 (2011)
- Y.B. Assoa, S. Zamini, W. Sprenger, M. Pellegrino, & A. Astigarraga Erleaga: Numerical Analysis Of The Impact Of Environmental Conditions On Bipv Systems. Vortrag: 27th European Photovoltaic Solar Energy Conference and Exhibition, Frankfurt; 24.09.2012 - 28.09.2012; in: EU PVSEC Proceedings, (2012), ISBN: 3-936338-28-0; Paper-Nr. 5AV.2.42

4.3.3 Österreichisches Forschungsinstitut (OFI)

Basic information on the institution	
Research group	Material analytics, surface science and environmental simulation
Team Leader	Gabriele C. Eder
Number of researchers in the team	15
Number of researchers on BIPV	6
Number of FTE on BIPV	2

BIPV related research projects / fields:

- The project "PV@Fassade" started in 2014 and addresses integration of photovoltaic modules in façade elements. This concerns construction, interconnection, design, materials and long-term durability and efficiency of PV components, in order to integrate façade elements with PV-active coatings in aesthetically attractive ways into buildings.
- The project ANALYSIS OF PV AGING ended in 2014 and was focused on aging of PV modules in relation to all the materials and components in the module.
- The project PAMINA (2012-2014) aimed at developing methods for systematic diagnostics of PV-plants based on infra-red-thermography.an
- AMSEL is a running project (2015-2018) on indoor non-destructive characterization methods for failure diagnostics of PV-modules.

References:

- Y. Voronko, G. Eder, M. Knausz, G. Oreski, T. Koch, & K. Berger: Correlation of the loss in photovoltaic module performance with the aging behaviour of the backsheets used, Prog. Photovolt: Res. Appl. (2015)
- B. Chernev, C. Hirschl, & G. Eder: Non-destructive determination of ethylene vinyl acetate crosslinking in PV modules by Raman Spectroscopy, Applied Spectroscopy, Vol. 67, Issue 11, pp. 1296-1301 (2013)
- Yuliya Voronko, Gabriele Eder, Manuel Weiss, Marlene Knausz, Gernot Oreski, Thomas Koch, & Karl Berger: Long term performance of PV modules: System optimization through the application of innovative non-destructive Characterization methods; Proc. 27th PV SEC, Frankfurt/Main, Sept. 2012; p. 3530 – 3535; ISBN: 3-936338-28-0; DOI: 10.4229/27thEUPVSEC2012-4BV.3.41; (2012)
- Ch. Hirschl, M. Biebl–Rydlo, M. DeBiasio, W. Mühleisen, L. Neumaier, W. Scherf, G. Oreski, G. Eder, B. Chernev, W. Schwab, & M. Kraft: Determining the degree of crosslinking of ethylene vinyl acetate photovoltaic module encapsulants — A comparative study; Solar Energy Materials & Solar Cells 116 (2013), pp 203-218

- L. Kuna, G. Eder, C. Leiner, & G. Peharz: Reducing shadowing losses with femtosecond laser written deflective optical elements in the bulk of EVA encapsulation, Progress in Photovoltaics; Article first published online: 19 JUL 2014; DOI: 10.1002/pip.2530

4.4 Belgium

In Belgium, initiatives have been taken to create an alliance of knowledge institutes that brings BIPV R&D institutions together. This alliance is called Energyville. Partners in Energyville are: IMEC, KU Leuven, Univ Hasselt and Vito. In addition, the Belgian Building Research Institute (BBRI) is active on BIPV testing.

4.4.1 Energyville

Basic information on the institution	
Research group	Various (Energyville is not yet integrated)
Team Leader	Dr. Marc Meuris and Dr. Eszter Voroshazi (IMEC subteam) Marlies Van Holm and Raf Ponette (Vito subteam) Prof. Dirk Saelens and Prof. Johan Driesen (KU Leuven)
Number of researchers in the teams	80
Number of researchers on BIPV	10
Number of FTE on BIPV	5

BIPV related research projects / fields:

- Novel aesthetic cell interconnection technologies, compatible with advanced cell architectures such as bifacial and back-contact and adapted to custom-sized modules;
- Precise energy yield prediction based on bottom-up physics models;
- Reconfigurable PV module topology design and fabrication for efficient energy harvesting in deep and varying shadows.
- Integration of renewable energy (incl. BIPV) technologies in districts as well as in societal aspects and grid integration of PV and BIPV.
- Building physics of BIPV and power electronics for PV grids (including BIPV).
- Design and electronic modeling of c-Si and TF PV modules for BIPV, including cabling.
- Reliability of BIPV modules including cabling and building installation requirements.
- Reliability of BIPV system electronics and building requirements.

References:

- H. Goverde et al.: Spatial and temporal analysis of wind effects on PV module temperature and performance; Sustainable Energy Technologies and Assessments 11 (2015) 36–41
- T. Borgers et al.: Adapting conventional tabbing–stringing technology for back-contact solar cells and modules, Photovoltaics International (2015)
- M. Baka et al.: Configurable module topology to recover power lost due to current mismatch, European Photovoltaic Solar Energy Conference and Exhibition - EUPVSEC (2014)

4.4.2 Université Libre de Bruxelles (ATM Department)

Basic information on the institution	
Research group	ULB-ATM
Team Leader	Patrick Hendrick
Number of researcher in the team	12
Number of researcher on BIPV	1
Number of FTE on BIPV	1

BIPV related research projects / fields:

- The ULB - ATM Department works with electriXities, UCL, Besix/Cobelba, ICEDD and CETIC on BIPV REINTEREST project with a focus on electrical storage and BIPV economic model.
- The REINTEREST project represents a toolbox for Intelligent Renewal (sensors, monitoring and control) and Multifunctional (PV, electrical storage, thermal capture and storage, insulation and ventilation) of the Building Envelope, based on Renewable Energy and Clean Technologies. It aims to design multi-functional products (materials and/or constructive systems) for existing residential buildings (retrofit) in order to optimize the use of buildings envelopes, by employing renewable energy sources, reducing heating, cooling and lighting. In addition, it aims to optimize building performance by employing energy modeling programs, optimize system control strategies by using occupancy sensors and other air quality alarms and monitor project performance through a policy of commissioning and metering.

References:

- G. Al Zohbi & G. & P. Hendrick: REINTEREST: Renewable Energy and Cleantech-based Multifunctional & INTelligent Envelope Retrofitting Systems' Toolbox". 4th Doctoral Seminar on Sustainability Research in the Built Environment Book of Abstracts, SBD Lab, Liege University, ISBN 978-2-930909-06-6. (2017)
- G. Silva & P. Hendrick: Lead-acid batteries coupled with photovoltaics for increased electricity self-sufficiency in households. Applied Energy 178 (2016) 856-867.

- G. Silva & P. Hendrick: Photovoltaic self-sufficiency in households using lithium-ion batteries, and its impact on the grid. Applied Energy 195 (2017) 786-799.

4.4.3 Université Catholique de Louvain (Architecture and Climate Dept.)

Basic information on the institution	
Research group	UCL-ARCH-CLI
Team Leader	Geoffrey Van Moeseke
Number of researcher in the team	2
Number of researcher on BIPV	1
Number of FTE on BIPV	1

BIPV related research projects / fields:

- Support sustainable development by developing and disseminating specific scientific knowledge to architecture.
- Works with ULB, electriXities, Besix/Cobelba, ICEDD, CETIC on BIPV REINTEREST project with a focus on the best materials, solutions of insulation, structure and assembling, manufacturing techniques to integrate BIPV in sustainable renovations.

References:

- O. Dartevelle: Comparing the efficiency of solar shading devices in reducing building cooling needs, 10th Advanced Building Skins (ABS) conference, Bern, Switzerland, 03-04 November 2015.
- J-S. Mouthuy: Facing the building façade's growing complexity, 11th Advanced Building Skins (ABS) conference, Bern, Switzerland, 10-11 October 2016.

4.5 Canada

4.5.1 Natural Resources Canada

Basic information on the institution	
Research group	Integration of Renewables and Distributed Energy Program
Team Leader	Alexandre Prieur
Number of researchers in the team	30
Number of researchers on BIPV	3
Number of FTE on BIPV	2

BIPV related research topics / projects / fields:

- BIPV standards and codes;
- Modelling, testing and performance characterization of BIPV with heat recovery using air as the heat recovery fluid (BIPVT/air); and,
- Cost-benefit analysis of BIPV compared to other solar technologies.

References:

- V. Delisle & M. Kummert: Cost-benefit analysis of integrating BIPV-T systems into energy-efficient homes. Solar Energy 136, 385-400, (2016)
- V. Delisle & M. Kummert: A novel approach to compare building-integrated photovoltaics/thermal air collectors to side-by-side PV modules and solar thermal collectors. Solar Energy 100, 50-65, (2014)
- V. Delisle & M. Kummert: Experimental study to characterize the Performance of Combined Photovoltaic/Thermal Air Collectors. Journal of Solar Energy Engineering 134 (3), (2012)
- V. Delisle: Modelling and performance study of a building integrated photovoltaic façade in northern Canadian climate, EUROSUN, Lisbon, Portugal, October 2008, (2008)
- M. Noguchi, A. Athienitis, V. Delisle, J. Ayoub, & B. Berneche: Net Zero Energy Homes of the Future: A Case Study of the ÉcoTerra House in Canada, Renewable Energy Congress, Glasgow, Scotland, July 2008, (2008)
- S. Pelland & Y. Poissant: An Evaluation of the potential of building integrated photovoltaics in Canada, 31st Annual Conference of the Solar Energy Society of Canada (SESCI), Montréal, Canada, August 2006, (2006)

4.5.2 Concordia University

Basic information on the institution	
Research group	Center for Zero Energy Building Studies, Department of Building, Civil and Environmental Engineering, Concordia University
Team Leader	Andreas Athienitis
Number of researchers in the team	10
Number of researchers on BIPV	4
Number of FTE on BIPV	-

BIPV related research topics / projects / fields:

- Product development and technical design of BIPV and BIPVT/air products;
- Model development (thermal, electrical and daylight) of BIPV and BIPVT/air systems; BIPV and BIPVT/air characterization under the Concordia indoor solar simulator and environmental chamber laboratory;
- Field testing (outdoor) of BIPV and air BIPVT/air (performance ratio, performance in pilots, temperature behaviour, etc.);
- BIPVT/air systems coupled with air source heat pumps and/or active thermal storage; and,
- Architectural and esthetical aspects of BIPV.

References:

- E. Rounis, A. Athienitis, & T. Stathopoulos: Multiple inlet Building-Integrated Photovoltaic/Thermal system modelling under varying wind and temperature conditions. Solar Energy 139, 157-170, (2016)
- T. Yang & A. Athienitis: Performance Evaluation of Air-based Building Integrated Photovoltaic/Thermal (BIPV/T) System with Multiple Inlets in a Cold Climate. Procedia Engineering 121, 2060-2067, (2015)
- M. Perino, J. Bambara & A. Athienitis: Experimental Evaluation and Energy Modelling of a Greenhouse Concept with Semi-transparent Photovoltaics. Energy Procedia 78, 435-440, (2015)
- O. Temby, K. Kapsis, H. Berton, D. Rosenbloom, G. Gibson, A. Athienitis, & J. Meadowcroft: Building-Integrated Photovoltaics: Distributed Energy Development for Urban Sustainability. Environment Science and Policy for Sustainable Development 56 (6), 4-16, (2015)
- K. Kapsis & A. Athienitis: A study of the potential benefits of semi-transparent photovoltaics in commercial buildings. Solar Energy 115, (2015)

- Y. Chen, A. Athienitis, & K. Galal: A charging control strategy for active building-integrated thermal energy storage systems using frequency domain modelling, Energy and Buildings 84, 651-661, (2014)

4.6 Denmark

4.6.1 Technical University of Denmark

Basic information on the institution	
Research group	Department of Photonics Engineering
Team Leader	MSc Peter Behrensdorff Poulsen
Number of researchers in the team	5
Number of researchers on BIPV	4
Number of FTE on BIPV	4

BIPV related research projects:

- DronEL - Fast and accurate inspection of photovoltaics using aerial drone imaging (EL/PL);
- Black Silicon BIPV - Cost and energy effective all-black solar cell panel;
- PV BALCONY FENCE – a highly esthetic cost efficient PV integrated balcony;
- New technology for fast localization and characterization of faults in solar cell systems; and,
- BICPV – Building integrated Concentrator PV window.

BIPV related research fields:

- BIPV-Facade element development;
- BIPV-element testing;
- Performance modelling and testing.

References:

- N. Riedel, G. Benatto, S. Thorsteinsson, P. Poulsen, S. Spataru, & D. Sera: Toward a drone-based EL and PL inspection tool for PV power plants (DronEL). NREL/SNL/BNL PV Reliability Workshops – Lakewood, CO, February 28 – March 2, 2017
- L., T. Juutilainen, S Thorsteinsson, P. Poulsen, A. Thorseth, M. W. Amdemeskel, S. Canulescu, P. M. Rødder, & K. Rødder: Angle Resolved Performance Measurements on PV Glass and Modules. European Photovoltaic Solar Energy Conference and Exhibition 2016. 2016. p. 2235-8

- Davidsen, RS, Tang, PT, Mizushima, I, Thorsteinsson, S, Poulsen, PB, Frausig, J, Nordseth, Ø, & Hansen, O 2016, Black silicon solar cells with black bus-bar strings. in Proceedings of 43rd IEEE Photovoltaic Specialists Conference. IEEE, pp. 2885-2888
- Oprea, M, Spataru, S, Sera, D, Basu, R, Andersen, A, Poulsen, PB & Thorsteinsson, S, 2016, Detection of Potential Induced Degradation in c-Si PV Panels Using Electrical Impedance Spectroscopy. in 43rd IEEE Photovoltaic Specialist Conference. IEEE, pp. 1575-1579. DOI: 10.1109/PVSC.2016.7749885
- Poulsen, PB, Juutilainen, LT, Thorsteinsson, S, Thorseth, A, Amdemeskel, MW, Canulescu, S, Rødder, PM, & Rødder, K, 2016, 'PV BALCONY FENCE - a highly esthetic cost efficient PV integrated balcony' Norwegian Solar Cell Conference 2016, Oslo, Norway, 31/05/2016 - 01/06/2016

4.7 France

4.7.1 CEA-INES

Basic information on the institution	
Research group	Solar Technologies division
Team Leader	Dr Anis Jouini
Number of researchers in the team	450
Number of researchers on BIPV	12
Number of FTE on BIPV	-

BIPV related research topics / projects / fields:

In general, the interest of CEA-INES in BIPV is broad:

- Development on PV cells and modules; new material, new interconnection, new process, prototyping: light module, integration in construction material;
- Design, characterization and simulation of BIPV panel: yield and thermal behavior;
- Hybridization: BIPVT, heat recovery (water or air) and coupling with HVAC;
- BIPV and electric storage; load / energy management
- Electronic Development: inverter and conversion system
- Energy Management system and smart grid
- Model development and performance simulation (Thermal, electrical, daylight)
- Field testing and performance assessment at different scales up to full integration in a building envelop and building system.
- Lab testing: full characterization, ageing and reliability testing (certification-like)
- Recycling of cells and modules

References:

- Y.B. Assoa & C. Ménézo: Dynamic study of a new concept of photovoltaic–thermal hybrid collector, Solar Energy 107 (2014) 637–652.A58
- Y.B. Assoa, C. Ménézo, G.Fraisse, et al.: Study of a new concept of photovoltaic-thermal hybrid collector. Solar Energy, 2007, vol. 81, n° 9, pp. 1132-1143
- Y. B. Assoa, E. Gerritsen, & P. Malbranche: Challenges and solutions for integration of photovoltaics into the built and urban environment and the rural landscape, in booklet: Photovoltaics Forms Landscapes. Beauty and Power of designed Photovoltaics, editor: Alessandra Sconamiglio, 177 p, ISBN: 9788889407110

4.7.2 CSTB

Basic information on the institution	
Research group	Energy Systems from Building to Territory
Team Leader	Thierry GUIOT
Number of researchers in the team	8
Number of researchers on BIPV	5
Number of FTE on BIPV	3,5

BIPV related research topics / projects / fields:

- Power flow model to study grid and consumer interaction, effect of massive PV injection, and grid support;
- LCA on complete electricity cost and identify weight of renewable energy on energetic mix on French market;
- Support of innovation in electrical and chemical field to develop and design new materials or new components for PV modules;
- Analysis and assessment of the interactions between PV components and building to determine thermal and electrical behavior;
- Conformity with French standards following construction standards, security requirement, and insurability;
- Definition of "French Thermal Regulation" (RT 2012) taking into account effect of PV production;
- Hybrid system PVT with heat recovery and management energy system;
- Electric storage and load/energy management;
- Facade BIPV component, thermal optical and energetic assessment;
- Bifacial components in several BIPV configurations; and,
- Thermo-electrical modeling and contribution in building load.

References:

- S. Boddaert, C. Gay, K. Taira, J. Nakata: Thermal aspects of Spheral® modules in different building integration mode, 22nd International Photovoltaic Science and Engineering Conference, Hangzhou, CHINA, (2012)
- S. Boddaert, F. Chervet: Long-term experimental validation of NOCT method for PV integration under several conditions, 27th European Photovoltaic conference, 5AV1.21, Frankfurt, GERMANY, (2012)
- S. Boddaert, S. Pincemin, F. Chervet: Development of NOCT method adapted to integration under several conditions, 26th European Photovoltaic conference, 4AV1.32, Hamburg, GERMANY, (2011)
- Y.B. Assoa, B. Boillot, S. Boddaert: Numerical Study of the Thermal Performance of an Innovative Integrated Photovoltaic System Suitable for Drying Applications, 25th European Photovoltaic conference, 5BV5.21, Valencia, Spain, (2010)
- C. Cristofari, G. Notton, P. Poggi, M. Mattei and S. Boddaert: Performance comparison between two copolymer hybrid PV/T collectors, ISES Solar world congress Beijing, China, (2007)

4.8 Germany

4.8.1 Fraunhofer ISE

Basic information on the institution	
Research group / team	Solar Facades / BIPV
Team Leader	Tilmann Kuhn
Number of researchers in the team	182
Number of researchers on BIPV	12
Number of FTE on BIPV	8

BIPV related research topics / projects / fields:

- Building information management (BIM);
- Electrical design of BIPV systems;
- Development of PV cells and modules for building integration purposes;
- Yield simulation (ab initio, incl. irradiance, temperature, partial shading);
- BIPV standardization;
- BIPV monitoring;
- TCO / LCC analysis;
- Accredited measurements (g-value, U-value, R, T);
- Research on micro- and nanostructures on PV cells and glazing units (AR, coloured PV); and,

- Certified IEC testing procedures.

References:

- W. Sprenger: Electricity yield simulation of complex BIPV systems, PhD thesis, Delft (2013)
- W. Sprenger, Developments in BIPV evaluation, certification and regulation, 31st European Photovoltaic Solar Energy Conference (EU PVSEC), Hamburg (2015)
- W. Sprenger, H.R. Wilson, & T.E. Kuhn, Electrical design of customized PV modules, 10th Energy Forum for Advanced Building Skins, Bern (2015)
- W. Sprenger, H.R. Wilson, & T.E. Kuhn, Elektrisches Design einer PV-Anlage mit bauwerkbedingten Modulgrößen, 8.OTTI-Forum BIPV, Bad Staffelstein (2016)
- C. Ferrara & C. Vicente Iñigo: Future BIPV Market(s)?!, Sechstes Forum Bauwerkintegrierte Photovoltaik, Kloster Banz, Bad Staffelstein (2016)

4.8.2 Fraunhofer IEE (former IWES)

Basic information on the institution	
Research group / team	Systems Engineering and Distribution Grids
Team Leader	Dr. Philipp Strauß
Number of researchers in the team	10
Number of researchers on BIPV	3
Number of FTE on BIPV	2

BIPV related research topics / projects / fields:

Fraunhofer IEE research focuses on providing answers to the following emerging BIPV challenges:

- What are the main obstacles for a broader market of BIPV systems?
- What are the operational conditions of BIPV components and the differences between operational conditions of added PV-systems and BIPV-systems?
- Are building codes suitable for BIPV-facade elements? Do we need to adapt building codes and PV standards for BIPV?
- Which facade systems are suitable for BIPV-facades? How can we integrate the added value of BIPV systems in the planning process of BIPV-facades?

4.9 Italy

4.9.1 Institute for Renewable Energy EURAC

Basic information on the institution	
Research group / team	Photovoltaic Energy Systems/ Energy Efficient Buildings
Team Leader	David Moser / Roberto Lollini
Number of researchers in the team	15+20
Number of researchers on BIPV	8
Number of FTE on BIPV	3

BIPV related research topics:

The EURAC BIPV team focuses on providing answers to the following research challenges:

- What is the energy interaction between PV and the BUI (building)? i.e. energy impact of PV on the BUI (e.g. daylighting, thermal impact etc.) and energy impact of the BUI on PV (e.g. temperature issue on PV performance and lifetime);
- How to accelerate BIPV market penetration i.e. by removing barriers and increasing broad acceptance; and,
- How to support designers/architects in the early design stage of BIPV systems.

BIPV related research fields:

The main activities on BIPV are:

- Energy simulations of PV integrated systems;
- Monitoring of BIPV systems, indoor testing and outdoor testing;
- Prototyping support; and
- Dissemination.

BIPV related research projects:

The main projects related to BIPV are:

- IEA SHC TASK 41, 51 and IEA PVPS TASK 15;
- In the FP7 framework: SOLAR DESIGN, iNSPiRe, CommONEnergy; and,
- EFRE: The Flexi BIPV is a BIPV outdoor test facility with a mock-up orientable roof, a mock-up façade and a small prefabricated wooden house. It is under construction.

References:

- L. Maturi, G. Belluardo, D. Moser, & M. Del Buono: BIPV system performance and efficiency drops: overview on PV module temperature conditions of different module types, SHC2013, Elsevier's Energy Procedia Energy Procedia. 2014;48:1311–1319. (2014)
- L. Maturi, R. Lollini, D. Moser, & W. Sparber: Experimental investigation of a low cost passive strategy to improve the performance of Building Integrated Photovoltaic systems, Solar energy Volume 111, January 2015, Pages 288–296, (2015)
- M. Lovati, P. Ingenhoven, G. De Michele, L. Baglivo, L. Maturi, & D. Moser: Energy, daylight and thermal analysis of a geodesic dome with photovoltaic envelope, Energy forum 2015 Conference Proceedings Conference Advanced Building Skins, (2015)
- L. Maturi: Building skin as energy supply: Prototype development of a wooden prefabricated BiPV wall. PhD thesis, University of Trento, 2013. Available at <http://eprints-phd.biblio.unitn.it/954/>" (2013)
- D. Moser, W. Bresciani, M. Nikolaeva-Dimitrova, & L. Maturi: 6 Months Monitoring of Roof Integrated Modules and Performance Comparison in Different Installation Types. EuroSun (2012)

4.9.2 ENEA, Italian National Agency for New Technologies, Energy and Sustainable Economic Development

Basic information on the institutions	
Research group / team	ENEA, Photovoltaic Systems and Smart Grids Unit
Team Leader	Giorgio Graditi
Number of researchers in the team	24
Number of researchers on BIPV	2
Number of FTE on BIPV	

BIPV related research topics / projects / fields:

- Reliability and quality improvement of BIPV systems and components;
- Characterization of BIPV systems;
- Standard, testing procedures and certification scheme development;
- New products, concepts development;
- Simulation and modelling (electrical and thermal);
- Market analysis; and
- Awareness increase through dissemination and teaching activities.

In addition, ENEA participated in the following IEA Tasks related to the integration of Solar Energy in the built environment:

- IEA SHC Task 51 Solar Energy in Urban Planning; and,
- IEA SHC Task 41 Solar energy and architecture.

ENEA is also participating in several European Projects on BIPV, e.g.: BFIRST and Construct PV. Moreover, it is active in some the COST action PEARL (Performance and Reliability of Photovoltaic Systems: Evaluations of Large-Scale Monitoring Data); with the role of WG leader of the topic PV and the Built Environment (Alessandra Scognamiglio).

References:

- F. Garde, J. Ayoub, L. Aelenei, D. Aelenei, & A. Scognamiglio, Solution sets for Net Zero Energy Buildings: Feedback from 30 buildings worldwide, John Wiley & Sons Inc, April 2017, ISBN 978-3-433-03072-1.
- Scognamiglio (editor) & H. Ossenbrink (foreword), Photovoltaics Forms Landscapes. Beauty and power of designed photovoltaics, ETA Florence, Florence, 2014, ISBN 9788889407110..
- Scognamiglio, P. Bosisio, V, Di Dio, Fotovoltaico negli edifici, (Photovoltaics in buildings), Edizioni Ambiente, Milano, 2013, ISBN 978-88-6627-025-6.
- A. Scognamiglio & F. Garde, Photovoltaics architectural and landscape design options for Net Zero Energy Buildings, towards Net Zero Energy Communities: spatial features and outdoor thermal comfort related considerations, Progress in Photovoltaics: Research and applications (2014), http://dx.doi.org/10.1002/pip.2563.
- A. Scognamiglio & H. Rostvik, Photovoltaics and Zero Energy Buildings: a new opportunity and challenge for design, Progress in Photovoltaics: Research and applications (2012), DOI: 10.1002/pip.2286; vol. 21, issue 6, September 2013, pp. 1319-1336.
- L. V. Mercaldo, M. L. Addonizio, M. Della Noce, P. Delli Veneri, A. Scognamiglio, & C. Privato, Thin film silicon Photovoltaics: architectural perspectives and technological issues, Applied Energy, Volume 86, Issue 10, October 2009, Pages 1836-1844, ISSN 0306-2619, http://dx.doi.org/10.1016/j.apenergy.2008.11.034.

4.10 Japan

The leading R&D institute on BIPV in Japan is PVTEC.

4.11 Morocco

4.11.1 Institut de Recherche en Energie Solaire et Energies Nouvelles (IRESEN)

Basic information on the institution	
Research group / team	Building Integrated Energy Systems
Team Leader	Mrs. Souad LALAMI & Mr. Zakaria Naimi
Number of researchers in the team	7
Number of researchers on BIPV	5
Number of FTE on BIPV	2

BIPV related research topics / projects / fields:

The focus of the IRESEN team is on testing BIPV technologies and determining which ones are the most suitable for extreme climatic conditions (e.g. high temperatures, sand storms and more).

References:

- Ennajdaoui, Z. Naimi, K. Belrhiti Alaoui, & B. Ikken: Brief Study of BIPV Potential in Morocco, EU-PVSEC 2014.(2014)
- K. Belrhiti Alaoui, A.Outzourhit, Z.Naimi, & A.Benlarabi: Pilot line preindustrial reactor installation for applied research in vacuum deposition techniques for the preparation and characterization of photovoltaic cells, IRSEC 2015. (2015)
- S. Malik, M. Ebert, Z. Naimi, & B. Ikken: DEVELOPMENT OF OUTDOOR RESEARCH PLATFORMS AND TESTS ON PHOTOVOLTAIC MODULES IN THE GREEN ENERGY PARK IN MOROCCO, Africa-PVSEC
- E.G. Bennouna & H. Frej: New solar research platform Green Energy Park, SolarPACES 2014, (2014)

4.12 The Netherlands

The BIPV research in the Netherlands is concentrated at SEAC, Zuyd University of Applied Sciences and ECN Petten. Additional research activities are carried out at the Technical University Eindhoven, University of Twente and University of Utrecht.

4.12.1 Solar Energy Application Center (SEAC)

Basic information on the institution	
Research group / team	SEAC
Team Leader	Wiep Folkerts
Number of researchers in the team	7
Number of researchers on BIPV	6
Number of FTE on BIPV	5

BIPV related research topics / projects / fields:

The SEAC focuses on providing answers to the following research topics:

- What are available BIPV products in the market, how can these be categorized, what is the price setting, what are success factors in the market, what are regional differences, what are driving factors in the market?
- How can PV element become successful building components?
- Field testing and performance assessment of BIPV products;
- BIPV from a financial perspective.

References:

- R.M.E. Valckenborg, J.L.M. Hensen, W. Folkerts, & A. de Vries: CHARACTERIZATION OF BIPV(T) APPLICATIONS IN RESEARCH FACILITY 'SOLARBEAT', EUPVSEC 2015., (2015)
- K. Sinapis, C. Tzikas, G Litjens, M. van den Donker, W. Folkerts, & W. van Sark, A. Smets: YIELD MODELLING FOR MICRO INVERTER, POWER OPTIMIZER AND STRING INVERTER UNDER CLEAR AND PARTIALLY SHADED CONDITIONS, EUPVSEC 2015, (2015)
- M.N. van den Donker, B. Hauck, R. Valckenborg, K. Sinapis, G.B.M.A. Litjens, W. Folkerts, R. Borro, & W. Passlack: HIGH THROUGHPUT ROOF RENOVATION USING PREFABBED AND PREWIRED WATERTIGHT PV INSULATION ELEMENTS, EUPVSEC-2014., (2014)
- G. Verberne, P. Bonomo, F. Frontini, M.N. van den Donker, A. Chatzipanagi, K. Sinapis, & W. Folkerts: BIPV PRODUCTS FOR FAÇADES AND ROOFS: A MARKET ANALYSIS, EUPVSEC-2014., (2014)

- K. Sinapis, M.N. van den Donker, G.B.M.A. Litjens, P.P. Michiels, E.J.M.G. Philipse, A. van Hese, & W. Folkerts, THE GLASS-GLASS AESTHETIC ENERGY ROOF: THERMAL BEHAVIOR FOR VARIOUS VENTILATION LEVELS, EUPVSEC-2013., (2013)

4.12.2 Zuyd University of Applied Sciences

Basic information on the institution	
Research group / team	Solar Energy in buildings
Team Leader	Zeger Vroon / Michiel Ritzen
Number of researchers in the team	7
Number of researchers on BIPV	6
Number of FTE on BIPV	3

BIPV related research topics:

- Implementation and demonstration of innovative PV products and electrical storage (DC) in the built environment;
- Lab- and field testing and monitoring of innovative PV products and electrical storage (DC) in the Built environment;
- Validation of innovative nanomaterials for solar energy applications.

BIPV related research projects:

- National: Zonnegevel, Smartchain, PVopMaat, IMDEP, Smart HiperPV, Colourmax, Werkelijk Bouwen aan BIPV;
- International: Cleantech, Enef, Organext, PVopMaat, Windows of the Future.

References:

- M. Ritzen, C. Geurts, , Z. Vroon, R. Rovers, & G. Vervuurt: Effective BIPV. In: Proceedings 7th Energy Forum on Solar Building Skins, Munich, Germany, 2012.
- M. Ritzen, Z. Vroon, R. Rovers, & C. Geurts: Comparative performance assessment of four BIPV roof solutions in the Netherlands. In: Proceedings ICBEST, R.D. Lieb (Ed.), Aachen, Germany, 2014.
- M. Ritzen, S. Heumen, Z. Vroon, R. Rovers, & C. Geurts: Innovative BIPV rooftops: development, realization, and monitoring of 2 BIPV field tests in the Netherlands. In: Proceedings 29th EU PVSEC, Amsterdam, the Netherlands, 2014.
- M. van Horrik, M. Ritzen, & Z. Vroon, technical report on non-technical bariers for BIPV acceleration in the Netherlands (Niet technische barrieres van BIPV), 2016.

- M. Ritzen, Z. Vroon, & C. Geurts: Building Integrated Photovoltaics. In: Photovoltaic Solar Energy: From Fundamentals to Applications, A. Reinders, P. Verlinden, W. van Sark & A. Freundlich (Eds.), pp. 579-590, Wiley, London, 2017
- M. Ritzen, Z. Vroon, R. Rovers, & C. Geurts: Comparative performance assessment of a non-ventilated and ventilated BIPV rooftop configurations in the Netherlands. Solar Energy, 2017. 146: p. 389-400.
- M. Ritzen, Z. Vroon, R. Rovers, A. Lupíšek, & C. Geurts: Environmental impact comparison of a ventilated and a non-ventilated building-integrated photovoltaic rooftop design in the Netherlands: Electricity output, energy payback time, and land claim, Solar Energy, vol. 155, pp. 304-313, 2017.

4.12.3 ECN Petten

Basic information on the institution	
Research group / team	PV Modules and Applications
Team Leader	Peter Blokker
Number of researchers in the team	17
Number of researchers on BIPV	9
Number of FTE on BIPV	4

The BIPV work of the team of ECN in Petten focuses on product development and reliability testing.

4.13 Norway

In Norway, a recent national program on BIPV has started in which various groups in Trondheim, Oslo and Grimstad work together.

Basic information on the institutions	
Research Institutes	NTNU, SINTEF, IFE, Teknova, University of Agder (UiA)
Research group / team	various
Team Leader	Bjørn Petter Jelle and others
Number of researchers in the team	60
Number of researchers on BIPV	12
Number of FTE on BIPV	4

BIPV related research topics / projects / fields:

The research topics are as follows:

- PV monitoring;
- Data collection and documentation;
- System performance evaluation;
- Technical and architectural integration;
- Development of robust components and solutions;
- Accelerated ageing and durability testing in Nordic climate exposure;
- Investigations of the link between aesthetic quality and solar cell efficiency;
- Assessment of environmental impact and carbon footprint;
- Snow and ice influence on solar energy yields, snow and ice impact on surface robustness and durability, advanced materials surface development for avoiding snow and ice formation; and,
- Effect of diffuse and variable solar irradiance on energy production, and advanced materials and solutions for better utilization of the solar radiation, as well as
- Analysis of production and load characteristics of zero energy buildings.

References:

- B. P. Jelle, C. Breivik and H. D. Røkenes: Building Integrated Photovoltaic Products: A State-of-the-Art Review and Future Research Opportunities, Solar Energy Materials and Solar Cells, 100, 69-96, (2012)
- B. P. Jelle: Accelerated Climate Ageing of Building Materials, Components and Structures in the Laboratory, Journal of Materials Science, 47, 6475-6496, (2012)

- B. P. Jelle: The Challenge of Removing Snow Downfall on Photovoltaic Solar Cell Roofs in order to Maximize Solar Energy Efficiency - Research Opportunities for the Future, Energy and Buildings, 67, 334-351, (2013)
- C. Breivik, B. P. Jelle, B. Time, Ø. Holmberget, J. Nygård, E. Bergheim, & A. Dalehaug: Large-Scale Experimental Wind-Driven Rain Exposure Investigations of Building Integrated Photovoltaics, Solar Energy, 90, 179-187, (2013)
- B. P. Jelle: Building Integrated Photovoltaics: A Concise Description of the Current State of the Art and Possible Research Pathways, Energies, 9, 1-30, Article no. 21, (2016)
- T.F. Kristjansdottir, C.S. Good, M.R. Inman, R.D. Schlanbusch, I. Andresen, Embodied greenhouse gas emissions from PV systems in Norwegian residential Zero Emission Pilot Buildings, Solar Energy 133 (2016), pp. 155-171.
- Imenes, A.G., Performance of BIPV and BAPV Installations in Norway, in: Proc. 43rd IEEE Photovoltaic Specialists Conference, Portland, US, 5-10 Jun 2016. Curran Associates, Inc. 2016. ISBN 978-1-5090-2724-8, pp. 3147-3152.
- Imenes, A.G., Kanters, J., 3D Solar Maps for the Evaluation of Building Integrated Photovoltaics in Future City Districts: a Norwegian Case Study, in: Proc. 43rd IEEE Photovoltaic Specialists Conference, Portland, US, 5-10 Jun 2016. Curran Associates, Inc. 2016. ISBN 978-1-5090-2724-8, pp. 3141-3146.
- A. Pettersen, H. Pedersen, J.K. Selj, E.S. Marstein, PV modules in Nordic climate: Effects of soiling and snow, 31st European Photovoltaic Solar Energy Conference, 14-18 Sep 2015, Hamburg GE. Poster 5BV.2.61.
- Imenes A.G., Yordanov G.H., Midtgård O.M., Saetre T.O. (2011), Development of a test station for accurate in situ I-V curve measurements of photovoltaic modules in Southern Norway, in: Proc. 37th IEEE Photovoltaic Specialists Conference, 19-24 June 2011, Seattle, Washington US, pp. 3103-3108.

4.14 Singapore

4.14.1Solar Energy Research Institute of Singapore (SERIS)

Basic information on the institution	
Research group	**Solar and Energy Efficient Buildings / Solar Energy Systems**
Team Leader	**Dr Thomas Reindl**
Number of researchers in the team	**58**
Number of researchers on BIPV	**6**
Number of FTE on BIPV	**4**

BIPV related research topics/projects/fields:

- Barriers for BIPV adoption in tropics;
- Holistic life-cycle cost analysis and real world test-bedding for BIPV facades;
- Monitoring of BIPV systems, indoor testing (thermal and optical properties), and outdoor testing (performance); and,
- Formulation of design support tool for customized BIPV (prototyping).

References:

- M. Bieri, V. Shabunko, L. Zhao, E Quek, & T Reindl: An economic viability study for building-integrated photovoltaic (BIPV) in the tropics, 26th International Photovoltaic Science and Engineering Conference (PVSEC-26), Singapore, 24-28 Oct 2016., (2016)
- C. Zomer, A. Nobre, P. Cassatella, T. Reindl, & R. Ruther: The balance between aesthetics and performance in building-integrated photovoltaics in the tropics. Progress in Photovoltaics: Research and Applications, 2013, doi:10.1002/pip.2430, (2013)
- C. D. Zomer, M. R. Costa, A. Nobre, & R. Rüther: Performance compromises of building-integrated and building-applied photovoltaics (BIPV and BAPV) in Brazilian airports. Energy and buildings, 66, 607-615., (2012)
- F. Chen, S. K. Wittkopf, P. K. Ng, & H. Du: Solar heat gain coefficient measurement of semi-transparent photovoltaic modules with indoor calorimetric hot box and solar simulator. Energy and Buildings, 53, 74-84., (2012)

4.15 South Korea

The leading R&D institute on BIPV in South Korea is KNU.

4.16 Spain

4.16.1 TECNALIA Research & Innovation

Basic information on the institutions	
Research group / team	Solar Energy – Photovoltaics
Team Leader	Eduardo Román
Number of researchers in the team	16
Number of researchers on BIPV	14
Number of FTE on BIPV	10

BIPV related research topics / projects / fields:

The BIPV R&D at TECNALIA focuses on:

- Advanced photovoltaic concepts for BIPV modules (novel materials and processes, modules design and prototyping);
- Optical, thermal, electrical and mechanical simulation;
- Electronic systems and devices for PV energy management within the building (grid connection, self-consumption, storage);
- Testing of BIPV modules against PV and construction standards;
- Characterization of modules (solar simulator, spectral response, spectrophotometry, electroluminescence, thermography, etc.); and,
- BIPV standardization activities.

References:

- T. Baenas & M. Machado: On the analytical calculation of the Solar Heat Gain Coefficient of a BIPV module, Energy and Buildings 151 (2017), 146-156
- T. Baenas & M. Machado: Optical model for multilayer glazing systems: Application to laminated glass and photovoltaic modules. Solar Energy 125 (2016) 256-266
- M. Machado, T. Baenas, & N. Yurrita: Optical model for multilayer glazing systems: experimental validation through the analytical prediction of encapsulation-induced variation of PV modules efficiency. Solar Energy 135 (2016) 77-83
- J. Zhu, R. Gottschalg, M. Koehl, O. Zubillaga, et al.: Towards PV module lifetime prediction-a joint effort within the Photovoltaic European Research Infrastructure (SOPHIA) project. NREL Reliability Workshop, Colorado (USA), February 2014
- R. Alonso, P. Ibáñez, V. Martínez, E. Roman, & A. Sanz: Analysis of Inverter Voltage Influence on Distributed MPPT Architectures Performance. IEEE Trans. Industrial Electronics Journal (Special Section ISIE2010) 59, 7, 3900, (2012)

4.16.2 CENER

Basic information on the institutions	
Research group / team	Solar PV Energy Department
Team Leader	Ana Rosa Lagunas
Number of researchers in the team	20
Number of researchers on BIPV	6
Number of FTE on BIPV	2

BIPV related research topics / projects / fields:

CENER BIPV activities are focused on:

- Development of new products from the technical design to the final product validation.
- BIPV testing against PV standards as IEC 61215, IEC 61730 and IEC 62108. CENER PV module laboratory is recognized by IEC as CTL (Certification Testing lab) under the IECEE Conformity Assessment Scheme. New BIPV developments tested under the same quality management system as required for the conventional PV modules.
- State of the art studies for different specific regions
- System performance monitoring
- Field testing of BIPV systems

CENER BIPV R&D projects at national and international level:

- ETFE. Development and demonstration of a flexible multifunctional ETFE module for architectural façade lighting. FP7 framework programme.
- AiSoVol. Innovative BIPV module design for use as construction material in buildings
- S-Light. Multifunctional BIPV solutions based on alternative encapsulation technology.
- Final deliverable of all those projects is a marketable BIPV module but using very different concept designs.

CENER participates in standardization activities at the IEC TC82 Technical Committee.

References:

- Cueli A.B., Bengoechea J., Murillo A., Rodríguez M.J., Lagunas A.R., Montes C., Linares A., Llarena E., González O., Molina D., Pío A., Ocaña L., Quinto C., Friend M., & Cendagorta M.: AISOVOL project: a photovoltaic generation solution as an alternative construction material 31st European Photovoltaic Solar Energy Conference. Munich, 2016
- Ezquer M., Bengoechea J., Cuadra J.M., Casajús L., Muñoz I., & Lagunas A.R.: Determination of incidence angle modifiers for different photovoltaic technologies through outdoor measurements, 29th European Photovoltaic Solar Energy Conference. Amsterdam, 2014
- Muñoz I., Sánchez I., Cueli A.B., Díaz J., Moracho J., & Lagunas A.R: Building integrated PV Installation at CENER. 20th European Photovoltaic Solar Energy Conference and Exhibition. Barcelona, 2005.
- Lagunas A.R., & Díaz J.: Building-integrated PV in architectural textiles, ETFE-MFM Workshop held at the World Sustainable Energy Days. Wels 2016.

4.16.3 CIEMAT

Basic information on the institutions	
Research group / team	Solar Energy – Photovoltaics
Team Leader	Nieves Vela
Number of researchers in the team	25
Number of researchers on BIPV	6
Number of FTE on BIPV	4

BIPV related research topics / projects / fields:

- BIPV modules testing, characterization and modeling (electrical, thermal, optical);
- Product development and technical design of BIPV products;
- Testing of BIPV products against building and PV norms (e.g. climate chamber testing, UV chamber, solar simulators, spectrophotometers and more);
- Outdoor field testing of BIPV;
- Battery solutions for BIPV;
- Participation in the National BIPV Working Group; and,
- Participation in the National (AENOR) and International (IEC, CENELEC) PV Standardization Committees.

References:

- F. J. Moralejo-Vazquez, N. Martín-Chivelet, L. Olivieri, & E. Caamaño-Martín: Luminous and solar characterization of PV modules for building integration, Energy and Buildings (2015)103, 326-337 DOI: 10.1016/j.enbuild.2015.06.067., (2015)
- L. Olivieri, E. Caamaño-Martin, F. J. Moralejo-Vazquez, & N. Martín-Chivelet: Energy saving potential of semi-transparent photovoltaic elements for building integration, Energy (2014)76, 572-583. DOI: 10.1016/j.energy.2014.08.054
- N. Martín-Chivelet: Photovoltaic potential and land-use estimation methodology, Energy (2016) 94, 233–242. DOI:10.1016/j.energy.2015.10.108
- Fornies, J.L. Balenzategui, M.C. Alonso-García, & J.P. Silva: Method for module Rsh determination and its comparison with standard methods, Solar Energy 109 (2014) 189-199., (2014)
- J.P. Silva, G. Nofuentes, & J.V. Muñoz: Spectral reflectance patterns of photovoltaic modules and their thermal effects. Journal of Solar Energy Engineering (2010)132(4), 041016-1 -13., (2014)

4.17 Sweden

In Sweden, the BIPV R&D community comprises of several institutes and universities. Apart from SP and Lund University (see below), Chalmers Univ, Mälardalen Univ and Dalarna Univ, have PhD students working on BIPV related topics.

4.17.1 RISE Research Institutes of Sweden (SP Technical Research Institute)

Basic information on the institutions	
Research group / team	PV and energy efficient buildings ("under construction")
Team Leader	Peter Kovacs
Number of researchers in the team	50
Number of researchers on BIPV	5-10
Number of FTE on BIPV	2

BIPV related research topics / projects / fields:

- Issues related to regulations and the Swedish building code when implementing BIPV;
- How standards and certification schemes affect innovation in the field of BIPV; and,
- How to accelerate innovation and achieve truly competitive BIPV solutions through multidisciplinary approaches and collaboration involving many parts of the value chain.

4.17.2 Lund University

Basic information on the institutions	
Research group / team	Energy and Building Design
Team Leader	Maria Wall
Number of researchers in the team	9
Number of researchers on BIPV	3
Number of FTE on BIPV	1.5

BIPV related research topics / projects / fields:

The Energy and Building Design Department at Lund University works with BIPV at different stages:

- Analysis of the solar energy potential and correspondent solar electricity production of building facades using BIPV;
- Constructive aspects of integrating PV modules into building facades; and,

- Integration of solar cells into active and pre-fabricated facade elements for multi-family houses.

In addition, Lund University is also participating in the following IEA Tasks related to the integration of Solar Energy in the built environment:

- IEA SHC Task 51 Solar Energy in Urban Planning; and,
- IEA SHC Task 41 Solar energy and architecture.

References:

- J. Kanters, M. Wall, & M. Dubois: Development of a Facade Assessment and Design Tool for Solar Energy (FASSADES). Buildings 2014 (4), 43-59., (2014)

4.18 Switzerland

In Switzerland, several research institutes and universities are active in the field of BIPV Below is a non-exhaustive list of these research institutes:

- CSEM, in Neuchatel
- EMPA, in Dubendorf;
- EPFL PVLab group, in Neuchatel;
- ETHZ, in Zurich;
- HSLU, in Luzern; and
- SUPSI, in Lugano.

The University of Applied Science and Arts of southern Switzerland is participating in this project and is responsible for representing the interest of the country on this topic. Moreover, industrial companies are developing new solutions and systems (e.g. Meyer Burger, Megasol, Userhuus, Sunage, Solaxess, Glass2energy, Flisom, and more).

4.18.1 University of Applied Sciences and Arts of Southern Switzerland (SUPSI)

Basic information on the institutions	
Research group / team	Swiss BIPV Competence Centre
Team Leader	Francesco Frontini
Number of researchers in the team	20
Number of researchers on BIPV	4
Number of FTE on BIPV	3

BIPV related research topics / projects / fields:

- Reliability and quality improvement of BIPV systems and components;
- Characterization of BIPV systems;
- Standard, testing procedures and certification scheme development;
- New products, concepts development;
- Simulation and modelling (electrical and thermal);
- Market analysis; and
- Awareness increase through dissemination and teaching activities.

In addition, SUPSI is also participating in the following IEA Tasks related to the integration of Solar Energy in the built environment:

- IEA SHC Task 51 Solar Energy in Urban Planning; and,
- IEA SHC Task 41 Solar energy and architecture.

References:

- F. Frontini, P. Bonomo, A. Chatzipanagi, M.N. van den Donker, G. Verberne, K. Sinapis, & W. Folkerts: Building Integrated Photovoltaics. Report 2015. Available on www.bipv.ch, (2015)
- P. Bonomo, A Chatzipanagi, & F Frontini: Overview and analysis of current BIPV products: new criteria for supporting the technological transfer in the building sector. VITRUVIO - International Journal of Architectural Technology and Sustainability, doi: http://dx.doi.org/10.4995/vitruvio-ijats.2015.4476, (2016)
- P. Bonomo, F. Frontini, P. De Berardinis, & I. Donsante: BIPV: Building Envelope Solutions in a Multicriteria Approach. A Method for Assessing Life-Cycle Costs in the Early Design Phase, Advances Building Energy Research, Taylor & Francis, (2016)
- E. Saretta, F. Frontini, & P. Bonomo: Mechanical and electrical reliability of laminated glass BIPV modules: assessment of interaction factors in building integration scenarios. Proceedings of the Engineered Transparency Conference 2016, (2016)
- L. Olivieri, F. Frontini, L. Polo, S. Cristina, D. Pahud, & E. Caamano: G-value indoor characterization of semi-transparent photovoltaic elements for building integration: New equipment and methodology. Energy and Buildings, 101. pp. 84-94. ISSN 0378-7788, (2015)

5 BIPV related research topics

The BIPV related research topics can be categorized as follows:

1. Market studies of BIPV (available products, market success factors, market drivers, market forecasts)
2. Product development and technical design of BIPV products
3. Testing of BIPV products against building and PV norms (climate chamber testing, mechanical testing etc.)
4. Field testing (outdoor) of BIPV (performance ratio, performance in pilots, temperature aspects, etc.)
5. Architectural and aesthetic aspects of BIPV
6. Social aspects of BIPV (acceptance in the market, acceptance in society, acceptance barriers and strategies)
7. Economic aspects of BIPV (cost price, cost price roadmaps, business models, business cases)
8. Electrical system solutions for BIPV
9. Other research topics related to BIPV

Based on the response on the questionnaire, the level of effort in BIPV R&D investments per country is shown in Table 1.

Table 1: Level of effort in BIPV R&D investments per Country

	Market studies	Product development	Testing against norms	Outdoor testing	Architectural	Social aspects	Economical aspects	Electrical system solutions	Other topics
Austria	medium	substantial	substantial	substantial	substantial	medium	small but relevant	medium	substantial
Belgium		substantial	substantial	medium	medium	medium			
Canada	small but relevant		medium	medium			medium		
Denmark	medium	large	medium	substantial	large	small but relevant	medium	medium	medium
France	small but relevant	large	large	large	medium		small but relevant	large	medium
Germany	medium	large	large	substantial	substantial		small but relevant	large	substantial
Italy		small but relevant	medium	medium	small but relevant				small but relevant
Morocco	small but relevant		medium	medium					
Netherlands	medium	large	large	large			medium	medium	
Norway	small but relevant	small but relevant	medium	medium	medium	small but relevant	small but relevant	small but relevant	medium
Spain	medium	large	large	substantial	medium	small but relevant	small but relevant	large	small but relevant
Sweden	small but relevant	small but relevant	small but relevant	medium	substantial		medium	small but relevant	small but relevant
Switzerland	substantial	large	substantial	medium	medium	medium	small but relevant		

Legend: large / substantial / medium / small but relevant

6 Detailed BIPV outdoor testing facilities mapping

This section provides an overview of outdoor testing facilities dedicated to BIPV, with detailed information related to the testing infrastructure and associated research capabilities. Table 2, lists the participating institutes and the corresponding contact person.

Table 2: List of participating BIPV test facilities / demonstration sites

	Test Facility /Institution	Country	Contact person
1	AIT	Austria	Berger Karl (Karl.Berger@ait.ac.at)
2	University of Applied Science Upper Austria, F&E GmbH (formerly ASiC)	Austria	Rechberger Philipp (rechberger.philipp@asic.at)
3	SFL	Austria	Michael Grobbauer (grobbauer.michael@sfl-technologies.com; Karl.berger@ait.ac.at)
4	Natural Resources Canada, CanmetENERGY	Canada	Véronique Delisle (veronique.delisle@canada.ca)
5	CEA	France	Ya-Brigitte Assoa (ya-brigitte.assoa@cea.fr) Francoise Burgun (francoise.burgun@cea.fr)
6	CSTB	France	Simon Boddaert (simon.boddaert@cstb.fr)
7	EURAC	Italy	Laura Maturi (laura.maturi@eurac.edu)
8	ENEA	Italy	Michele Pellegrino (michele.pellegrino@enea.it)
9	IRESEN	Marocco	Badr Ikken (ikken@iresen.org)
10	SEAC	Netherlands	Roland Valckenborg (valckenborg@seac.cc)
11	UTwente	Netherlands	Angèle Reinders (a.h.m.e.reinders@utwente.nl)
12	ZUYD	Netherlands	Michiel Ritzen (michiel.ritzen@zuyd.nl) Alex Masolin (alex.masolin@zuyd.nl)
13	SERIS	Singapore	thomas.reindl@nus.edu.sg; lu.zhao@nus.edu.sg
14	CIEMAT	Spain	Nuria Martín Chivelet (nuria.martin@ciemat.es)
15	Tecnalia	Spain	ines.apraiz@tecnalia.com; eduardo.roman@tecnalia.com; maider.machado@tecnalia.com
16	SP Technical Research Institute of Sweden / Rise Research Institute of Sweden	Sweden	peter.kovacs@ri.se
17	Lund University - Department of Energy and Building Design	Sweden	Ricardo.Bernardo@ebd.lth.se
18	SUPSI	Switzerland	Pierluigi Bonomo (pierluigi.bonomo@supsi.ch) Francesco Frontini (francesco.frontini@supsi.ch)
19	Danish Technological Institute	Denmark	Ivan Katic (Ik@teknologisk.dk), Karin Kappel (kk@solarcity.dk)
20	Technical University of Denmark (DTU)	Denmark	Nicholas Riedel (nrie@fotonik.dtu.dk)
21	University of Agder (UiA)	Norway	Anne Gerd Imenes (anne.g.imenes@uia.no)

6.1 AIT – Austrian Institute of Technology

Outdoor PV test stands are located on two of the roofs of the AIT TechBase Facility. The three test stands A, B, and C are identified in yellow in Figure 2.

Figure 2: AIT TechBase roof outdoor test stands

Mock-ups of BIPV facades can be installed and tested. In the case of large and heavy BIPV systems, a crane is used. In addition, the AIT has PV related research laboratories such as the PV precision laboratory with an A+A+A+ module flasher and steady state solar simulators, the PV optical laboratory with EL and PL and the environmental simulations laboratory with five climate chambers.

General information	
Name of the research institution:	AIT Austrian Institute of Technology, Energy Department
Name of the person in charge:	Karl A., Berger (AIT Energy Department)
Contact data (mail):	karl.berger@ait.ac.at
Country:	Austria
City / ZIP Code:	A-1210 Vienna
Climate Zone	Boreal and snow forest full humid Tmax<22 (Dfb - climate)
Total size of testing area / BIPV test module size applicable	
	[m]
max. length	8 / 6.5 / 5 (Stand A / B / C)
max. width	3.5 / 3.5 / 2 (Stand A / B / C)
orientation S/E/W/N	S / S / SbW (Stand A / B / C)
shading effects	small, season & tilt angle depending
monitoring of meteorological data	
air temperature	Yes
solar irradiance	Yes
wind velocity	Yes

wind direction	Yes
relative humidity	Yes
type of temp. measure used	4 wire Pt100 Type B, also on test objects
type of pyranometer used	CMP21, CMP11 (Kipp & Zonen), c-Si reference cells ISE WPVS & with KG3 & KG7 filter (matching TF spectrally)
type of anemometer	Gill Type Y WindSonic Anemometer
Electrical measurement	
max. number of connection points	>8
number of independent measurement points	>8
inverters available?	Yes
operated at AC-inverter (AC-grid connection and commercial MPP-tracker assumed) (A)?	Yes
MPP tracking possible?	Yes
operated at a DC dump load (with experimental MPP tracking system) (B)?	Yes, but linear operated MOSFET's on ventilated heat sinks as load
Measurement of U/I curve possible (UI)?	Yes
Measurement of Power at MPP possible?	Yes
maximum standalone recording period	2 weeks till 1 year
frequency of MPP recording?	(typ. every 5 seconds) 0.2 s-1
measuring equipment operated offline with (battery) or (grid) connected	equipment with power supply from mains and ethernet connection
if UI: frequency of U/I curve recording	set: every 2 minutes
all the time operated at MPP (B1) or idle unless measuring U/I curve (B2)?	B1 (MPP-setpoint between IV-meas.)
number of serially connected cells in measured array (MIN/MAX)	~4 … 100
array current limit (MIN/MAX)	~0.1 A / 12 A
array power limit (MIN/MAX)	3 x 300 Wp (IV+MPP) + 5 x 700 Wp, string inverters (several kW) power available

6.2 University of Applied Science Upper Austria, F&E GmbH (formerly ASiC)

An outdoor PV test bench tracker is located at the University of Applied Science Upper Austria, F&E GmbH (Figure 3).

Figure 3: Test bench at the University of Applied Science Upper Austria

General information	
Name of the research institution:	University of Applied Science Upper Austria, F&E GmbH (formerly ASiC)
Name of the person in charge:	Harald DEHNER
Contact data (mail):	harald.dehner@fh-wels.at
Country:	Austria
City / ZIP Code:	Wels / 4600
Climate Zone	Moderate full humid Tmax<22 (Cfb-climate)
Total size of testing area / BIPV test module size applicable	
	[m]
max. length	Indoor: 1,5m; Outdoor: 5 m
max. width	Indoor: 2,5m; Outdoor: 2,5 m
orientation S/E/W/N	Tracker
shading effects	no
Inclination of the tested modules (fixed/moveable / Degree)	Movable
type of BIPV: facade (Warm facade / Cold façade - ventilated?)/ roof (roof Integration / roof attached)?	Tracker, no facade (could be built, if necessary)
monitoring of meteorological data	
air temperature	Yes
solar irradiance	Yes
wind velocity	Yes
wind direction	No

relative humidity	Yes
type of temp. measure used	P 463; PT 100 (4 - Leiter); cal.
type of pyranometer used	Fa. Kipp&Zonen; CM21, CM11, CM6B, cal.
type of anemometer	Thies Clima; cup anemometer; ±0,1 m/s; cal.
Electrical measurement	
inverters available?	yes
operated at AC-inverter (AC-grid connection and commercial MPP-tracker assumed) (A)?	yes
MPP tracking possible?	yes
operated at a DC dump load (with experimental MPP tracking system) (B)?	no
Measurement of U/I curve possible (UI)?	yes
Measurement of Power at MPP possible?	yes
maximum standalone recording period	unlimited
frequency of MPP recording?	manually
measuring equipment operated offline with (battery) or (grid) connected	grid connected
if UI: frequency of U/I curve recording	manually
all the time operated at MPP (B1) or idle unless measuring U/I curve (B2)?	both possible
Environmental influence measurable	
Driving rain / moisture ingress measurable?	No, standard rain sensor installed.
Windload / Windproofness / Windsuction measurable?	No, but static load tests are possible (in lab)
Hail impact measurable?	-
Snowload measurable?	-
Thermal impact measurements	
Location of module temperature measurement? (where? at module frontsurface / module backsurface / if ventilated - air temperature on module backside)	Sensors could be used when necessary.

6.3 SFL Technologies GmbH

The SFL BIPV test facade combines electrical and mechanical measurements and is a unique test facility in Austria focusing on BIPV products. In order to simulate the thermal effects of a curtain wall, the BIPV facade elements are mounted on rails, creating a ventilation air gap between BIPV modules and the thermal insulation. Figure 4 shows the BIPV test facade with different types of BIPV modules.

Figure 4: SFL BIPV test facade

The basic elements are 1 m long x 0.7 m with a 0.02 m spacing between the elements. Smaller active BIPV-elements can also be tested and characterized, if necessary.

General information	
Name of the research institution:	SFL Technologies GmbH / Hans Höllwart Forschungszentrum für integrales Bauwesen FIBAG in cooperation with AIT Austrian Institute of Technology, Energy Department
Name of the person in charge:	Michael Grobbauer (SFL technologies GmbH), Karl A., Berger (AIT Energy Department)
Contact data (mail):	grobbauer.michael@sfl-technologies.com karl.berger@ait.ac.at
Country:	Austria
City / ZIP Code:	A-8152 Stallhofen
Climate Zone	Boreal and snow forest full humid Tmax<22 (Dfb - climate)
Total size of testing area / BIPV test module size applicable	
	[m]
max. length	4
min. length	0,12
max. width	1,4
min. width	0.5 m mounting rail distances
orientation S/E/W/N	SWbW (53° from South ->West), 90° tilt (vertical)

shading effects	self-shading starting with sunrise
monitoring of meteorological data	
air temperature	Yes
solar irradiance	Yes
wind velocity	Yes
wind direction	Yes
relative humidity	Yes
type of temp. measure used	4 wire Pt100 Type B
type of pyranometer used	c-Si: Mencke & Tegtmayer SI-13-TC(-T), Pyr. Ahlborn FL A613-GS
type of anemometer	Ahlborn, Multimeteo FMA510H
Electrical measurement	
max. number of connection points	10 x 4 & 4 x 2 wire connections (4mm² Cu)
number of independent measurement points	8 x 200 Wp + 6 x 100 Wp
inverters available?	No
operated at AC-inverter (AC-grid connection and commercial MPP-tracker assumed) (A)?	No
MPP tracking possible?	Yes
operated at a DC dump load (with experimental MPP tracking system) (B)?	Yes, but linear operated MOSFET's on ventilated heat sinks as load
Measurement of U/I curve possible (UI)?	Yes
Measurement of Power at MPP possible?	Yes
maximum standalone recording period	~ 1 year
number of serially connected cells in measured array (MIN/MAX)	~4 … 25
array current limit (MIN/MAX)	~0.1 A / 12 A
array power limit (MIN/MAX)	8 x 200 Wp + 6 x 100 Wp (2.2kWp)
measuring equipment operated offline with (battery) or (grid) connected	equipment with power supply from mains and ethernet connection
if UI: frequency of U/I curve recording	set: every 2 minutes
all the time operated at MPP (B1) or idle unless measuring U/I curve (B2)?	B1 (MPP-setpoint between IV-measurement)
Environmental influence measurable	
Driving rain / moisture ingress measurable?	No
Windload / Windproofness / Windsuction measurable?	No
Hail impact measurable?	No
Snowload measurable?	No
Thermal impact measurements	
Location of module temperature measurement? (where? at module frontsurface / module backsurface / if ventilated - air temperature on module backside)	Temperature sensors (PT100) laminated within the modules

6.4 Natural Resources Canada

Natural Resources Canada has an outdoor testing facility for characterizing the electric and thermal performance of photovoltaic modules with thermal energy recovery (PVT) that use air as the heat recovery fluid. It can also be used to characterize the performance of BIPVT/air or BIPV products (Figure 5).

Figure 5: CanmetENERGY, Natural Resources Canada Test Facility

General information	
Name of the research institution:	CanmetENERGY, Natural Resources Canada
Name of the person in charge:	Véronique Delisle
Contact data (mail):	veronique.delisle@canada.ca
Country:	Canada
City / ZIP Code:	Varennes, Quebec
Climate Zone	Cold (Continental), without dry season, warm summer (Dfb-climate)
Total size of testing area / BIPV test module size applicable	
	[m]
max. length	3,5
min. length	-
max. width	1
min. width	-
orientation S/E/W/N	All orientations are possible since the testing rig is mounted on a double-axis tracking system that can be operated in both fixed position and tracking modes
shading effects	Early morning, later afternoon
Inclination of the tested modules (fixed/moveable / Degree)	All slopes are possible since the testing rig is mounted on a double-axis tracking system that can be operated in both fixed position and tracking modes

monitoring of meteorological data	
air temperature	Yes
solar irradiance	Yes
wind velocity	Yes
wind direction	Yes
relative humidity	Yes
type of temp. measure used	High accuracy, capacity type humidity sensor and precision Platinum RTD temperature sensor with multi-plate radiation shield
type of pyranometer used	Precision spectral pyranometer Precision infrared radiometer
type of anemometer	Global wind speed/direction: Propeller-vane anemometer In-plane wind speed/direction: Ultrasonic anemometer
Electrical measurement	
max. number of connection points	3 modules simulatenously
number of independent measurement points	
inverters available?	No
operated at AC-inverter (AC-grid connection and commercial MPP-tracker assumed) (A)?	No
MPP tracking possible?	Yes
operated at a DC dump load (with experimental MPP tracking system) (B)?	No
Measurement of U/I curve possible (UI)?	Yes
Measurement of Power at MPP possible?	Yes
maximum standalone recording period	No max (data stored in database everynight)
number of serially connected cells in measured array (MIN/MAX)	No min/max
array current limit (MIN/MAX)	3 channels, Ch 1: Imax=20 A, Ch 2: Imax=20 A, Chl 3: Imax=10 A
array power limit (MIN/MAX)	3 channels, Ch 1: Pmax=400 W, Ch 2: Pmax =1000 W, Ch 3: Pmax=1000 W
measuring equipment operated offline with (battery) or (grid) connected	connected
if UI: frequency of U/I curve recording	1 minute
all the time operated at MPP (B1) or idle unless measuring U/I curve (B2)?	Operates at MPP all the time with U/I curves traced at a regular time interval set by the operator (manual I-V curves also possible)
Environmental influence measurable	
Driving rain / moisture ingress measurable?	No
Windload / Windproofness / Windsuction measurable?	No
Hail impact measurable?	No
Snowload measurable?	No
Thermal impact measurements	
Location of module temperature measurement? (where? at module frontsurface / module backsurface / if ventilated - air temperature on module backside)	Up to 10 temperature measurements can be made on the module back side When BIPV-T air modules are tested, the inlet and outlet fluid temperatures are measured with averaging RTD sensors

6.5 CEA INES

The Building experimental platform of the Building and Thermal Systems Lab named INCAS includes ten BIPV test benches, four experimental full-size low energy houses and four PASSYS test cells of which two of them are mounted on a rotating platform.

Figure 6 gives an overview of the outdoor test facility. Moreover, it has got an indoor solar simulator facility.

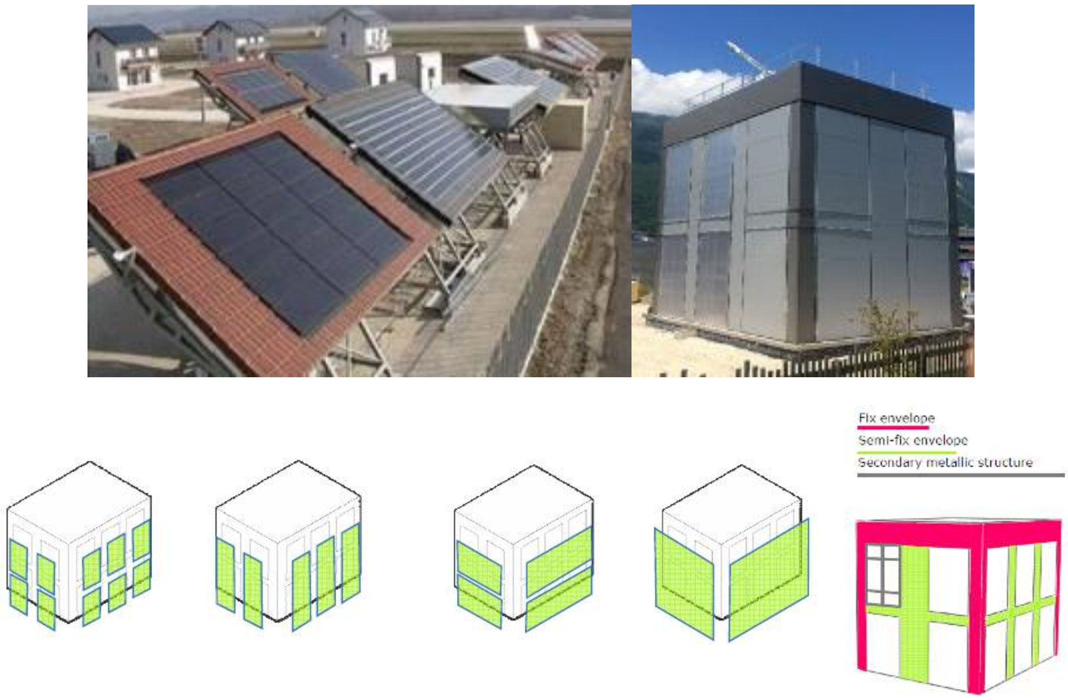


Figure 6: CEA INES test facility

The ten BIPV roof test benches face south: built in 2010 to test and characterize building integrated photovoltaic for roof. The benches can support 35 m^2 of south oriented roof elements with an orientation that can vary between 0 and 50°. The four experimental houses have the same geometry and four different types of construction with the ability to emulate occupancy; they are all fully instrumented for building envelope characterization and monitoring of the energy systems (HVAC, HSW, Solar thermal and BIPV systems). Also, a new platform dedicated to facade testing is the Façade Tool (FacT). (Figure 7).

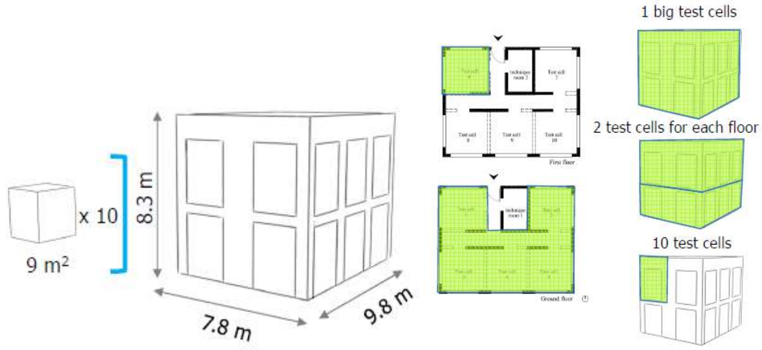


Figure 7:FacT Facade Tool

General information	
Name of the research institution:	CEA INES
Name of the person in charge:	Ya-Brigitte ASSOA, Francoise Burgun
Contact data (mail):	ya-brigitte.assoa@cea.fr francoise.burgun@cea.fr
Country:	France
City / ZIP Code:	50 avenue du lac Léman 73375 Le Bourget du Lac - France
Climate Zone	Moderate full humid Tmax<22 (Cfb-climate)
Total size of testing area / BIPV test module size applicable	
	[m]
max. length	7 for the BIPV Test Benches / about 9 m for FacT
min. length	-
max. width	5 for the BIPV Test Benches / about 8 m for FacT
min. width	-
orientation S/E/W/N	15.3°E for the BIPV Test Benches / east, south, or west for FacT
shading effects	none
Inclination of the tested modules (fixed/moveable / Degree)	variable tilt from 0 to 50° (with a path of 10°) for the BIPV Test Benches
monitoring of meteorological data	
air temperature	Yes
solar irradiance	Yes
wind velocity	Yes
wind direction	Yes
relative humidity	Yes
type of temp. measure used	RTD (PT100)
type of pyranometer used	Kipp & Zonen
type of anemometer	Windsonic
Electrical measurement	
max. number of connection points	1
number of independent measurement points	1
inverters available?	Yes
operated at AC-inverter (AC-grid connection and commercial MPP-tracker assumed) (A)?	Yes
MPP tracking possible?	Yes
operated at a DC dump load (with experimental MPP tracking system) (B)?	Yes
Measurement of U/I curve possible (UI)?	Yes
Measurement of Power at MPP possible?	Yes
maximum standalone recording period	No

6.6 CSTB

At CSTB, there are two outdoor test facilities for testing short and long lifetime effect on BIPV components. It includes assessment of efficiency, LID and PID. The test facility is shown in Figure 8.

Figure 8: CSTB Test facility

General information	
Name of the research institution:	CSTB, Centre Scientifique et Technique du Bâtiment
Name of the person in charge:	Simon BODDAERT
Contact data (mail):	simon.boddaert@cstb.fr
Country:	France
City / ZIP Code:	Sophia Antipolis 06904
Climate Zone	Moderate summer dry Tmax>22 (Csa-climate)
Total size of testing area / BIPV test module size applicable	
	[m]
max. length	12
min. length	-
max. width	4,5
min. width	-
orientation S/E/W/N	S by default, but All orientation available
shading effects	Yes
Inclination of the tested modules (fixed/moveable / Degree)	
Inclination of the tested modules (fixed/moveable / Degree)	Fixed or moveable, on demand from 0° to 90°orientation south +- 90°
type of BIPV: facade (Warm facade / Cold façade - ventilated?)/ roof (roof Integration /	any kind of facade warm (with insulation) cold or ventilated with variable thickness

roof attached)?	roof BIPV and BAPV with or without insulation under cover layer
monitoring of meteorological data	
air temperature	Yes
solar irradiance	Yes
wind velocity	Yes
wind direction	Yes
relative humidity	Yes
type of temp. measure used	PT100, RTD and 1 WIRE
type of pyranometer used	SMP 21 et CMP 22 (Kipp&Zonen)
type of anemometer	Gill Ultrasonic
Electrical measurement	
max. number of connection points	-
number of independent measurement points	-
inverters available?	Yes
operated at AC-inverter (AC-grid connection and commercial MPP-tracker assumed) (A)?	Yes
MPP tracking possible?	Yes
operated at a DC dump load (with experimental MPP tracking system) (B)?	Yes
Measurement of U/I curve possible (UI)?	Yes
Measurement of Power at MPP possible?	Yes
maximum standalone recording period	1 year
number of serially connected cells in measured array (MIN/MAX)	MIN 4 cells / Max under 1000V limitation
array current limit (MIN/MAX)	0,05 / 60A
array power limit (MIN/MAX)	0,2 kW / 30 kW (mono and three-phase)
Environmental influence measurable	
Driving rain / moisture ingress measurable?	Yes
Windload / Windproofness / Windsuction measurable?	Yes, according to eurocode
Hail impact measurable?	Yes
Snowload measurable?	Yes
Thermal impact measurements	
Location of module temperature measurement? (where? at module frontsurface / module backsurface / if ventilated - air temperature on module backside)	at any layers, front and back surface (inner layer when sensors are built in during lamination process) air gap temperature also measured

6.7 EURAC

Two outdoor test benches are located at EURAC (Figure 9): the first one is a fixed facade facing south and the other one is located on a tracker.

Figure 9: Test Site of EURAC

General information	
Name of the research institution:	EURAC
Name of the person in charge:	Laura Maturi
Contact data (mail):	laura.maturi@eurac.edu
Country:	ITALY
City / ZIP Code:	39100
Climate Zone	Boreal and snow forest full humid Tmax<22 (Dfb - climate)
Total size of testing area / BIPV test module size applicable	
	[m]
max. length	F = 6 R = 4
min. length	-
max. width	F = 4 R = 5
min. width	-
orientation S/E/W/N	F = South R = Any (orientable)
shading effects	F = No (only mountains / horizontal)

	R = No (only mountains / horizontal)
abbreviations	F = BIPV Facade test facility R = BIPV Roof test facility
Inclination of the tested modules (fixed/moveable / Degree)	R: moveable, F: 90°
type of BIPV: facade (Warm facade / Cold façade - ventilated?)/ roof (roof Integration / roof attached)?	Possibility to adapt any façade or roof integration type
monitoring of meteorological data	
air temperature	Yes
solar irradiance	Yes
wind velocity	Yes
wind direction	Yes
relative humidity	Yes
type of temp. measure used	Humidity/temperature sensor Tersid
type of pyranometer used	Kipp & Zonen CMP 11
type of anemometer	Deltaohm HD52.3D
Electrical measurement	
max. number of connection points	4 "MPPT stand alone systems"+2 inverters + 8 microinverters
number of independent measurement points	1 master CRIO
inverters available?	Yes
operated at AC-inverter (AC-grid connection and commercial MPP-tracker assumed) (A)?	Yes
MPP tracking possible?	Yes
operated at a DC dump load (with experimental MPP tracking system) (B)?	Yes
Measurement of U/I curve possible (UI)?	Yes
Measurement of Power at MPP possible?	Yes
maximum standalone recording period	Depending on the system
number of serially connected cells in measured array (MIN/MAX)	for the MPPT standalone system: 150V max for the other measurement system: adjustable
array current limit (MIN/MAX)	for the MPPT standalone system: 10 A for the other measurement system: adjustable
array power limit (MIN/MAX)	-
measuring equipment operated offline with (battery) or (grid) connected	Grid connected
if UI: frequency of U/I curve recording	1m
all the time operated at MPP (B1) or idle unless measuring U/I curve (B2)?	B1
Environmental influence measurable	
Driving rain / moisture ingress measurable?	-
Windload / Windproofness / Windsuction measurable?	-
Hail impact measurable?	-
Snowload measurable?	-
Thermal impact measurements	
Location of module temperature measurement? (where? at module frontsurface / module backsurface / if ventilated - air temperature on module backside)	Depends on the specific test (many temperature sensors available). Usually on the back surface of the module. If ventilated, also air temperature on module backside and wall surfaces.

6.8 ENEA

The facility at ENEA consists of different equipment for indoor and outdoor characterization. Besides these tests different climatic chambers are available. (Figure 19).

Figure 20: ENEA Test facilities

General information	
Name of the research institution:	ENEA
Name of the person in charge:	Michele Pellegrino
Contact data (mail):	Michele.pellegrino@enea.it
Country:	Italy
City / ZIP Code:	Portici/80055
Climate Zone	Maritime climate
Total size of testing area / BIPV test module size applicable	
	[m]
max. length	2
min. length	-
max. width	2
min. width	-
orientation S/E/W/N	S
Inclination of the tested modules (fixed/moveable / Degree)	40°
shading effects	none
monitoring of meteorological data	
air temperature	Yes
solar irradiance	Yes
wind velocity	Yes

wind direction	Yes
relative humidity	Yes
type of temp. measure used	Different
type of pyranometer used	global
type of anemometer	-
Electrical measurement	
max. number of connection points	Different
number of independent measurement points	Different
inverters available?	-
operated at AC-inverter (AC-grid connection and commercial MPP-tracker assumed) (A)?	No
MPP tracking possible?	no
operated at a DC dump load (with experimental MPP tracking system) (B)?	no
Measurement of U/I curve possible (UI)?	no
Measurement of Power at MPP possible?	no
maximum standalone recording period	-
number of serially connected cells in measured array (MIN/MAX)	-
array current limit (MIN/MAX)	-
array power limit (MIN/MAX)	-
measuring equipment operated offline with (battery) or (grid) connected	Off line
if UI: frequency of U/I curve recording	no
all the time operated at MPP (B1) or idle unless measuring U/I curve (B2)?	no
Environmental influence measurable	
Driving rain / moisture ingress measurable?	No
Windload / Windproofness / Windsuction measurable?	YES
Hail impact measurable?	Yes
Snowload measurable?	Yes
Thermal impact measurements	
Location of module temperature measurement? (where? at module frontsurface / module backsurface / if ventilated - air temperature on module backside)	backsurface

6.9 IRESEN

The Green Energy Park at IRESEN is an R&D test platform for solar energy, involving Moroccan and foreign universities. The outdoor research platform is part of it (Figure 10).

Figure 10: IRESEN outdoor research platform

General information	
Name of the research institution:	IRESEN - Institut de Recherche en Eergie Solaire et Energies Nouvelles / Green Energy Park
Name of the person in charge:	Badr Ikken / Aboubakr Benazzouz (Responsible of the outdoor test platform)
Contact data (mail):	ikken@iresen.org / benazzouz@iresen.org
Country:	Morocco
City / ZIP Code:	Benguerir
Climate Zone	Hot and dry (B-climate)
Total size of testing area / BIPV test module size applicable	
	[m]
max. length	60 (total size)
min. length	-
max. width	30 (total siz)
min. width	-
orientation S/E/W/N	S
shading effects	None
monitoring of meteorological data	
air temperature	Yes
solar irradiance	Yes
wind velocity	Yes
wind direction	Yes

relative humidity	Yes
type of temp. measure used	Campbell Scientific CS215
type of pyranometer used	Kipp&Zonen CMP21 & HuxseFlux SRA11
type of anemometer	NRG #40C
Electrical measurement	
max. number of connection points	34
number of independent measurement points	34
inverters available?	Yes
operated at AC-inverter (AC-grid connection and commercial MPP-tracker assumed) (A)?	Yes
MPP tracking possible?	Yes
operated at a DC dump load (with experimental MPP tracking system) (B)?	Yes
Measurement of U/I curve possible (UI)?	Yes
Measurement of Power at MPP possible?	Yes
maximum standalone recording period	-
number of serially connected cells in measured array (MIN/MAX)	-
array current limit (MIN/MAX)	~0.1 A / 12.5 A
array power- limit (MIN/MAX)	1 mW / 300 W
measuring equipment operated offline with (battery) or (grid) connected	Grid connected
if UI: frequency of U/I curve recording	60s
all the time operated at MPP (B1) or idle unless measuring U/I curve (B2)?	B1

6.10 SERIS

Two outdoor test benches are located at SERIS (Figure 11): one for façade test and one for roof test applications.

Figure 11: SERIS outdoor test facility

General information	
Name of the research institution:	Solar Energy Research Institute of Singapore (SERIS)
Name of the person in charge:	Dr Thomas REINDL; Dr Veronika SHABUNKO
Contact data (mail):	thomas.reindl@nus.edu.sg; veronika.shabunko@nus.edu.sg
Country:	Singapore
City / ZIP Code:	117574
Climate Zone	Tropical rainforest climate (Af)
Total size of testing area / BIPV test module size applicable	
	[m]
max. length	1.5m indoor; Customizable for outdoor
min. length	Customizable for outdoor
max. width	1.6m indoor; Customizable for outdoor
min. width	Customizable for outdoor
orientation S/E/W/N	2m indoor; Customizable for outdoor
Inclination of the tested modules (fixed/moveable / Degree)	0-90 degree
shading effects	Negligible
type of BIPV: facade (Warm facade / Cold façade - ventilated?)/ roof (roof Integration / roof attached)?	Façade combinations (Calorimeter lab, indoor) Ventilated/non-ventilated façades Roof applications (Outdoor module testing, flat roof)
monitoring of meteorological data	
air temperature	Yes
solar irradiance	Yes
wind velocity	Yes
wind direction	Yes
relative humidity	Yes
type of temp. measure used	PT 1000 thermocouples
type of pyranometer used	Kipp & Zonen CMP11 pyranometer
type of anemometer	Cupstar Anemometer
Electrical measurement	
max. number of connection points	different (total 30 slots)

number of independent measurement points	different (total 30 slots)
inverters available?	on request
operated at AC-inverter (AC-grid connection and commercial MPP-tracker assumed) (A)?	Commercial MPP-tracker, automatically carried out by the measurement setup
MPP tracking possible?	Yes
operated at a DC dump load (with experimental MPP tracking system) (B)?	No
Measurement of U/I curve possible (UI)?	Yes
Measurement of Power at MPP possible?	Yes
maximum standalone recording period	-
number of serially connected cells in measured array (MIN/MAX)	-
array current limit (MIN/MAX)	2.5A (MIN)/ 10A (MAX)
array power limit (MIN/MAX)	30W (MIN)/ 280W (MAX)
Environmental influence measurable	
Driving rain / moisture ingress measurable?	No
Windload / Windproofness / Windsuction measurable?	No
Hail impact measurable?	Not applicable for Singapore
Snowload measurable?	Not applicable for Singapore
Thermal impact measurements	
Location of module temperature measurement? (where? at module frontsurface / module backsurface / if ventilated - air temperature on module backside)	Customizable, both module front and back surface possible

6.11 SEAC

The R&D facility SolarBEAT is a partnership of SEAC with the Technical University Eindhoven. It contains six positions for dummy houses with BIPV and/or PVT equipped with temperature sensors, pyranometers and I/V tracing. The facility has a full infrastructure for the study of solar thermal systems and a weather station that includes measurements of direct and diffuse irradiance. Figure 12 gives an overview of the SolarBEAT test facility.

Figure 12: SEAC SolarBEAT test facility

General information	
Name of the research institution:	Solar Energy Application Centre (SEAC)
Name of the person in charge:	Roland Valckenborg
Contact data (mail):	valckenborg@seac.cc
Country:	Netherlands
City / ZIP Code:	5656AE Eindhoven
Climate Zone	Moderate full humid Tmax<22 (Cfb-climate)
Total size of testing area / BIPV test module size applicable	
	[m]
max. length	5
min. length	-
max. width	6
min. width	-
orientation S/E/W/N	S
Inclination of the tested modules (fixed/moveable / Degree)	> All fixed, inclination (+ nr. of projects) at the moment: 15 degrees (1 project) 30 degrees (1 project) 35 degrees (4 projects) 90 degrees = façade (2 projects)

shading effects	minor shading in December & January
type of BIPV: facade (Warm facade / Cold façade - ventilated?)/ roof (roof Integration / roof attached)?	facades: at the moment only cold façade (cladding) ventilated + to be built warm façade (2017Q1) * roofs: BAPV (two PVT-systems), all the others BIPV
monitoring of meteorological data	
air temperature	Yes
solar irradiance	Yes
wind velocity	Yes
wind direction	Yes
relative humidity	Yes
type of temp. measure used	NTC
type of pyranometer used	Secondary standard
type of anemometer	Ultrasonic (Lufft WS600)
Electrical measurement	
max. number of connection points	-
number of independent measurement points	12
inverters available?	Yes
operated at AC-inverter (AC-grid connection and commercial MPP-tracker assumed) (A)?	Yes
MPP tracking possible?	Yes
operated at a DC dump load (with experimental MPP tracking system) (B)?	Yes
Measurement of U/I curve possible (UI)?	Yes
Measurement of Power at MPP possible?	Yes
maximum standalone recording period	Unlimited (24/7)
number of serially connected cells in measured array (MIN/MAX)	depending on set-up
array current limit (MIN/MAX)	depending on set-up
array power limit (MIN/MAX)	depending on set-up
Environmental influence measurable	
Driving rain / moisture ingress measurable?	Just visual inspection after heavy rain. No measurement method available
Windload / Windproofness / Windsuction measurable?	In one project, the wind suction was measured for one full year (2015). After project ended, it has not repeated on other projects, yet. Equipment (and knowledge) available, in stock.
Hail impact measurable?	Not measurable directly. But outdoor EL-setup in development. EL is a great tool for detecting failures after a hail storm has passed.
Snowload measurable?	Not measurable. Just visual inspection (webcams) of snow building up and sliding off
Thermal impact measurements	
Location of module temperature measurement? (where? at module frontsurface / module backsurface / if ventilated - air temperature on module backside)	> Many options: * Thermocouple build-in (1 project) * Thermocouples attached to back (7 projects) * Air temperature (5 projects) * Air flow (3 projects)

6.12 University of Twente

The university of Twente facility focuses on special module designs and their impact on the module electrical yield and cell temperature (Figure 13).

Figure 13: test facility of the University of Twente

General information	
Name of the research institution:	University of Twente
Name of the person in charge:	Dr. Angèle Reinders
Contact data (mail):	a.h.m.e.reinders@utwente.nl
Country:	Netherlands
City / ZIP Code:	7500 AE
Climate Zone	Moderate full humid Tmax<22 (Cfb-climate)
Total size of testing area / BIPV test module size applicable	
	[m]
max. length	8
min. length	-
max. width	8
min. width	-
orientation S/E/W/N	S
shading effects	none
Inclination of the tested modules (fixed/moveable / Degree)	30 degrees South
type of BIPV: facade (Warm facade / Cold façade - ventilated?)/ roof (roof Integration / roof attached)?	No façade, for now we focus on special module designs, a façade is under construction
monitoring of meteorological data	
air temperature	Yes
solar irradiance	Yes

wind velocity	Yes
wind direction	No
relative humidity	No
type of temp. measure used	Theodor Friedrichs PT100 element
type of pyranometer used	Kipp&Zonen CMP 11
type of anemometer	Theodor Friedrichs type 4034
Electrical measurement	
max. number of connection points	12
number of independent measurement points	12
inverters available?	No
operated at AC-inverter (AC-grid connection and commercial MPP-tracker assumed) (A)?	No
MPP tracking possible?	No
operated at a DC dump load (with experimental MPP tracking system) (B)?	No
Measurement of U/I curve possible (UI)?	Possible
Measurement of Power at MPP possible?	-
maximum standalone recording period	-
number of serially connected cells in measured array (MIN/MAX)	-
array current limit (MIN/MAX)	-
array power limit (MIN/MAX)	-
measuring equipment operated offline with (battery) or (grid) connected	-
if UI: frequency of U/I curve recording	-
all the time operated at MPP (B1) or idle unless measuring U/I curve (B2)?	-
Environmental influence measurable	
Driving rain / moisture ingress measurable?	-
Windload / Windproofness / Windsuction measurable?	Wind speed is measured with a cup anemometer
Hail impact measurable?	-
Snowload measurable?	-
Thermal impact measurements	
Location of module temperature measurement? (where? at module frontsurface / module backsurface / if ventilated - air temperature on module backside)	for each module, we have two temperature sensors, now attached to back surface but they can be moved for different experiments

6.13 ZUYD

The Wijk van Morgen ("District of tomorrow") is a living lab for energy in the built environment. It consists of two test houses that inherit several BIPV installations (Figure 14).

Figure 14: District of tomorrow BIPV test facility

General information	
Name of the research institution:	The District of Tomorrow, University of Applied Science Zuyd
Name of the person in charge:	Alex Masolin, Michiel Ritzen
Contact data (mail):	alex.masolin@zuyd.nl, michiel.ritzen@zuyd.nl
Country:	Netherlands
City / ZIP Code:	Heerlen, 6422RG,
Climate Zone	Moderate full humid Tmax<22 (Cfb-climate)
Total size of testing area / BIPV testmodule size applicable	
	[m]
max. length	3 different rooftops (inclination 0 (10x10 m), 12 (15x7 m) and 35 (8x8 m) degrees), all facades
min. length	
max. width	
min. width	
orientation S/E/W/N	All
Inclination of the tested modules (fixed/moveable / Degree)	Fixed inclinations, different degrees *azimuth - all (current buildings have facades facing east, south, west and north) elevation - current rooftops have elevation / inclination of 36 degrees, 12 degrees and 0 degrees. Facades 90 degrees
shading effects	With shading constructors
type of BIPV: facade (Warm facade / Cold façade - ventilated?)/ roof (roof Integration / roof attached)?	Cold façade solutions and roof integrated test beds (additional watertight layer)
monitoring of meteorological data	
air temperature	Yes
solar irradiance	Yes
wind velocity	Yes
wind direction	Yes
relative humidity	Yes
type of temp. measure used	PT100
type of pyranometer used	Kipp&Zonen secondary standard (Global Horizontal Solar Spectrum avalable (spectrometer EKO SRF-02))
type of anemometer	2D ultrasonic
Electrical measurement	

max. number of connection points	1 per module
number of independent measurement points	No limit
inverters available?	Yes
operated at AC-inverter (AC-grid connection and commercial MPP-tracker assumed) (A)?	The inverters are grid connected. The MMPT is a dedicated solution. Commercial MPPT is possible.
MPP tracking possible?	Yes
operated at a DC dump load (with experimental MPP tracking system) (B)?	No DC dump load. Power optimizer per module and inverter per string/system. There is the possibility to use an experimental MPPT
Measurement of U/I curve possible (UI)?	Yes
Measurement of Power at MPP possible?	Yes
maximum standalone recording period	No limit
number of serially connected cells in measured array (MIN/MAX)	Measurements are performed at module level. Voltage: 10-85V, Imax: 11A, Pmax: 330W
array current limit (MIN/MAX)	
array power limit (MIN/MAX)	
measuring equipment operated offline with (battery) or (grid) connected	Grid + UPS
if UI: frequency of U/I curve recording	User selectable (1min - 12hours)
all the time operated at MPP (B1) or idle unless measuring U/I curve (B2)?	All time MPP unless during U/I swipe
Thermal impact measurements	
Location of module temperature measurement? (where? at module frontsurface / module backsurface / if ventilated - air temperature on module backside)	Surface temperature measurement at back of cell (PT100 encapsulated), back of module, roof surface

6.14 CIEMAT

The CIEMAT facility has several south-facing test benches able to tilt from 0° to 90° (Figure 15). It can perform a variety of tests including hot spot endurance and durability. It can also be used for real operation of PV systems and performance ratio.

Figure 15: Test facility of CIEMAT

General information	
Name of the research institution:	CIEMAT
Name of the person in charge:	Nuria Martín Chivelet
Contact data (mail):	nuria.martin@ciemat.es
Country:	SPAIN
City / ZIP Code:	28040
Climate Zone	Moderate summer dry Tmax>22 (Csa-climate)
Total size of testing area / BIPV test module size applicable	
	[m]
max. length	36
min. length	-
max. width	2
min. width	-
orientation S/E/W/N	S
shading effects	No
monitoring of meteorological data	
air temperature	Yes
solar irradiance	Yes
wind velocity	Yes
wind direction	Yes
relative humidity	Yes
type of temp. measure used	PT100, TC
type of pyranometer used	Secondary standard

type of anemometer	ultrasonic / cups
Inclination of the tested modules (fixed/moveable / Degree)	Moveable from 0° to 90° (South oriented). In addition, a 2 m x 2 m East façade (90°) and a 2 m x 2 m South façade (90°) is available
type of BIPV: facade (Warm facade / Cold façade - ventilated?)/ roof (roof Integration / roof attached)?	Cold façade - ventilated or insulated (real façade and movable structure with insulation panels), Roof attached (movable structure with insulation panels).
Electrical measurement	
max. number of connection points	120
number of independent measurement points	120
inverters available?	Yes
operated at AC-inverter (AC-grid connection and commercial MPP-tracker assumed) (A)?	Yes
MPP tracking possible?	Yes
operated at a DC dump load (with experimental MPP tracking system) (B)?	Yes
Measurement of U/I curve possible (UI)?	Yes
Measurement of Power at MPP possible?	Yes
maximum standalone recording period	No limit
number of serially connected cells in measured array (MIN/MAX)	From 1 to 2000
array current limit (MIN/MAX)	1 mA / 100 A
array power limit (MIN/MAX)	-
measuring equipment operated offline with (battery) or (grid) connected	Yes
if UI: frequency of U/I curve recording	4 min.
all the time operated at MPP (B1) or idle unless measuring U/I curve (B2)?	-
Environmental influence measurable	
Driving rain / moisture ingress measurable?	-
Windload / Windproofness / Windsuction measurable?	-
Hail impact measurable?	-
Snowload measurable?	-
Thermal impact measurements	
Location of module temperature measurement? (where? at module frontsurface / module backsurface / if ventilated - air temperature on module backside)	At module front surface / back surface/ back air temperature.

6.15 TECNALIA

The experimental KUBIK building at TECNALIA is dedicated to real-life component testing, including BIPV. Figure 16 gives an overview of the BIPV test facility.

Figure 16: Tecnalia KUBIK BIPV outdoor test facility

General information	
Name of the research institution:	Tecnalia Research & Innovation
Name of the person in charge:	Inés Apraiz
Contact data (mail):	ines.apraiz@tecnalia.com;eduardo.roman@tecnalia.com;maider.machado@tecnalia.com
Country:	SPAIN
City / ZIP Code:	Derio, 48160
Climate Zone	Moderate full humid Tmax<22 (Cfb-climate)
Total size of testing area / BIPV test module size applicable	
	[m]
max. length	9,791
min. length	-
max. width	6,11
min. width	-
orientation S/E/W/N	S, E, W, N
shading effects	None
Inclination of the tested modules (fixed/moveable / Degree)	Fixed inclination (vertical façade)
type of BIPV: facade (Warm facade / Cold façade - ventilated?)/ roof (roof Integration / roof attached)?	Warm façade, Roof attached
monitoring of meteorological data	
air temperature	Yes
solar irradiance	Yes
wind velocity	Yes
wind direction	Yes

relative humidity	Yes
type of temp..measure used	PT 100
type of pyranometer used	Kipp&Zonen
type of anemometer	SCHMIDT® Flow sensor SS 20.500, Ultrasonic
Type of radiation measurements	Direct radiation in horizontal and vertical planes and diffuse radiation
Other measurements in the test facility	Atmospheric pressure, thermal flux with colliding areas, illumination level (in luxes)
Electrical measurement	
max. number of connection points	No limit in number, only limitation in the added power (50 kW max.)
number of independent measurement points	Independent points for each installation, TBD
inverters available?	On demand
MPP tracking possible?	Yes
Environmental influence measurable	
Driving rain / moisture ingress measurable?	Not on the experimental building but measurable at laboratory scale
Windload / Windproofness / Windsuction measurable?	Same as above
Hail impact measurable?	Same as above
Snowload measurable?	Same as above
Thermal impact measurements	
Location of module temperature measurement? (where? at module frontsurface / module backsurface / if ventilated - air temperature on module backside)	Measurable at module front surface

6.16 RISE Research Institutes of Sweden (SP Technical Research Institute)

SP has both a fully monitored single-family house and a roof test element for PV / BIPV outdoor testing (Figure 17).

Figure 17: SP Technical Research outdoor test facility for PV / BIPV

General information	
Name of the research institution:	SP Technical Research Institute of Sweden
Name of the person in charge:	Peter Kovacs
Contact data (mail):	peter.kovacs@ri.se
Country:	Sweden
City / ZIP Code:	50115
Climate Zone	Boreal and snowforest full humid Tmax<22 (Dfb - climate)
Total size of testing area / BIPV test module size applicable	
	[m]
max. length	8
min. length	-
max. width	8
min. width	-
orientation S/E/W/N	S
shading effects	In winter, early spring and late autumn
monitoring of meteorological data	
air temperature	Yes
solar irradiance	Yes
wind velocity	Yes
wind direction	Yes
relative humidity	Yes
type of temp. measure used	-
type of pyranometer used	-
type of anemometer	-
Electrical measurement	
max. number of connection points	-
number of independent measurement points	-
inverters available?	Yes
operated at AC-inverter (AC-grid connection	Yes

and commercial MPP-tracker assumed) (A)?	
MPP tracking possible?	Yes
operated at a DC dump load (with experimental MPP tracking system) (B)?	No
Measurement of U/I curve possible (UI)?	Yes
Measurement of Power at MPP possible?	Yes
maximum standalone recording period	-
number of serially connected cells in measured array (MIN/MAX)	-
array current limit (MIN/MAX)	-
array power limit (MIN/MAX)	-
measuring equipment operated offline with (battery) or (grid) connected	-
if UI: frequency of U/I curve recording	-
all the time operated at MPP (B1) or idle unless measuring U/I curve (B2)?	

6.17 Lund University - Department of Energy and Building Design

The Lund university has an outdoor laboratory where facades can be exchanged to test BIPV elements and its impact on the building energy performance and daylight (Figure 18).

Figure 18: Lund Universtiy outdoor BIPV test facility

General information	
Name of the research institution:	Lund University - Department of Energy and Building Design
Name of the person in charge:	Ricardo Bernardo
Contact data (mail):	Ricardo.Bernardo@ebd.lth.se
Country:	Sweden
City / ZIP Code:	223 62 Lund
Climate Zone	Boreal and snowforest full humid Tmax<22 (Dfb - climate)
Total size of testing area / BIPV test module size applicable	
	[m]
max. length	10
min. length	-
max. width	15
min. width	-
orientation S/E/W/N	S
shading effects	No
monitoring of meteorological data	
air temperature	Yes
solar irradiance	Yes
wind velocity	Yes
wind direction	Yes
relative humidity	Yes
type of temp. measure used	PT 1000
type of pyranometer used	Kipp&Zonen
type of anemometer	Testo
Electrical measurement	
max. number of connection points	flexible
number of independent measurement points	flexible
inverters available?	-
operated at AC-inverter (AC-grid connection	No

and commercial MPP-tracker assumed) (A)?	
MPP tracking possible?	No
operated at a DC dump load (with experimental MPP tracking system) (B)?	No
Measurement of U/I curve possible (UI)?	Yes
Measurement of Power at MPP possible?	Yes
maximum standalone recording period	-
number of serially connected cells in measured array (MIN/MAX)	-
array current limit (MIN/MAX)	-
array power limit (MIN/MAX)	-
measuring equipment operated offline with (battery) or (grid) connected	-
if UI: frequency of U/I curve recording	-
all the time operated at MPP (B1) or idle unless measuring U/I curve (B2)?	

6.18 SUPSI

The BIPV outdoor facility at SUPSI consists of dummy buildings equipped with pyranometers and temperature sensors. It includes façade and roof test benches (Figure 19).

Figure 19: SUPSI BIPV Test facilities

General information	
Name of the research institution:	Scuola Universitaria Professionale della Svizzera Italiana (SUPSI)
Name of the person in charge:	Pierluigi Bonomo
Contact data (mail):	pierluigi.bonomo@supsi.ch
Country:	Switzerland
City / ZIP Code:	6952
Climate Zone	Moderate full humid Tmax>22 (Cfa-climate)
Total size of testing area / BIPV test module size applicable	
	[m]
max. length	6,4
min. length	-
max. width	2
min. width	-
orientation S/E/W/N	S
Inclination of the tested modules (fixed/moveable / Degree)	For the roof test stand it is possible to tilt differently the roof (from 0° to almost 90°)
shading effects	none
monitoring of meteorological data	
air temperature	Yes
solar irradiance	Yes
wind velocity	Yes
wind direction	Yes
relative humidity	Yes
type of temp. measure used	Different
type of pyranometer used	Kipp&Zonen CM11
type of anemometer	-
Electrical measurement	
max. number of connection points	Different
number of independent measurement points	Different
inverters available?	-
operated at AC-inverter (AC-grid connection	No

and commercial MPP-tracker assumed) (A)?	
MPP tracking possible?	Yes
operated at a DC dump load (with experimental MPP tracking system) (B)?	Yes
Measurement of U/I curve possible (UI)?	Yes
Measurement of Power at MPP possible?	Yes
maximum standalone recording period	-
number of serially connected cells in measured array (MIN/MAX)	-
array current limit (MIN/MAX)	-
array power limit (MIN/MAX)	-
measuring equipment operated offline with (battery) or (grid) connected	Grid connected
if UI: frequency of U/I curve recording	from 5 sec.
all the time operated at MPP (B1) or idle unless measuring U/I curve (B2)?	B1
Environmental influence measurable	
Driving rain / moisture ingress measurable?	We can measure in our lab (indoor) wind pressure, snow load and hail impact test (from 25 up to 65mm ice balls)
Windload / Windproofness / Windsuction measurable?	
Hail impact measurable?	
Snowload measurable?	
Thermal impact measurements	
Location of module temperature measurement? (where? at module frontsurface / module backsurface / if ventilated - air temperature on module backside)	Different sensors at different layers: back of the module, air cavity, insulation layer

6.19 Danish Technological Institute

The BIPV outdoor facility at DTI consists of two buildings equipped with pyranometers and temperature sensors and side-by-side south facing rooms with indoor climate monitoring system (Figure 20). There is also a BIPV façade test stand in an office building and a ground mounted platform for up to 10 roof and façade BIPV systems (under construction).

Figure 20: DTI BIPV Test facilities

General information (preliminary version)	
Name of the research institution:	Danish Technological Institute
Name of the person in charge:	Ivan Katic
Contact data (mail):	Ik@teknologisk.dk
Country:	Denmark
City / ZIP Code:	2630
Climate Zone	Moderate full humid Tmax<22 (Cfb-climate)
Total size of testing area / BIPV test module size applicable	
	[m]
max. length	10
min. length	-
max. width	5
min. width	-
orientation S/E/W/N	S
Inclination of the tested modules (fixed/moveable / Degree)	30 / 45 /90
shading effects	none
monitoring of meteorological data	
air temperature	Yes
solar irradiance	Yes
wind velocity	Yes
wind direction	no
relative humidity	Yes
type of temp. measure used	Pt100
type of pyranometer used	Kipp and Zonen
type of anemometer	Thies
Electrical measurement	
max. number of connection points	8
number of independent measurement points	8
inverters available?	Yes
operated at AC-inverter (AC-grid connection and commercial MPP-tracker assumed) (A)?	No

MPP tracking possible?	Yes
operated at a DC dump load (with experimental MPP tracking system) (B)?	Yes
Measurement of U/I curve possible (UI)?	Yes
Measurement of Power at MPP possible?	Yes
maximum standalone recording period	1 year
number of serially connected cells in measured array (MIN/MAX)	Up to 200 V with MPP tracker
array current limit (MIN/MAX)	20 A
array power limit (MIN/MAX)	1 kW with MPP tracker
measuring equipment operated offline with (battery) or (grid) connected	Both are available
if UI: frequency of U/I curve recording	TBD
all the time operated at MPP (B1) or idle unless measuring U/I curve (B2)?	TBD
Environmental influence measurable	
Driving rain / moisture ingress measurable?	Not on same location, but rain test and mechanical load test is possible in other department of DTI
Windload / Windproofness / Windsuction measurable?	
Hail impact measurable?	
Snowload measurable?	
Thermal impact measurements	
Location of module temperature measurement? (where? at module frontsurface / module backsurface / if ventilated - air temperature on module backside)	Project dependent

6.20 Technical University of Denmark (DTU), Department of Photonics Engineering

The outdoor PV facilities at DTU Fotonik include a 3 kWp grid tied system with 10 individual data acquisition (DAQ) channels for I-V and impedance measurements (*Figure 21*). There is additional racking space for up to 9 kWp for further developments. The weather station at DTU Fotonik features eight instruments for characterizing the solar resource plus an all-in-one smart sensor for measuring atmospheric data.

Figure 21: DTU Fotonik, Outdoor PV performance test bed (left) and weather station (right)

General information	
Name of the research institution:	Technical University of Denmark (DTU), Department of Photonics Engineering
Name of the person in charge:	Nicholas Riedel
Contact data (mail):	nrie@fotonik.dtu.dk
Country:	Denmark
City / ZIP Code:	4000
Climate Zone	Moderate full humid Tmax<22 (Cfb-climate)
Total size of testing area / BIPV test module size applicable	
	[m]
max. length	6
min. length	-
max. width	3
min. width	-
orientation S/E/W/N	S
Inclination of the tested modules (fixed/moveable / Degree)	60° (latitude + 5°)
shading effects	none
monitoring of meteorological data	
Air temperature	Yes
Solar broadband irradiance (direct normal, diffuse horizontal, global horizontal and infrared)	Yes
Spectral solar irradiance	Yes (300 - 1100 nm)
Solar position data	Yes (measured directly during clear sky and calculated during diffuse conditions)
Wind velocity	Yes
Wind direction	Yes

Relative humidity	Yes
Atmospheric pressure	Yes
Precipitation (rain and snow)	Yes
Type of air temp. measure used	Aspirated NTC resistor
Type of pyranometers used	EKO MS-802F (ventilated thermopile detector) and EKO ML-01 (unventilated, fast Si detector)
Type of pyrheliometer used	EKO MS-56
Type of pyrgeometer used	EKO MS-202 (unventilated)
Type of spectrometers used	EKO MS-711 (diffuse) and EKO MS-711DNI (direct)
Type of 2-axis tracker	EKO STR-22
Type of anemometer	Lufft Instruments WS600-UMB
Electrical measurement	
Max. number of connection points	10
number of independent measurement points	10
Inverters available?	Yes
Operated at AC-inverter (AC-grid connection and commercial MPP-tracker assumed) (A)?	Yes
MPP tracking possible?	Yes
Operated at a DC dump load (with experimental MPP tracking system) (B)?	No
Measurement of U/I curve possible (UI)?	Yes. Performed with 4-wire measurement and single quadrant load.
Measurement of Power at MPP possible?	Yes (DC and AC)
maximum standalone recording period	10 months
number of serially connected cells in measured array (MIN/MAX)	300 - 500 V
array current limit (MIN/MAX)	11,5 A
array power limit (MIN/MAX)	4 kW
measuring equipment operated offline with (battery) or (grid) connected	Grid Connected
if UI: frequency of U/I curve recording	2min 30sec
all the time operated at MPP (B1) or idle unless measuring U/I curve (B2)?	DUT is operated at MPP until a relay pulls it out of the grid tied circuit and into the I-V measurement circuit.
Environmental influence measurable	
Driving rain / moisture ingress measurable?	Indoor wind and snow load testing with sand bag method.
Windload / Windproofness / Windsuction measurable?	
Hail impact measurable?	
Snowload measurable?	
Thermal impact measurements	
Location of module temperature measurement? (where? at module frontsurface / module backsurface / if ventilated - air temperature on module backside)	K-type thermocouples placed on backsheet. Correction from backsheet to cell temperature applied based on the Sandia model. Down welling IR data continuously logged with pyrgeometer.

6.21 University of Agder (UiA), Department of Engineering Sciences

Figure 22: Outdoor PV module test facility at the University of Agder

General information	
Name of the research institution:	University of Agder (UiA)
Name of the person in charge:	Prof. Anne Gerd Imenes
Contact data (mail):	anne.g.imenes@uia.no
Country:	Norway
City / ZIP Code:	NO-4879 Grimstad
Climate Zone	Temperate oceanic (Cfb-climate), Tmax<22
Total size of testing area / BIPV testmodule size applicable	
	[m]
max. length	11
min. length	-
max. width	2.85
min. width	-
orientation S/E/W/N	S (deviation 7° towards East)
Inclination of the tested modules (fixed/moveable / Degree)	39 degrees
shading effects	None for top half (width 1.5 m), small shade from safety rail for bottom half (width 1.35 m)
monitoring of meteorological data	
air temperature	Yes
solar irradiance	Yes
wind velocity	Yes
wind direction	Yes
relative humidity	No
type of temp. measure used	PT100 and thermistor 110PV
type of pyranometer used	Kipp&Zonen CMP11 with CVF3 ventilator
type of anemometer	R M Young 05103 Wind monitor
Electrical measurement	
max. number of connection points	10
number of independent measurement points	10
inverters available?	No
operated at AC-inverter (AC-grid connection and commercial MPP-tracker assumed) (A)?	No
MPP tracking possible?	Yes

operated at a DC dump load (with experimental MPP tracking system) (B)?	Yes
Measurement of U/I curve possible (UI)?	Yes
Measurement of Power at MPP possible?	Yes
maximum standalone recording period	-
number of serially connected cells in measured array (MIN/MAX)	-
array current limit (MIN/MAX)	20 A (module)
array power limit (MIN/MAX)	350 W (module)
measuring equipment operated offline with (battery) or (grid) connected	-
if UI: frequency of U/I curve recording	Sampling 1 sec, recording 1 min average
all the time operated at MPP (B1) or idle unless measuring U/I curve (B2)?	B1
Environmental influence measurable	
Driving rain / moisture ingress measurable?	No
Windload / Windproofness / Windsuction measurable?	Wind speed and direction measured with anemometer
Hail impact measurable?	No
Snowload measurable?	No
Thermal impact measurements	
Location of module temperature measurement? (where? at module frontsurface / module backsurface / if ventilated - air temperature on module backside)	Temperature sensor attached to backside of modules

7 Other R&D facilities

7.1 Labs for BIPV/PV module manufacturing and/or performance testing

AIT

PV precision laboratory with Module flasher and solar simulator. PV optical laboratory with EL and PL.

CEA-INES

The PV module lab focuses on module design and material selection, manufacturing processes (cell lamination & interconnection), evaluation of performance and reliability, durability and failure analysis. The group is equipped with a pilot line for pre-industrial prototyping of up to 15 modules/hour.

CENER

The PV modules testing lab at CENER is equipped with EL, thermographic cameras, pulse simulator and steady-state simulator.

Concordia University

Steady-state solar simulator for testing PV, BIPV and BIPVT/air modules as well as solar thermal air or water collectors. Two-level environmental chamber with a mobile solar simulator lamp that can be used to test building components under controlled conditions.

CSTB

Assessment of efficiency, and LID or PID.

Danish Technological Institute

Side by side performance test platforms. Long term monitoring including field test equipment. PV/thermal collector testing on an outdoor test rig.

CIEMAT

Laboratory equipped with indoor climatic chambers (damp heat, thermal cycling, soil fog chambers, UV chamber), thermographic cameras, pulse simulator and steady-state simulator.

ECN Petten

R&D module lab and pulse solar simulator. BIPV element lab (BEL) for creation of BIPV components in R&D.

Enerville

Vito: electrical test labs for grid studies, district level design of electrical and thermal systems.
KU Leuven: power electronics design and prototyping.

EURAC

Indoor solar simulator.

FRAUNHOFER ISE

CalLab PV cells: certified efficiency measurements, calibration etc. CalLab PV modules: power rating, angular response measurements (IEC 61853); low light behavior, temperature coefficients etc. New BSDF measurement device for optical characterization of advanced surfaces and anti-glare analysis. Devices for microstructural analysis: scanning electron microscopes, atomic force microscopes and Auger spectrometry (for depth profiles of surfaces) g value tracker: parallel measurement of IV curves and g value (including sun tracking).

IMEC

PV module assembly up to 60 x 60 cm and PV characterization tools.

IRESEN

Thin film cell lab for producing thin film cells for BIPV.

Natural Resources Canada

A large area pulse solar simulator.

OFI

Adhesive and coating laboratory, spectroscopy (IR, Raman, UV-VIS) and thermography, mechanical testing equipment.

SP Sweden

Steady state solar simulators. PV precision laboratory with Module pulse and steady state solar simulator, hotbox for (Dynamic) U-value determination.

SUPSI

Two different pulse solar simulators, steady state and UV solar simulator.

TECNALIA

Laboratory for photovoltaic modules manufacturing and a laboratory for photovoltaic components characterization: UV-Vis-NIR spectrophotometer with integrating sphere, External Quantum Efficiency measurement, solar cells tester, solar simulator, FTIR, RAMAN, SEM, AFM, optical microscopy and EL. Development and evaluation tools for MPPT algorithms: solar simulator, simulators of photovoltaic field and control software.

7.2 Testing of PV and BIPV components (compliant with norms)

AIT

PV laboratory. Environmental simulations laboratory with five climate chambers.

BBRI

Wind resistance and mechanical tests.

CENER

Accelerated weathering with three climate chambers. UV exposure chamber with temperature control. Mechanical testing and electrical safety tests.

CIEMAT

PV modules testing Laboratory. Indoors: solar simulators for I-V curves at different levels of irradiance and temperatures, electrical isolation dry and wet tests, PID tests, spectral optical reflectance and transmittance, electroluminescence, IR thermography, climatic chambers. Outdoors: power rating, I-V curves, NOCT and NMOT, angular response.

CSTB

Determination of reliability and durability.

Danish Technological Institute

Outdoor IV curve measurement

ECN Petten

Climate chambers and equipment for reliability testing.

Energyville

Univ Hasselt: Mechanical and electrical reliability testing (climate chambers). Indoor climate chamber with illumination, adhesion and stress testing, soldering, welding and cabling of modules.

EURAC

“SoLaRE PV Lab” (PV characterization) with climatic chambers also for BIPV testing. “INTENT Lab” - INtegrated Energy walls (active/multifunctional envelope characterization, e.g. BiPV and BiST): Double climatic chamber equipped with a dedicated sun simulator and hydraulic circuit.

FRAUNHOFER ISE

TestLab PV modules: certified IEC tests for PV modules (IEC 61646, IEC 61730, PID, degradation etc.). TestLab Power Electronics: e.g. conversion efficiency and MPPT efficiency tests for inverters.

Accredited R, T (including spectrally and angular resolved measurements), g value, U value measurements in the TestLab Solar Facades.

FRAUNHOFER IEE

Outdoor and Indoor Measurements of PV-Systems, PV-Modules and system components.

IMEC

Climate chambers.

OFI

Climate chambers (three in various sizes, one equipped with lamps to simulate sunlight). Xenon (simulation of sunlight) and UV-weathering systems. Corrosion testing (salt mist, condensed water chambers, kesternich chamber (SO2), corrosive gas (e.g.ammonia)- test chambers).

Sintef / NTNU

Laboratory for Climate Testing and Development of Building Envelopes: Nano Materials Development Laboratory, Advanced Spectrometer, Thermal Transport Laboratory, Climate Exposure Laboratory, Accelerated Climate Ageing Laboratory.

SP Sweden

Fully equipped lab for testing PV modules against IEC 61215 and 61730

SUPSI

Laboratory for photovoltaic modules system durability and performance testing: Mechanical, thermal and optical characterization. Certified Accredited lab for indoor and outdoor measurements.

TECNALIA

Laboratory for photovoltaic modules durability testing: UV chambers, climatic chambers, Kesternich test chambers, salt spray chambers. Laboratory for testing and certification of photovoltaic inverters.

8 Appendix A – Questionnaire 1

International Energy Agency
Photovoltaic Power Systems Programme

Please fill in only the yellow fields (instructions to be found in the comments at each cell)

1. Organisation	
Research group	
Research team leader	
Number of researchers in the research team	
Number of researchers in the research team working on BIPV	
Number of FTE in the research team working on BIPV	

2. Description

Please describe the BIPV related research questions, that your team focuses on

Please indicate the relative importantce of the following BIPV related research topics in your team (should add up to 100%)

Market studies of BIPV (available products, market success factors, market drivers, market forecasts)	0%
Product development and technical design of BIPV products	0%
Testing of BIPV products against building norms and against PV norms (climate chamber testing, mechanical testing etc)	0%
Field testing (outdoor) of BIPV (performance ratio, performance in pilots, temperature aspects, etc)	0%
Architectural and esthetical aspects of BIPV	0%
Social aspects of BIPV (acceptance in the market, acceptance in society, acceptance barriers and strategies)	0%
Economical aspects of BIPV (cost price, cost price roadmaps, business models, business cases)	0%
Electrical system solutions for BIPV	0%
Other research topics related to BIPV	0%
Total should be 100%	0%

3. Facilities

Please describe the R&D facilities specific for BIPV that your research group has (laboratories, test facilities, pilot areas, ...)

4. Publications

Please list relevant publications on BIPV research from your team (maximum 5 publications)

9 Appendix B – Questionnaire 2

PVPS TASK 15; SUBTASK E ; E 2.2 Analysis of the test methodology of outdoor test sites	
GENERAL INFORAMTION	
Location of the testsite:	
Name of the research Insitution:	
Name of the person in charge:	
Contct data (mail):	
Country:	
City / ZIP Code:	
Climate Zone	
TEST FACILITY	
Total size of testing area	
	[m]
max. length	
max. width	
orientation S/E/W/N	
shading effects	
Incliniation of the tested modules (fixed/moveable / Degree)	

TEST -MODULES	
BIPV testmodule size applicable	
	[m]
max. length	
min. length	
max. width	
min. width	
Type of BIPV testmodul applicable	
crystalline	
thin film	
type of BIPV: facade (Warm facade / Cold façade - ventilated?)/ roof (roof Integration /	
supplementary irradiation measurements in modul plane performed?	

CLIMATE DATA			
monitoring of the climatic conditions			
Please indicate with yes or no		**Additional information:**	
air temperature		type of temp.measure used	
solar irradiance		type of pyranometer used	
wind velocity		type of anemometer	
wind direction			
relative humidity			

ELECTRICAL MESUREMENTS			
Connection and measurment points		**Additional information:**	
max. number of connection points		frequency of MPP recording?	
number of independent measurment points		measuring equipment operated offline with (battery) or (grid) connected	
Please indicate with yes or no		if UI: frequency of U/I curve recording	
inverters available ?		all the time operated at MPP (B1) or idle unless measuring U/I curve (B2)?	
operated at AC-inverter (AC-grid connection and commercial MPP-tracker assumed) (A)?		Maximum stand alone recording period?	
MPP tracking possible?		Recording includes time of day?	
Operated at a DC dump load (with experimental MPP tracking system) (B)?		Number of serially connected cells in measured array (MIN/MAX)	
Measurement of U/I curve possible (UI)?		Array current limit (MIN/MAX)	
Measurement of Power at MPP possible?		Array power limit (MIN/MAX)	

PHYSICAL MEASUREMENTS		
Environmental influence measureable		**Additional information:**
Driving rain / moisture ingress measureable?		
Windload / Windproofness / Windsuction measurable?		
Hail impact measurable?		
Snowload measurable?		
Thermal impact measurements		
Location of module temperature measurment? (where? at module frontsurface / module backsurface / if ventilated - air temperature on module		

10 Appendix C – Questionnaire 3

Indoor R&D facilities – Table 1

Testing and performance requirements	R&D facilities - Indoor										
	AIT - Austrian Institute of Technology (AT)	University of Applied Science Upper Austria, F&E GmbH (AT)	OFI - Österreichisches Forschungsinstitut (AT)	Energyville (BE)	Natural Resources Canada (CA)	Concordia University (CA)	Technical University of Denmark (DK)	Danish Technological Institute (DK)	CEA-INES (FR)	CSTB (FR)	Fraunhofer ISE (DE)
Electrical properties and performance (e.g. maximum power, temperature corefficients, light-soaking, hot-spot test and more)	A, B, C, D, E	A, B, C, D, E	_	A, B, C, D, E	A, B, C, D, E	A, B, C, D, E	A, B, C, D, E	-	A, B, C, D, E	A, B, C, D, E	A,B,C,D,E
Energy economy and heat retention (e.g. luminous and solar characteristics, g-value, U-value and more)	-	A, B, C, D, E	_	-	-	A, B, C, D, E	-	C,D	A, B, C, D, E	A, B, C, D, E	A,B,C,D,E
Durability/Reliability (e.g. PID durability, thermal cycling damp-heat, Influence of module temperature rise, and more)	A, B, C, D, E	-	A,B, C, D, E	A,B,E	-	-	-	C,D	A, B, C, D, E	A, B, C, D, E	A,B,C,D,E
Mechanical resistance and stability (e.g. mechanical load, structural design requirements, ball drop test, pendulum test, hail test and more)	A, B, C, D, E	-	_	A,B,E	-	-	-	A,B,C,D	A, B, C, D, E	A, B, C, D, E	-
Safety in use (e.g. basic electrical safety, falling of module or parts, wind load resistance, wet leakage current and more)	A, B, C, D, E	-	_	-	-	-	-	-	A, B, C, D, E	A, B, C, D, E	A,B,C,D,E
Safety in case of fire (e.g. fire resistance, reaction to fire tests, exposure to external fire, bypass diode thermal test, and more)	A, B, C, D, E	-	_	-	-	-	-	-	-	A, B, C, D, E	-
Hygiene, health and the environment (e.g. fire test, waterproofing, product requirements of metal roofing sheet and more)	A, B, C, D, E	-	_	A,B,E	-	-	-	-	-	A, B, C, D, E	-
Sustainable use of natural resources (e.g. deterioration of heat insulation property, generic and core sustainability rules and more)	-	-	_	-	-	-	-	-	-	A, B, C, D, E	-
Water tightness (e.g. water tightness, high temperature test)	A, B, C, D, E C, D	-	_	A,B,E	-	A, B, C, D, E	-	A,B,C,D	-	A, B, C, D, E	-
Air tightness (e.g. air tightness)	C, D	-	_	-	-	A, B, C, D, E	-	-	-	A, B, C, D, E	-
Protection against noise (e.g. airborne sound insulation)	A, B, C, D, E	-	_	-	-	-	-	-	-	A, B, C, D, E	-
Seismic resistance (e.g. peformance following replacement, cable soundness)	A, B, C, D, E	-	_	-	-	-	-	-	-	A, B, C, D, E	-
Other (e.g. various sizes of PV modules, bifacial PV modules, curved laminated PV glass and more)	A, B, C, D, E	A, B, C, D, E	A,B,C,D,E	A, B, C, D, E	-	-	-	-	A, B, C, D, E	A, B, C, D, E	-

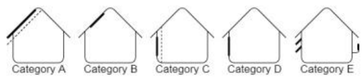
Note. The presence of a letter implies that the R&D facility could perform one or more tests under the specific "testing and performance requirement".
Categories A to E are defined based on EN 50583 Photovoltaics in Buildings standard as follows

Category A: Sloped, roof-integrated, not accessible from within the building
Category B: Sloped, roof-integrated, accessible from within the building
Category C: Non-sloped (vertically) mounted not accessible from within the building
Category D: Non-sloped (vertically) mounted accessible from within the building
Category E: Externally integrated, accessible or not accessible from within the building

Indoor R&D facilities – Table 2

Testing and performance requirements	R&D facilities - Indoor											
	EURAC (IT)	ENEA (IT)	University of Twente (NL)	SERIS (SG)	KCL(KR)	Tecnalia (ES)	CENER (ES)	CIEMAT (ES)	SUPSI (CH)	EMPA / ETHZ (CH)	EPFL / CSEM (CH)	Rise (Former SP) Research Institutes of Sweden (SE)
Electrical properties and performance (e.g. maximum power, temperature corefficients, light-soaking, hot-spot test and more)	A, B, C, D, E	A, B, C, D, E	A, C	B,D	A, B, C, D, E	A, B, C, D, E	A, B, C, D, E	A, B, C, D, E	A, B, C, D, E	-	A, B, C, D, E	A, B, C, D, E
Energy economy and heat retention (e.g. luminous and solar characteristics, g-value, U-value and more)	C,D,E	A, B, C, D, E	-	A,B,C,D	A, B, C, D	A,B, C, D, E	-	A, B, C, D, E	B, D	-	-	A, B, C, D, E
Durability/Reliability (e.g. PID durability, thermal cycling damp-heat, Influence of module temperature rise, and more)	A, B, C, D, E	A, B, C, D, E	A, C	B,D	A, B, C, D, E	A,B, C, D, E	A, B, C, D, E	A, B, C, D, E	A, B, C, D, E	-	A, B, C, D, E	A, B, C, D, E
Mechanical resistance and stability (e.g. mechanical load, structural design requirements, ball drop test, pendulum test, hail test and more)	-	A, B, C, D, E	A, C	B,D	A, B, C, D, E	A,B, C, D, E	A, B, C, D, E	A, B, C, D, E	A, B, C, D, E	A, B, C, D, E	A, B, C, D, E	A, B, C, D, E
Safety in use (e.g. basic electrical safety, falling of module or parts, wind load resistance, wet leakage current and more)	-	A, B, C, D, E	A, C	B,D	A, B, C, D, E	A,B, C, D, E	A, B, C, D, E	A, B, C, D, E	A, B, C, D, E	-	A, B, C, D, E	A, B, C, D, E
Safety in case of fire (e.g. fire resistance, reaction to fire tests, exposure to external fire, bypass diode thermal test, and more)	-	-	-	-	A, B, C, D, E	A,B, C, D, E	A, B, C, D, E	A, B, C, D, E	-	-	-	A, B, C, D, E
Hygiene, health and the environment (e.g. fire test, waterproofing, product requirements of metal roofing sheet and more)	-	-	-	-	-	A,B, C, D, E	-	-	-	-	-	A, B, C, D, E
Sustainable use of natural resources (e.g. deterioration of heat insulation property, generic and core sustainability rules and more)	-	-	-	-	-	-	-	-	-	-	-	-
Water tightness (e.g. water tightness, high temperature test)	-	-	-	-	A, B, C, D	A,B, C, D, E	-	A, B, C, D, E	-	-	-	A, B, C, D, E
Air tightness (e.g. air tightness)	-	-	-	A,B,C,D	A, B, C, D	A,B, C, D, E	-	-	-	-	-	A, B, C, D, E
Protection against noise (e.g. airborne sound insulation)	-	-	-	-	-	A,B, C, D, E	-	-	-	-	-	A, B, C, D, E
Seismic resistance (e.g. peformance following replacement, cable soundness)	-	-	-	-	-	A,B, C, D, E	-	-	-	-	-	-
Other (e.g. various sizes of PV modules, bifacial PV modules, curved laminated PV glass and more)	-	-	-	B,D	-	A,B, C, D, E	A,B, C, D, E	A, B, C, D, E	A, B, C, D, E	-	A, B, C, D, E	A, B, C, D, E

Note. The presence of a letter implies that the R&D facility could perform one or more tests under the specific "testing and performance requirement".
Categories A to E are defined based on EN 50583 Photovoltaics in Buildings standard as follows

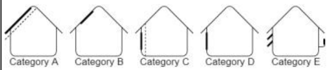


Category A: Sloped, roof-integrated, not accessible from within the building
Category B: Sloped, roof-integrated, accessible from within the building
Category C: Non-sloped (vertically) mounted not accessible from within the building
Category D: Non-sloped (vertically) mounted accessible from within the building
Category E: Externally integrated, accessible or not accessible from within the building

Outdoor R&D facilities – Table 1

Testing and performance requirements	R&D facilities - Outdoor												
	AIT - Austrian Institute of Technology (AT)	University of Applied Science Upper Austria, F&E GmbH (AT)	Energyville (BE)	Université Libre de Bruxelles, ATM Department (BE)	Natural Resources Canada (CA)	Concordia University (CA)	Technical University of Denmark (DK)	Danish Technological Institute (DK)	CEA-INES (FR)	CSTB (FR)	Fraunhofer ISE (DE)	Fraunhofer IEE (DE)	EURAC (IT)
Electrical properties and performance (e.g. maximum power, temperature corefficients, light-soaking, hot-spot test and more)	A, B, C, D, E	A, B, C, D, E	D	A, C, E	A, B, C, D, E	A, B, C, D, E	A, B, C, D, E	A,B,C,D,E	A, B, C, D, E	A, B, C, D, E	-	A,B	A, B, C, D, E
Energy economy and heat retention (e.g. luminous and solar characteristics, g-value, U-value and more)	-	A, B, C, D, E	D	A, C, E	-	C, D	-	A,B,C,D,E	A, B, C, D, E	A, B, C, D, E	A,B,C,D	A,B	C, D
Durability/Reliability (e.g. PID durability, Influence of module temperature rise, and more)	A, B, C, D, E	-	D	A, C, E	-	-	-	A,B,C,D,E	A, B, C, D, E	A, B, C, D, E	-	-	-
Mechanical resistance and stability (e.g. mechanical load, structural design requirements, ball drop test, pendulum test, hail test and more)	A, B, C, D, E	-	D	-	-	-	-	-	-	-	-	A,B	-
Safety in use (e.g. basic electrical safety, falling of module or parts, wind load resistance, wet leakage current and more)	A, B, C, D, E	-	-	-	-	-	-	-	-	-	-	-	-
Safety in case of fire (e.g. fire resistance, reaction to fire tests, exposure to external fire, bypass diode thermal test, and more)	A, B, C, D, E	-	-	-	-	-	-	-	-	A, B, C, D, E	-	-	-
Hygiene, health and the environment (e.g. fire test, waterproofing, product requirements of metal roofing sheet and more)	-	-	-	-	-	-	-	-	-	-	-	-	-
Sustainable use of natural resources (e.g. deterioration of heat insulation property, generic and core sustainability rules and more)	-	-	-	-	-	-	-	-	-	-	-	-	-
Water tightness (e.g. water tightness, high temperature test)	C, D	-	-	-	-	-	-	-	-	-	-	-	-
Air tightness (e.g. air tightness)	C, D	-	-	-	-	-	-	-	A, B, C, D	-	-	-	-
Protection against noise (e.g. airborne sound insulation)	A, B, C, D, E	-	-	-	-	-	-	-	-	-	-	-	-
Seismic resistance (e.g. peformance following replacement, cable soundness)	A, B, C, D, E	-	-	-	-	-	-	-	-	-	-	-	-
Other (e.g. various sizes of PV modules, bifacial PV modules, curved laminated PV glass and more)	A, B, C, D, E	A, B, C, D, E	-	A, C, E	-	-	-	-	A, B, C, D, E	A, B, C, D, E	-	-	-

Note. The presence of a letter implies that the R&D facility could perform one or more tests under the specific "testing and performance requirement".
Categories A to E are defined based on EN 50583 Photovoltaics in Buildings standard as follows



Category A: Sloped, roof-integrated, not accessible from within the building
Category B: Sloped, roof-integrated, accessible from within the building
Category C: Non-sloped (vertically) mounted not accessible from within the building
Category D: Non-sloped (vertically) mounted accessible from within the building
Category E: Externally integrated, accessible or not accessible from within the building

Outdoor R&D facilities – Table 2

Testing and performance requirements	R&D facilities - Outdoor														
	ENEA (IT)	SEAC (NL)	ZUYD (NL)	University of Twente (NL)	Utrecht University (NL)	University of Agder (NO)	SERIS (SG)	KNU(KR)	KCL(KR)	Tecnalia (ES)	CENER (ES)	CIEMAT (ES)	SUPSI (CH)	EMPA / ETHZ (CH)	Rise (Former SP) Research Institutes of Sweden (SE)
Electrical properties and performance (e.g. maximum power, temperature corefficients, light-soaking, hot-spot test and more)	A,B,C,D,E	A, B, C, D, E	A,B,C,D,E	A, B, C, D, E	A, B, C, D, E	C, E	A,B,C,D,E	A, B, C, D, E	-	A, B, C, D, E	A, B, C, D, E	A, B, C, D, E	A, B, C, D, E	-	A, B, C, D, E
Energy economy and heat retention (e.g. luminous and solar characteristics, g-value, U-value and more)	A,B,C,D,E	A, B, C, D, E	-	-	A, B, C, D, E	-	-	-	-	A, B, C, D, E	-	A, B, C, D, E	B, D	-	-
Durability/Reliability (e.g. PID durability, Influence of module temperature rise, and more)	A,B,C,D,E	A, B, C, D, E	A,B,C,D,E	-	A, B, C, D, E	-	A,B,C,D	-	-	A, B, C, D, E	A, B, C, D, E	A, B, C, D, E	A, C	-	-
Mechanical resistance and stability (e.g. mechanical load, structural design requirements, ball drop test, pendulum test, hail test and more)	-	A, B, C, D, E	-	-	-	-	-	-	-	-	A, B, C, D, E	-	-	A, B, C, D, E	-
Safety in use (e.g. basic electrical safety, falling of module or parts, wind load resistance, wet leakage current and more)	-	A, B, C, D, E	-	-	-	-	-	-	-	-	A, B, C, D, E	A, B, C, D, E	A, B, C	-	-
Safety in case of fire (e.g. fire resistance, reaction to fire tests, exposure to external fire, bypass diode thermal test, and more)	-	-	-	-	-	-	-	-	-	-	A, B, C, D, E	-	-	-	-
Hygiene, health and the environment (e.g. fire test, waterproofing, product requirements of metal roofing sheet and more)	-	A, B, C, D, E	-	-	-	-	-	-	-	-	-	-	A	-	-
Sustainable use of natural resources (e.g. deterioration of heat insulation property, generic and core sustainability rules and more)	-	A, B, C, D, E	-	-	-	-	-	-	-	-	-	-	-	-	-
Water tightness (e.g. water tightness, high temperature test)	-	A, B, C, D, E	-	-	-	-	-	-	C,D	-	-	A, B, C, D, E	A	-	A, B, C, D, E
Air tightness (e.g. air tightness)	-	A, B, C, D, E	-	-	-	-	A,B,C,D	-	C,D	-	-	-	-	-	A,B,C,D
Protection against noise (e.g. airborne sound insulation)	-	A, B, C, D, E	-	-	-	-	-	-	-	-	-	-	-	-	-
Seismic resistance (e.g. peformance following replacement, cable soundness)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other (e.g. various sizes of PV modules, bifacial PV modules, curved laminated PV glass and more)	A,B,C,D,E	A, B, C, D, E	A,B,C,D,E	-	A, B, C, D, E	-	A,B,C,D,E	-	-	-	A,B, C, D, E	A, B, C, D, E	A, B, C, D, E	-	-

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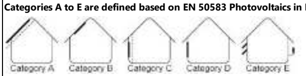

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For further information about the IEA – Photovoltaic Power Systems Programme and Task 15 publications, please visit www.iea-pvps.org.

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