Publishable Summary for 16ENG02 PV-Enerate
Advanced PV Energy Rating

Overview

The project provided metrological infrastructure, techniques and guidance to accelerate time-to-market for emerging photovoltaics (PV) technologies, which have the potential to significantly reduce the cost of photovoltaic energy.

The project had two main objectives: Firstly, to improve the PV energy rating standards and secondly, to improve the measurement equipment and methodologies to enable precise measurements of the parameters required for the energy rating.

Need

According to the United Nations Framework Convention on Climate Change COP 21 in Paris, anthropogenic greenhouse gas emissions must be reduced drastically. As direct combustion of fossil fuels is reduced, renewable energy sources will cover the energy needs to the greatest extent – directly in individual sectors such as heating or in the form of renewable electricity, particularly from wind and solar energy. It is estimated that by 2050, electricity will cover roughly 50 % of all our energy needs – compared with around 25 % today. Renewable electricity will increasingly be used as an energy source and will primarily use technologies that replace a large amount of fuel with a small amount of renewable electricity. To minimise costs of energy storage, around one third of the renewable energy will be produced by photovoltaics.

Currently PV modules are optimised, selected and sold on the basis of power produced under standard test conditions (STC), however this does not allow for differentiation according to the most relevant parameter in the marketplace which is energy production under specific climatic conditions. However, this metric does not always reflect real-world conditions as location-dependent variations in ambient temperature, irradiance, angle-of-incidence, spectrum and wind-speed cause deviations in annually averaged module efficiencies of up to 20 %. This impedes the uptake of emerging and innovative technologies, such as modules optimised for specific climates.

A new set of standards, IEC 61853 provides a framework for energy rating of PV, including measurement, modelling and reference meteorological data. This is an important first step towards universal energy rating of PV modules, however, stakeholders have identified a number of remaining challenges arising from emerging technologies and market trends:

- Bifacial modules claim to increase energy yields by 10 % - 20 % by harvesting light from the rear of the panel, yet investors are nervous about the lack of standard tests and rating methods,
- PV modules on buildings experience different operating conditions compared to ground-mounted PV and this is not reflected in the current documentary standards,
- Module characterisation requires the use of new technology (such as LED simulators) for fast and accurate characterisation at the module scale and to harmonise handling of test data in order to improve the uptake of energy rating,

Thus, precise metrology and realistic, representative standards for PV are required to support one of the most important future energy sources.

Objectives

The project extended the metric for an energy-based photovoltaic classification to roof-mounted photovoltaics as well as to the fast-growing fields of bifacial and building-integrated photovoltaics.

The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

The specific objectives of the project were:

1. To define and realise standard testing conditions for the measurement of the power or the short-circuit current of bifacial solar devices Different approaches for laboratory measurements and for production line measurements will be developed, realised, compared, selected and standardised. This will form the basis for the extended energy rating and the standardisation of measurement of bifacial solar devices.
2. To improve the method of uncertainty evaluation of the spectral mismatch correction in the calibration of solar devices when combining the spectral irradiance and spectral responsivity, taking the correlation of the spectral data into account.
3. To develop traceable measurement methods for extending energy rating to bifacial solar modules and to modules (bifacial or monofacial) applied to or integrated into buildings. This will include the definition of a harmonised data format for solar device properties, required for PV Energy rating measurement standards.
4. To enable instantaneous measurement of the spectral radiance of the complete sky for improved determination of real outdoor measurement conditions and the irradiance spectral-angular distribution by hyperspectral imaging.
5. To develop more accurate measurement methods for traditional and emerging solar modules, including the spectral responsivity of the complete module, fast linearity measurements for modules, angular dependency of modules, with an uncertainty of <1 % for the angular dependency impact, <3 °C for the nominal operating module temperature (NOMT), <1 % for the impact of spectral responsivity and <1 % for the impact of non-linearity.
6. To facilitate the uptake of the technology and measurement infrastructure developed in the project by the measurement supply chain (NMIs, calibration laboratories), standards developing organisations and end users (photovoltaics industry).

Progress beyond the state of the art

This project improved upon the most recently developed methods for the determination of the energy rating characteristics, yield prediction, and the energy rating of solar modules, which are currently not applicable to some emerging technologies such as bifacial solar modules and building-applied or -integrated photovoltaics (BAPV, BIPV). The existing methods and calculations do not take into account the irradiance that impinges on the rear side of the solar cell and thus are not applicable to bifacial solar devices.

Power rating measurements of bifacial solar devices have had deviations in excess of 10 % reported between ISO/IEC 17025 accredited laboratories. This compares to less than 2 % for conventional technologies. This project closed this uncertainty gap by establishing appropriate measurement standards and verified them by comparisons between the laboratories. (Objective1)

The spectral mismatch correction is one of the largest uncertainty components associated with the calibration of solar devices using solar simulators. At present only approximations for the uncertainty calculation of the spectral mismatch factor exist. The calculation method for the spectral mismatch was extended to bifacial solar devices (cells and modules), taking into account both the front and rear spectral responsivities, and the correlation between spectral responsivity and spectral irradiance. (Objective 2)

Building integrated photovoltaics (BIPV) are becoming a more common installation mode, but complex urban environments and interaction with the building envelope require better consideration of the albedo component and thermal operating conditions. PV-Enerate adapted the methods included in the IEC 61853 standards to deliver all data required for the yield prediction in a BIPV or BAPV mode. (Objective 3)

Standardisation technical committees have identified that the nominal operating module temperatures (NOMTs) of solar modules are difficult to determine and that results from the outdoor method are highly site dependent. For this reason, a comprehensive analysis of the effects was performed. The project tried to compare data from the world's most advanced facility for simultaneous measurement of sky spectra from over 100 different directions, using a hyperspectral imaging approach, with the approach of scanning one direction after the other, just developed in the previous EMRP project ENG55 PhotoClass. (Objective 4)

Advanced metrology for the characterisation of solar modules was developed as part of this project. One example for such development is a non-destructive method for the fast measurement of current-voltage (IV) characteristics of each solar cell within a module using digital light projection and other modulation techniques. Another was the setting up and application of one of the first LED-based solar simulators worldwide for modules (incorporating more than 16000 LEDs in total, of 18 different types), which was used for the realisation of the different radiation conditions experienced by a PV module across a typical year of operation and the comprehensive characterisation of modules as required for the energy rating. (Objective 5). An LED based module solar simulator has been built at PTB and is currently being characterized. It significantly extends the measurement possibilities that can be obtained by use of state-of-the-art sun simulators that are use flashing Xe bulbs.

Results

To define and realise standard testing conditions for the measurement of the power or the short-circuit current of bifacial solar devices Different approaches for laboratory measurements and for production line measurements will be developed, realised, compared, selected and standardised. This will form the basis for the extended energy rating and the standardisation of measurement of bifacial solar devices.

Several recommendations for the measurement of bifacial solar devices have been submitted, mainly within discussions during the IEC TC82-WG2 meetings. The main issues being recommended by members of the PV-Enerate consortium are use of different background colours (grey and as black as possible) to enable an extrapolation to completely black background without interreflections. The second issue put forward by the consortium is the addition of a two light-source method (illumination of front side and back side) that can be used in addition to the previously favoured one light source method with increased light power. The two light-source method realizes more realistic test conditions and does not need overpowering of the light source for the front side. The IEC TS 60904-1-2 “Photovoltaic devices - Part 1-2: Measurement of current-voltage characteristics of bifacial photovoltaic (PV) devices” was published as a technical specification at 2019-01-29. Many new installations are using the two light-source method propagated by the project team. Within the project a comparison between different members of the consortium and stakeholders / collaborators were successfully performed. This objective was successfully achieved.

To improve the method of uncertainty evaluation of the spectral mismatch correction in the calibration of solar devices when combining the spectral irradiance and spectral responsivity, taking the correlation of the spectral data into account.

All involved project partners worked on different new realisations for the uncertainty calculation of the spectral mismatch. Those realisations result in uncertainties between 0.05% to 0.8%. PTB provided a set of spectral responsivity curves with low uncertainty as base data for testing the algorithms. An internal workshop “Measurement uncertainties of the spectral mismatch correction” took place to compare the results of the partners which was held one day before the project meeting in December 2018. As a result, from this workshop a comparison between the different realisations took place. This comparison of uncertainties calculations based on the same input data. A general guideline that describes the implementation of measurement uncertainties including correlations in spectral mismatch calculations was developed and published as open access together with the source code of an implementation as open source / open data. The approach derives an Ishikawa diagram that includes all possible sources of uncertainties. It finds a (simplified) model equation for each source of uncertainty that is quantitatively reasonable and that allows Monte Carlo methods to propagate correlations correctly. It provides all relevant information and guidelines on how to experimentally determine correction factors and uncertainties. For illustration it demonstrates the procedure on a typical example. This objective was successfully achieved.

To develop traceable measurement methods for extending energy rating to bifacial solar modules and to modules (bifacial or monofacial) applied to or integrated into buildings. This will include the definition of a harmonised data format for solar device properties, required for PV Energy rating measurement standards.

An extension of the IEC 61853 standard series for the energy rating of bifacial modules has been described. All 4 parts of IEC 61853 will need to be modified for application to bifacial modules. The proposed extension aims to follows as much as possible the philosophy of the existing standard, while the changes that would be necessary are summarised below.

Part 1: Power matrix with Equivalent Irradiance and Bifaciality Factor. The required maximum irradiance will increase, depending on mounting condition and the albedo chosen. A strong assumption about the uniformity of the rear side irradiance has been made. This may tend to over-estimate the bifacial gain that would be experienced in a real system, and this may be compensated in the tabulated rear side irradiance values by defining lower values.

Part 2: SR and AOI (ar) of the rear side should be measured. The methodology of NMOT measurement most likely will need to be adjusted to the appropriate operating conditions, considering also heating from both sides.

Part 3: Additional calculation steps are required, principally to obtain the equivalent irradiance by summing front and rear side contributions. If the proposed rooftop configuration is to be rated at different elevation above ground than the one considered in the existing standard (2m), this will require an additional step to calculate the wind speed at the defined rooftop height.

Part 4: New hourly data per climatic dataset may be generated using a transposition or other model.

Transposition models (analogous to those used to create the current mono-facial Part 4 datasets) have been implemented to create additional datasets for three of the standard reference climatic profiles. These datasets are used to simulate the full energy rating procedure.

The performance characteristics (c.f. parts 1 and 2 of IEC 61853) of two real c-Si modules have been used to generate two representative bifacial modules, both having a bifaciality of 90%.

The proposed new calculation steps in part 3 of IEC 61853 have been implemented in software and have been used to calculate CSER values for the different bifacial mounting cases for both c-Si modules in order to validate the approach used.

The results show significant differences between the calculated CSER values, between different module types, between different bifacial configurations, and between the mono-facial and bifacial configurations. This suggests that the proposed modifications could usefully help end-users evaluate and select appropriate bifacial modules with the relevant mounting configuration and climatic profile appropriate to their intended use.

An extension of the IEC 61853 standard series for the energy rating of BIPV/BAPV modules has been described, too. It requires changes in different parts of the energy rating standards series IEC 61853. Part 1 must be extended as BIPV modules reach higher temperatures than standard modules. In Part 2 the mounting conditions for BIPV modules must be added to enable comparability between different manufacturer. In part 4 of the IEC 61853 series additional BIPV/BAPV specific scenario for a PV façade would be useful, especially the consideration of a higher wind speed at elevations above ground level, which would simply define the roof elevation of the system, but would not require any further data. The standard data set is limited to 20° equator facing open-rack mounted modules. The data set can be applied for roof mounted modules, but not for façade modules. A façade element is subject to lower irradiances, higher angle of incidences and back-side ventilation.

This objective was successfully achieved.

To enable instantaneous measurement of the spectral radiance of the complete sky for improved determination of real outdoor measurement conditions and the irradiance spectral-angular distribution by hyperspectral imaging.

The intercomparison of spectral sky radiance measurements has been completed in Summer 2019. The comparison took place at the roof of LUH. Two different measurement facilities were compared. One portable sky-scanning facility of PTB scanned the sky direction by direction within 30 minutes and measured at all direction the spectral radiance. The AMUDIS facility of LUH measured the spectral sky radiance of nearly 150 directions simultaneously. The evaluation of the scanning facility has been finished. The evaluation of the measurements with the AMUDIS unfortunately failed within the extended project time due to the complexity of the measurement and evaluation process. Thus, at the current stage of development the AMUDIS cannot be recommended for the spectrally and angularly resolved measurement of the irradiance or the spectral radiance of the sky. Despite the limitations regarding the simultaneity of the measurements, only PTB's scanning system can be recommended at this time. This objective was partly successfully achieved. The direct comparison of the two methods were not successful, nevertheless a recommendation concerning the methods can be given.

To develop more accurate measurement methods for traditional and emerging solar modules, including the spectral responsivity of the complete module, fast linearity measurements for modules, angular dependency of modules, with an uncertainty of <1 % for the angular dependency impact, <3 °C for the nominal operating module temperature (NOMT), <1 % for the impact of spectral responsivity and <1 % for the impact of non-linearity.

PTB, TUBITAK, TÜV Rheinland, SUPSI and LU of this consortium improved and extended their portfolio of calibration methods necessary for Energy Rating concerning GT-Matrix, AOI, NMOT, SR and Non-linearity or a part of it. In the publishable summary a detailed list of the current calibration services provided by the individual members is given. This objective was successfully achieved.

Impact

A number of 20 articles including 10 peer-reviewed journal publications have been written in order to disseminate the outputs of the project.

Partners had 38 presentations including 10 poster presentations at international conferences where the project and its preliminary results were presented. The topic of advanced energy rating was presented at a parallel event to the EUPVSEC conference in September 2018. A minimum of 50 attendees were present from PV research and test laboratories, manufacturers of advanced PV and BIPV products, consultancies and software producers. The event was advertised via the EURAMET website.

The E-Learning has been setup by NPL with a training course featuring 9 detailed articles in 3 modules on metrology for energy rating of photovoltaics and has been made public. A link from the PTB hosted project site to the E-learning system of NPL is given. It is intermediate level.

The project homepage has a blog about PV metrology for energy rating with 12 articles. The name of the course is “PV Module Performance Measurements and Energy Rating”

SUPSI carried out a session at the Monitoring and simulation of the performance and reliability of photovoltaics in the built environment training school from 23-26 October 2018. The school focused on the special requirements and challenges of integrating PV into the built environment and grids, with a focus on the determination and prediction of performance and reliability. School trainees (students, researchers, educators and practitioners) participated in expert lectures, interactive seminars and practical courses.

The 80th IEC TC82 WG2- meeting “Solar photovoltaic energy systems - Modules, non-concentrating” with 108 registrations was organised and hosted by PTB. Not only fruitful discussion about the development of international PV standards have taken place, but also the results of the EMPIR project PV-Enerate could be presented during the laboratory tours to the participants, e.g. the LED-based solar simulator with more than 16.000 LEDs of 18 different spectra for accurate solar module calibrations.

TÜV Rheinland hosted the “PV Module Forum” with more than 100 external European participants from industry, that included a full session “Advanced PV Energy Rating” with 5 presentations from the PV-Enerate project.

In addition, the project results were shown at the PTB boost at the Hannover Messe 2019.

Impact on industrial and other user communities

Designers, manufacturers and end users of PV technology will benefit from the capabilities and outputs developed by the project. The extension of the IEC 61853 energy rating standards developed by the project, and the capacity to measure PV devices according to the new standards will benefit industry by enabling a fair and impartial intercomparison between different technologies.

The achieved faster and more accurate characterisation of PV cells and modules will enable manufacturers to better optimise their products for real applications and locations. The provision of accurate measurement data on BIPV and bifacial modules, as well as comprehensive indoor/ outdoor measurement comparisons will benefit the software used for the design and monitoring of PV installations, hence improving the accuracy of energy yield estimates from PV technology. The suggested common data format for module energy rating developed by the project can be implemented into commercial modelling software thus reducing barriers to collecting, sharing and implementing advanced module characterisation data. Uptake of new measurement standards will reduce the uncertainty in energy yield estimates at the planning stage of a PV project, provide technological solutions to reduce the costs of acquiring such data and encourage rapid uptake of energy rating measurements. Finally, customers will benefit from accurate validated energy rating standards and validated software to inform decisions on choice of technology and optimise system design, delivering more clean energy and better return on investment.

Impact on the metrology and scientific communities

New and improved measurement capabilities are available within the NMIs/DIs to support the adoption of the new standard test conditions for bifacial PV devices according to the new IEC 61853 standards. Documented calibration methods for more accurate determination of PV module power output are available. Two organisations have new capability to measure the operating temperature of modules as a function of wind-speed, which is currently a significant source of uncertainty in module energy rating and this will lead to more accurate determination of the relevant coefficients. Adoption of the common data format for reporting and sharing module energy rating measurements will reduce the complexity and costs for customers of energy rating measurements and lead to more efficient implementation into end users' models. New measurement facilities, such as LED-based spectral responsivity, LED solar simulator and instrumentation for structure light sources will contribute to improved understanding of the properties and loss mechanisms of new solar technologies.

Impact on relevant standards

Recommendations were submitted to project IEC 60904-1-2 on two different methods to extend the standard test conditions (STC) for bifacial solar devices together with a draft annex providing guidelines for the measurements of bifacial modules required for the energy rating standard IEC 61853. Guidelines on extending the energy rating model and reference conditions to include bifacial PV and PV on buildings were presented during a IEC TC 82 WG 2 meeting and a written technical report distributed afterwards. In the report the required extension of IEC 61853-3 & -4 was demonstrated. It could be shown that the reproducibility of the nominal operation module temperature (NOMT) measurement method described in IEC 61853-2 and required by IEC 61215 is a significant source of uncertainty in predicting the energy yield of PV modules. A member of the consortium took over the leadership in the IEC TC 82 standardisation project for an amendment proposed to IEC 61853-2.

Longer-term economic, social and environmental impacts

To achieve the target, increase in photovoltaics as a source of electricity requires a large Europe-wide increase of PV installations by several 100 GW, with an associated investment cost of several 100 billion Euro. Thus, every percent measurement uncertainty in energy yield estimation leads to a financial uncertainty of several billion Euros. The techniques and standards developed in the project will enable a more precise classification of the expected energy output from different emerging PV technologies such as building-applied and building-integrated PV, based on realistic operational conditions. This will enable, for example, a seamless integration into smart grids through the accurate calculation of the power contribution dependent on the time of day and weather conditions, providing better security of supply. It will also enable more reliable requirements for power control, reducing balance-of-system costs and, most importantly, enable a much-improved forecasting of solar yield. Without the latter, significant percentages of generated electricity may be lost as the distribution infrastructure is not in a state to accept injection from this energy source and it is instead dumped to ensure stability of the power network.

List of publications

[1] G. Koutsourakis, M. Bliss, T.R. Betts, R. Gottschalg, Utilising Digital Light Processing and Compressed Sensing for Photocurrent Mapping of Encapsulated Photovoltaic Modules. *Proceedings of EUPVSEC* (2018), https://doi.org/10.4229/35thEUPVSEC20182018-5BO.11.6 https://zenodo.org/record/4055644#.X3HNZWhKi70

[2] R. P. Kenny, E. Garcia Menendez, J. Lopez-Garcia, B. Haile, Characterizing the operating conditions of bifacial modules. *AIP Conference Proceedings 1999, 020014 (2018)* (2018), https://doi.org/10.1063/1.5049253 https://aip.scitation.org/doi/10.1063/1.5049253

[3] J. Lopez-Garcia, A. Casado, T. Sample, Electrical performance of bifacial silicon PV modules under different indoor mounting configurations affecting the rear reflected irradiance. *Solar Energy*. **177**, 471–482 (2019), https://doi.org/10.1016/j.solener.2018.11.051

[4] E. Salis *et al.,* Results of four European round-robins on short-circuit current temperature coefficient measurements of photovoltaic devices of different size. *Solar Energy*. **179**, 424–436 (2019), https://doi.org/10.1016/j.solener.2018.10.051 https://dspace.lboro.ac.uk/dspace-jspui/handle/2134/34784
[5] G. Koutsourakis, M. Bliss, T.R. Betts, R. Gottschalg, Accessing the Performance of Individual Cells of Fully Encapsulated PV Modules Using a Commercial Digital Light Processing Projector. *PVSAT proceedings* (2018), http://dx.doi.org/10.1109/JPHOTOV.2019.2933190
[6] H. Baumgartner, B. Oksanen, P. Kärhä, E. Ikonen, Optical Characterization of III-V Multijunction Solar Cells for Temperature-Independent Band Gap Features. *IEEE Journal of Photovoltaics*. **9**, 1631–1636 (2019), https://doi.org/10.1109/JPHOTOV.2019.2933190
[7] J. C. Blakesley *et al.,* Accuracy, cost and sensitivity analysis of PV energy rating. *Solar Energy*. **203**, 91–100 (2020), https://doi.org/10.1016/j.solener.2020.03.088
[8] P. Kärhä *et al.,* Measurement setup for differential spectral responsivity of solar cells. *Optical Review* (2020), https://doi.org/10.1007/s10043-020-00584-x
[9] C. Schinke, M. Franke, K. Bothe, S. Nevas, Implementation and uncertainty evaluation of spectral stray light correction by Zong's method. *Applied Optics*. **58**, 9998 (2019), https://doi.org/10.1364/AO.58.009998
[10] G. Koutsourakis, J. C. Blakesley, F. A. Castro, Signal Amplification Gains of Compressive Sampling for Photocurrent Response Mapping of Optoelectronic Devices. *Sensors*. **19**, 2870 (2019), https://doi.org/10.3390/s19132870
[11] F. Bausi, G. Koutsourakis, J. C. Blakesley, F. A. Castro, High-speed digital light source photocurrent mapping system. *Measurement Science and Technology*. **30**, 95902 (2019), https://doi.org/10.1088/1361-6501/ab1f40
[12] C. Schinke *et al.,* Calibrating spectrometers for measurements of the spectral irradiance caused by solar radiation. Metrologia (2020), https://doi.org/10.1088/1681-7575/abafc5
[13] F. Plag, PhD thesis, Integral methods of measurement for photovoltaics. *TU Braunschweig,* https://doi.org/10.7795/110.20200615
[14] Sträter, Hendrik; Riechelmann, Stefan; Neuberger, Frank; Winter, Stefan, LED-Based Differential Spectral Responsivity Measurements of PV Modules. *https://www.eupvsec-proceedings.com/proceedings* (2019) https://zenodo.org/record/3784708
[15] S. Riechelmann, Characterizing the Angular Distribution of an LED-Based Solar Simulator for PV Modules. *https://www.eupvsec-proceedings.com/proceedings* (2019) https://zenodo.org/record/3784748
[16] S. Riechelmann, H. Straeter, S. Winter, Determination of a PV module power matrix with an LED solar simulator. *EUPVSEC-proceedings* (2020) https://zenodo.org/record/4049818
[17] J. C. Blakesley, G. Koutsourakis, Energy Rating for Evaluating Performance of Perovskite and Perovskite-on-Silicon Tandem Devices in Real-World Conditions. *Proceedings of EUPVSEC (*2019), http://doi.org/10.4229/EUPVSEC20192019-3CO.6.2 https://zenodo.org/record/4055579#.X3HLCGhKi70
[18] G. Koutsourakis *et al*., Results of the Bifacial PV Cells and PV Modules Power Measurement Round Robin Activity of the PV-Enerate Project. *Proceedings of EUPVSEC* (2020), http://doi.org/10.4229/EUPVSEC20202020-4CO.2.2 https://zenodo.org/record/4055707#.X3Hc1WhKi70
[19] J. C. Blakesley *et al*., Effective Spectral Albedo from Satellite Data for Bifacial Gain Calculations of PV Systems. *Proceedings of EUPVSEC* (2020), http://doi.org/10.4229/EUPVSEC20202020-5CO.9.3 https://zenodo.org/record/4055920#.X3HfPGhKi70
[20] G. Koutsourakis, T. D. Eales, I. Kroeger, J. Blakesley, High resolution linearity measurements of photovoltaic devices using digital light processing projection. *Measurement Science and Technology* (2021), https://doi.org/10.1088/1361-6501/abe162 https://iopscience.iop.org/article/10.1088/1361-6501/abe162/meta

This list is also available here: https://www.euramet.org/repository/research-publications-repository-link/

Project start date and duration:	01 May 2017, 41 months	
Coordinator: Dr. Stefan Winter Physikalisch-Technische Bundesanstalt (PTB), Tel: +49 531 924 140 E-mail: Stefan.Winter@ptb.de Project website address: www.pv-enerate.ptb.de		
Internal Funded Partners: 1 PTB, Germany 2 Aalto, Finland 3 INTA, Spain 4 LNE, France 5 NPL, United Kingdom 6 TUBITAK, Turkey	External Funded Partners: 7 FhG, Germany 8 ISFH, Germany 9 JRC, Belgium 10 LU, United Kingdom 11 LUH, Germany 12 TÜV Rheinland, Germany	Unfunded Partners: 13 SUPSI, Switzerland
RMG1: IMBiH, Bosnia and Herzegovina (Employing organisation); PTB, Germany (Guestworking organisation)		