PROJECT FINAL REPORT

Project Acronym:	PERFORMER
Project Full Title:	Portable, Exhaustive, Reliable, Flexible and Optimized appRoach to Monitoring and Evaluation of building eneRgy performance
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1 FINAL PUBLISHABLE SUMMARY REPORT

1.1 EXECUTIVE SUMMARY

The aim of PERFORMER is to reduce the gap between expected and actual building energy performance through the development of innovative, scalable and replicable solutions to assess, monitor and ensure continuous (and optimal) management and guarantee of building energy performance. The translation of this global aim into a series of scientific and technical objectives has led to the development of a prototype technology platform and a suite of innovative tools and methodologies which have been deployed and tested at four pilot sites in the UK, France, Spain and Poland. Identification of energy saving opportunities at the pilot buildings offers the possibility to close the performance gap, thus reducing energy consumption and associated CO_2 emissions. As Buildings are responsible for 40% of energy consumption and 36% of CO2 emissions in the EU the deployment of PERFORMER across the EU presents significant economy of scale opportunities.

The demonstration and assessment phases have highlighted the technical challenges and opportunities for replicating a common solution across a range of different building types throughout the EU. The main results of the project that are most likely to be exploited by the project partners have been described. Many of these can be exploited in the short term, including some that will be usable at the end of the project, whilst others are more technologically challenging and will require further work to become usable and marketable. In terms of impact, it has been shown that the PERFORMER solution has the potential to assist building owners and managers to optimise their assets, while also supporting energy consultants and energy service providers (i.e. ESCOs) to deliver energy management opportunities to their clients. In addition, some results relating to the in-situ assessment of building envelope performance have been fed into on-going standardisation work.

Workshops involving external representatives from industry have been held to discuss the market potential for the PERFORMER solution. These have identified positive impacts in the PERFORMER solution's differentiating features and confirmed areas of innovation. Outputs from workshops have been used to steer the development of the final business model and a replication strategy to roll out the solution across the EU. The business model capitalises on the technical advancements of PERFORMER compared to existing tools and will target building owners and managers as well as carefully selected professionals from the construction and services sector (e.g. ESCOs) to support and promote the implementation of PERFORMER. It has been shown that the retrofit market is likely to be the best target audience to get the most from the solution and different 'levels' of offering will allow the solution to be competitive amongst the range of energy management tools already on the market.

The new service concept that PERFORMER vehicles through its integration framework can act as a spring board for energy reduction and as such has a huge potential for impact in the European Construction and energy sectors.

1.2 PROJECT CONTEXT AND OBJECTIVES

1.2.1 Context

Global warming has drastically increased the pressure to reduce energy use in buildings. In the EU, energy from the built environment represents more than 40% of Europe's energy and CO2 emissions. The European Commission has defined a clear 2020 target to reduce energy consumption and the CO_2 emissions by 20%, while increasing renewable energy generation by 20%. These objectives have been translated into stringent regulations and policies at the European and National levels. For instance, the recast of the Energy Performance of Buildings Directive (2010/31/EU) imposes stringent requirements in terms of energy efficiency for new and retrofitted buildings.

A significant number of buildings at a European level are directly impacted by these regulations and policy enforcements. Nevertheless, despite an increased awareness and engagement of building stakeholders, the monitoring of actual energy performance consistently reveals significant discrepancies between energy design targets and real consumption once a building is occupied. Hence, building performance optimisation remains an important challenge faced by the building energy value chain. In fact, this major barrier hinders the achievement of the aforementioned EU targets for a sustainable future.

Actual energy performance of buildings is not an issue restricted to the operational phase and has to be considered as the result of an entire process from pre-design through to de-commissioning. Energy performance targets are defined very early in a building's life-cycle and in a large majority of cases, a significant gap between expected and actual energy performance exists. This gap, as illustrated in **Figure 1**, can be explained by a wide range of factors that seem to increase throughout the building life-cycle.

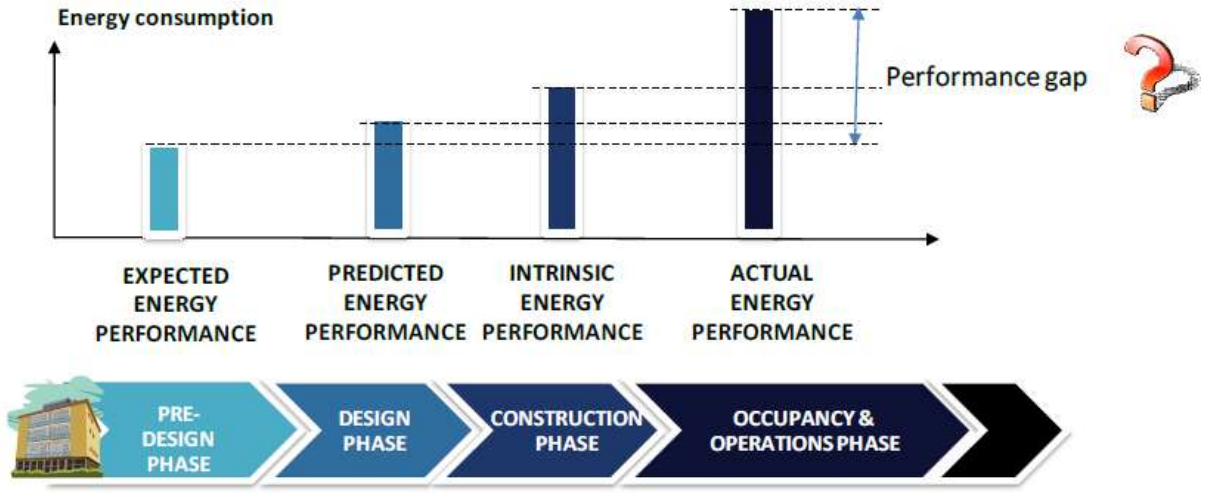

Figure 1 – Factors explaining the performance gap throughout the life-cycle

The actual energy performance of a building can be considered as the result of the interaction of three major key components (**Figure 2**) intrinsic quality of the building, operation & maintenance, and "in use" conditions and occupant's behaviours.

Figure 2 – Key components of actual energy performance

1.2.2 Project objectives

PERFORMER aims to reduce the gap between expected and actual energy performance through the development of innovative, scalable and replicable solutions to assess, monitor and ensure continuous (and optimal) management and guarantee of building energy performance.

This global objective can be translated into a series of specific and operational objectives, summarised as follows:

Scientific and technological objectives

- Devise a holistic (total lifecycle, multi-aspects, context-based) building energy monitoring methodology that factors in appropriate energy performance indicators, information models and simulation tools to achieve building energy performance targets;
- Specify and assemble a configurable prototype "Energy Instrumentation Kit[1]" to establish energy performance accounts during operation and retrofit / post-retrofit stages;
- Specify, adapt, integrate and deliver a comprehensive framework for in-situ assessment of building intrinsic performance of the envelope;
- Specify and prototype a secure data storage and simulation facility that can be hosted either in-house (on a local server) or outsourced and ported on a cloud high-performance computing infrastructure.

Demonstration objectives

- Provide robust demonstrations of (i) the "Energy instrumentation kit", (ii) the Energy Simulation Environment and (iii) the data storage and computing infrastructure in the context of the four selected demonstration projects, identifying limitations and areas of improvements for further refinement and consolidation;
- Test and validate the holistic building energy monitoring methodology in the context of each selected demonstration project, articulating common attributes as well as general and unique features with a view of ensuring scalability and EU wide application;
- Locate the proposed methodology within the procurement path and project delivery life-cycle applicable within each participating country;
- Establish a live repository of historic and real-time monitored data of the demonstration buildings accessible using a simple interface for testing and validation / assessment purposes;

[1] This "Energy Instrumentation Kit" is the so-called PERFORMER box in the following pages.

Assessment, replication and concept awareness

- Deliver knowledge transfer and embed related activities, via the elaboration of a PERFORMER replication guide "Project Handbook", to ensure uptake by industry across Europe;
- Active participation to standardisation activities at international and national levels exploiting existing EU channels.

Four demonstration buildings have been selected across Europe to deploy, demonstrate and assess the various components of the PERFORMER solution. These demonstrators have been used to assess energy and environmental benefits of the new methodology and also to validate the framework and technologies in order for the concept to be easily replicable throughout all countries taking into account climatic condition variations across Europe. The location and type of these buildings are illustrated below in **Figure 3**.

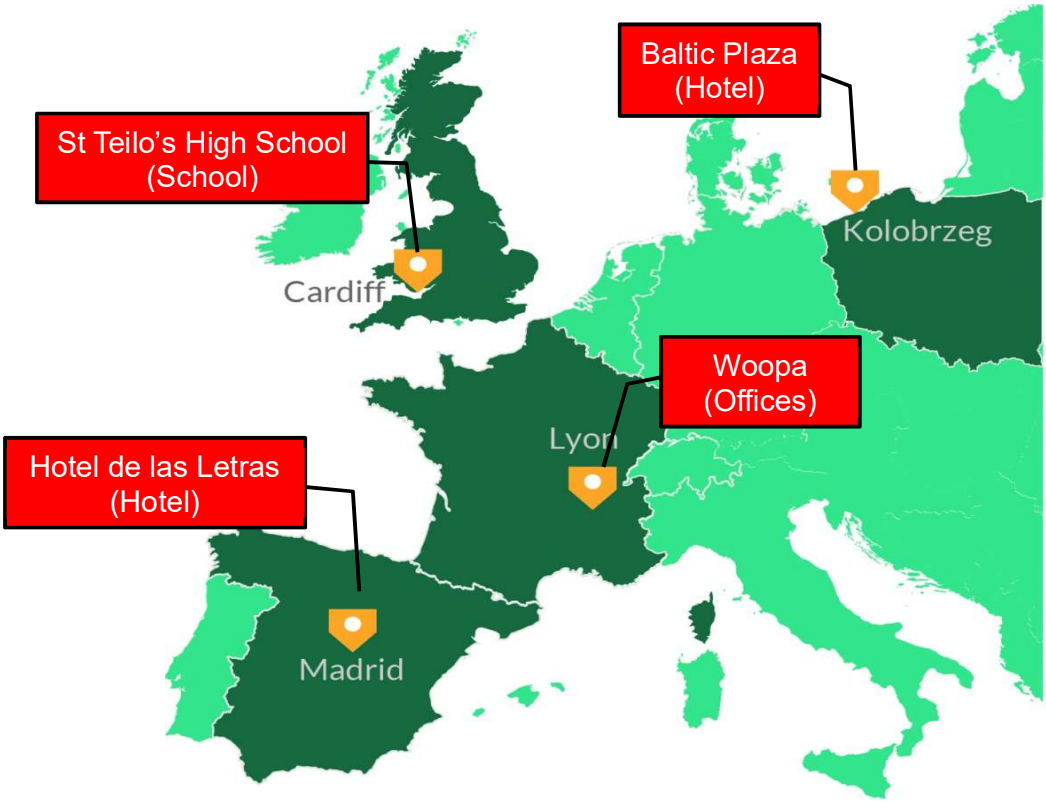

Figure 3 – PERFORMER pilot sites

1.3 MAIN SCIENTIFIC AND TECHNICAL RESULTS AND FOREGROUND GENERATED

PERFORMER took place over a period of 4 years and included the following main project steps:

- Elicitation of requirements from the pilot demonstrators;
- Development of core concepts and methodologies;
- Specification and development of various ICT tools to support the PERFORMER concepts;
- Cost-efficient installation of required sensors and meters at pilot sites;
- Deployment and assessment of the PERFORMER solution.

T demonstration and assessment phases have highlighted the technical challenges of replicating a common solution across a range of different building types. Several methods for the in-situ assessment of building envelope performance (the so-called intrinsic energy performance) have been tested, with and without occupancy. The real challenge has been to find an acceptable compromise between accuracy, simplicity and costs. Results have been fed into on-going standardisation work (CEN TC 89).

Overview of the PERFORMER solution

Figure 4 below outlines the overall architecture of the PERFORMER solution that has been deployed to support the continuous monitoring of actual energy performance.

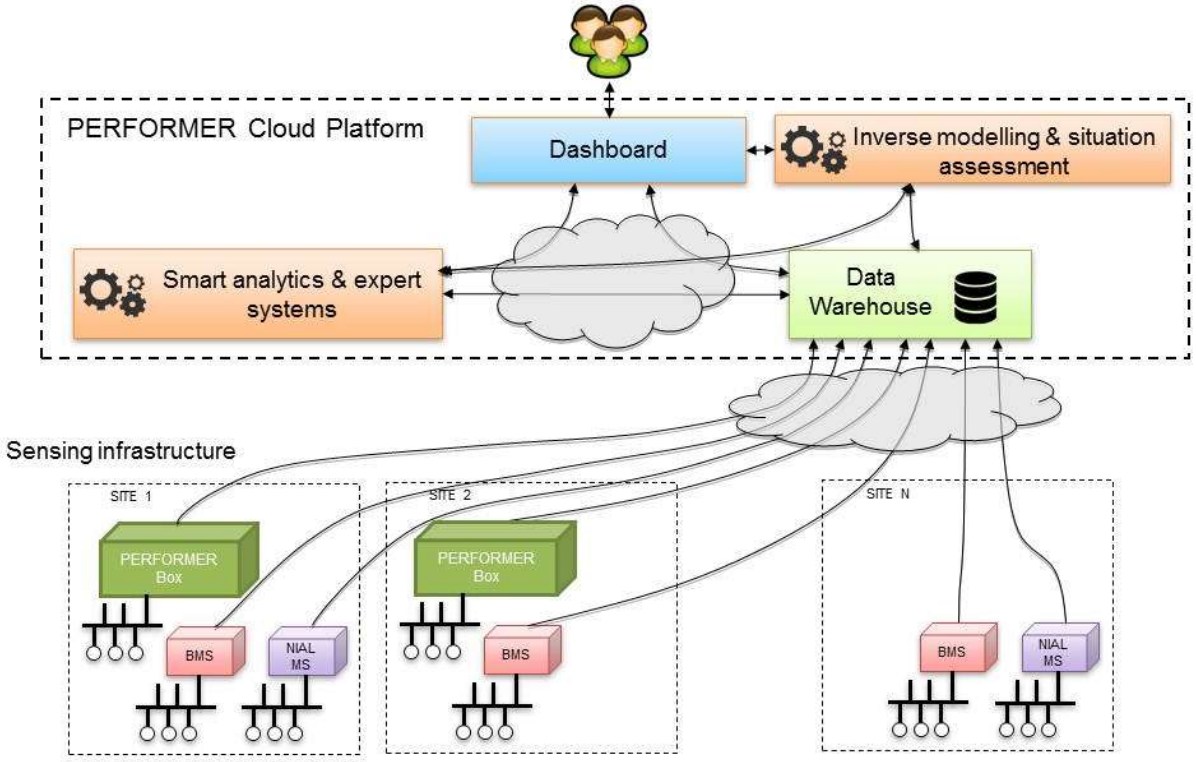

Figure 4 – ICT architecture of the PERFORMER solution

Part of the specification of the PERFORMER Data Warehouse (PDW) involved developing a method for assimilating data from a range of devices (BMS, sensors, meters, etc). Scripts were developed for each demonstrator to extract data from respective BMS and 3rd party data collection systems and upload it onto the PDW through RESTful Web services. It is noteworthy that this approach was also required for BMS at two of the demonstrators that utilise the BACnet communications protocol for Building Automation and Control (which although being a global standard under ISO 16484-5 is applied differently by BMS manufacturers). The scripts enabled data in a range of formats to be successfully transferred to the PERFORMER Data

Warehouse (PDW) in a consistent format. This approach of hosting all monitoring data in one place in the "cloud" is a PERFORMER innovation that has the potential to find support from industry as it would provide greater opportunities for standardisation and enable third party applications to be developed to further exploit data for building energy management purposes. Furthermore, it is envisioned that a fully commercialised version of PERFORMER would incorporate a library of scripts (built up over time) to cater for the extraction of data regardless of BMS / third party data collection type.

Once available within the PDW, data relating to specific variables can be analysed using the various expert rules (anomaly, fault and gap detection modules) and viewed using the PERFORMER visualisation tool. Initially, a large proportion of variables within the PDW were found to contain anomalies which led to poor training of the prediction models. As a result, a new anomaly detection module was developed to allow early detection of data problems and decide whether or not a prediction model can be learnt, thereby freeing up computation time for the generation of reliable prediction models. Expert rules relating to fault detection (data that falls outside of an acceptable range) and gap detection (measured data that is significantly different to a predicted value) have been developed to identify variables that are candidates for further interrogation via the PERFORMER visualisation tool. This innovative approach of using expert rules analysis prior to visualisation allows identification of issues more easily than certain other non-smart platforms that are only capable of displaying unprocessed data from a range of sources. In particular the "Heat Maps" tool allows a first and quick visualisation of the probability of faults (for example, lighting being on when not needed, or sensor failure). A bright red colour indicates when a fault is detected for a particular variable, whereas normal operating conditions are represented by a green colour (**Figure 5**).

Electricity_Sprinkler_Control_Panel_kWh_Energy_gap	1,004711576	1,102989581	1,171908	1,057418939	1,05374788	1,238734384	1,304363252	0,913926215	0,936983761	0,982064838
Block11FF_B2O_temperature_gap	1,004711576	1,102989581	1,171908	1,057418939	1,05374788	1,238734384	1,304363252	0,913926215	0,936983761	0,982064838
Ventilation_AHU03_Supply_Duct_Flow_gap	1,004711576	1,102989581	1,171908	1,057418939	1,05374788	1,238734384	1,304363252	0,913926215	0,936983761	0,982064838
Block2GF_D1D_temperature_gap	1,004711576	1,102989581	1,171908	1,057418939	1,05374788	1,238734384	1,304363252	0,913926215	0,936983761	0,982064838
Block3GF_E1B_temperature_CU_gap	1,004711576	1,102989581	1,171908	1,057418939	1,05374788	1,238734384	1,304363252	0,913926215	0,936983761	0,982064838
Block1GF_C12_concentration_gap	1,004711576	1,102989581	1,171908	1,057418939	1,05374788	1,238734384	1,304363252	0,913926215	0,936983761	0,982064838
Block2GF_D13_temperature_gap	1,004711576	1,102989581	1,171908	1,057418939	1,05374788	1,238734384	1,304363252	0,913926215	0,936983761	0,982064838
Block8FF_A2K_temperature_gap	1,004711576	1,102989581	1,171908	1,057418939	1,05374788	1,238734384	1,304363252	0,913926215	0,936983761	0,982064838
Electricity_Block456_DB24_Roof_Mechanical_Plant_gap	1,004711576	1,102989581	1,171908	1,057418939	1,05374788	1,238734384	1,304363252	0,913926215	0,936983761	0,982064838
Ventilation_AHU08_Return_Duct_Flow_gap	1,004711576	1,102989581	1,171908	1,057418939	1,05374788	1,238734384	1,304363252	0,913926215	0,936983761	0,982064838
Block11FF_B2A_temperature_gap	1,004711576	1,102989581	1,171908	1,057418939	1,05374788	1,238734384	1,304363252	0,913926215	0,936983761	0,982064838
Block8GF_A1E_temperature_gap	1,004711576	1,102989581	1,171908	1,057418939	1,05374788	1,238734384	1,304363252	0,913926215	0,936983761	0,982064838
Electricity_Block1_DB1_Lighting_gap	1,004711576	1,102989581	1,171908	1,057418939	1,05374788	1,238734384	1,304363252	0,913926215	0,936983761	0,982064838
Electricity_Block789GF_DB061_Lighting_gap	1,004711576	1,102989581	1,171908	1,057418939	1,05374788	1,238734384	1,304363252	0,913926215	0,936983761	0,982064838
Block11GF_B1E_temperature_gap	1,004711576	1,102989581	1,171908	1,057418939	1,05374788	1,238734384	1,304363252	0,913926215	0,936983761	0,982064838
Block8GF_B11_temperature_gap	87,02508344	89,43224435	90,2437303	87,77208824	88,25861213	91,44430383	98,87788581	95,9708446	91,19811479	90,74106672
Block1FF_C2A_temperature_CU_gap	87,02508344	89,43224435	90,2437303	87,77208824	88,25861213	91,44430383	98,87788581	95,9708446	91,19811479	90,74106672
Electricity_Block1FF_DB162_Power_gap	87,02508344	89,43224435	90,2437303	87,77208824	88,25861213	91,44430383	98,87788581	95,9708446	91,19811479	90,74106672
Block11GF_B1J_temperature_gap	87,02508344	89,43224435	90,2437303	87,77208824	88,25861213	91,44430383	98,87788581	95,9708446	91,19811479	90,74106672
Block2FF_D26_concentration_gap	87,02508344	89,43224435	90,2437303	87,77208824	88,25861213	91,44430383	98,87788581	95,9708446	91,19811479	90,74106672
Block2FF_D21_concentration_gap	87,02508344	89,43224435	90,2437303	87,77208824	88,25861213	91,44430383	98,87788581	95,9708446	91,19811479	90,74106672
Block4GF_F17_concentration_gap	87,02508344	89,43224435	90,2437303	87,77208824	88,25861213	91,44430383	98,87788581	95,9708446	91,19811479	90,74106672
Electricity_Block4GF_DB122_Power_gap	87,02508344	89,43224435	90,2437303	87,77208824	88,25861213	91,44430383	98,87788581	95,9708446	91,19811479	90,74106672
Block3GF_E11_temperature_gap	87,02508344	89,43224435	90,2437303	87,77208824	88,25861213	91,44430383	98,87788581	95,9708446	91,19811479	90,74106672
Block4FF_F26_concentration_gap	87,02508344	89,43224435	90,2437303	87,77208824	88,25861213	91,44430383	98,87788581	95,9708446	91,19811479	90,74106672
Block1FF_C23_concentration_gap	87,02508344	89,43224435	90,2437303	87,77208824	88,25861213	91,44430383	98,87788581	95,9708446	91,19811479	90,74106672
Electricity_Block3_DB22_ICT_Server_Room_gap	87,02508344	89,43224435	90,2437303	87,77208824	88,25861213	91,44430383	98,87788581	95,9708446	91,19811479	90,74106672
Date	2016-08-01	2016-08-02	2016-08-03	2016-08-04	2016-08-05	2016-08-06	2016-08-07	2016-08-08	2016-08-09	2016-08-10

Figure 5 - Example (1) of a "Heat Map"

The PERFORMER analytical tools mean that it can be used to identify problems that may not otherwise be apparent, or to diagnose causes for known energy or environmental issues (e.g. high energy costs or comfort issues). Smart analytics modules can be used to identify trends, forecast future consumption and calculate KPIs for different building types. The tools are particularly tailored for use by building or facilities managers, but could also be exploited by energy consultants or ESCOs supporting clients with improvement aspirations, thanks to remote web access and the common visualisation format that negates the need for users to have to understand multiple BMS/ monitoring interfaces. This also makes it particularly suited for local authorities or other managers of multiple buildings, allowing easy comparative analysis in a unified format.

Main results

The PERFORMER project results fall into two main categories; methodologies and tools. In many cases, a tool has to be developed as part of a methodology. The whole project has generated many different results. Most of them have been described in the contractually agreed deliverables. This section gives a summary of the main results, focusing on those results that are most likely to be exploited by the project partners.

Some tools and methods can be used independently and others are only meaningful when used together with other tools or methods. The table below gives an overview of the main PERFORMER results and the PERFORMER partner(s) that has developed those results.

Table 1 – Summary of main PERFORMER Exploitable Results

Methodology/tool	Short description	Owner
Building energy KPI library and selection methodology	Methodology to allow a smart selection of building energy KPIs using predefined libraries.	CSTB
Critical measurement identification and sensor gap analysis methodology	Methodology for critical measurement point identification and sensor gap analysis (gap between existing & required sensors).	BRE, SMS
Cost optimised sensor selection support tool	Cost optimised sensor selection support tool for building energy performance measurement and characterisation incorporating sensor database.	SMS
Building information collection standard for energy performance assessment	Standard outlining methodology to collect the critical information required from any building to enable accurate energy performance assessment e.g. building envelope characteristics, MEP equipment, occupancy data, acceptable sources of information (design models, drawings, etc.).	ECG, DRA
Building energy performance visualisation tool	Visualisation software to include more sophisticated visualisations of current and historic building energy performance.	ECG
Expert rules database for building energy performance and users' comfort	Expert system that could automatically detect faults, diagnose any performance gap and provide a set of recommendations to reduce the gap and achieve the expected energy and comfort performance values.	ENG, SMS
Building data warehouse service	Software platform, based on open source tools, that allows storing and managing data series collected from a building monitoring system. It provides a set of generic web services for loading data and allows third-party applications to query and retrieve stored data.	CSTB
Building intrinsic performances assessment software	This software is able, from measures collected in a building over a limited period of time, to reliably assess the thermal performances of the envelope.	CEA
Energy performance monitoring algorithms	Algorithms to allow the assessment of the building energy baseline and for the on-going assessment of energy performances (including deviations awareness).	CEA
Expert system for building energy performance and fault detection and diagnosis	Expert rules software that is able to: 1. Find gaps between actual and predicted energy consumption, 2. Detect and diagnose faults in HVAC systems. NB: It is expected that the system will reduce energy consumption while maintaining thermal comfort.	CU
PERFORMER Box	Software toolkit for creating embedded applications for smart buildings. Can be used as a gateway between the sensor network of a pilot building and the PERFORMER Data Warehouse, for those sensors that are not connected to an existing BEMS. It also provides local processing of the raw data collected from the sensors.	CSTB

1.3.1 Building energy KPI library and selection methodology

A library of relevant KPIs has been created by CSTB (with support from ENGIE, SMS, BRE, ASM and DRA) in order to support the PERFORMER approach. The library is made up of a set of KPIs divided in two levels. The first are primary KPIs used to assess the energy performance of the building. The secondary KPIs are then used to explain the gap between expected and actual energy performance of the building. This library includes a detailed description of each KPI, as well as priorities, which have been defined for each KPI in order to help the PERFORMER client choose the most suitable set of KPIs according to their requirements. This approach gives a standardised and repeatable method which will help building managers to select the most appropriate KPI(s) to assess and monitor building energy performance of the buildings they manage. The KPI library produced is publicly available and ready to be disseminated to interested parties. It is applicable for any building and can be either; directly proposed and tailored to managers of (non-residential) buildings, an added-value supplement to their energy performance assessment methodology, or used by ESCOs to improve their consultancy services.

The set of primary KPIs is shown in **Figure 6** on the following page. These address the three pillars of sustainability that are: environment, social and economics.

The secondary KPIs were classified and identified thanks to the three-following group of metrics:

- KPIs for intrinsic performance of envelope,
- KPIs for global performance of systems and FDD (Fault Detection and Diagnosis),
- KPIs for building usage (including both occupancy and occupant's behaviour).

The resulting set of secondary KPIs are shown in **Figure 7**, **Figure 8** and **Figure 9** respectively.

		INDICATOR	UNIT	DESCRIPTION ELEMENT and MEASUREMENT REQUIRED
ENVIRONMENT 	Energy consumptions	**Total primary energy consumption (with other uses of electricity)**	kWhEP	Type of energy involved (electricty, gas, etc.) National primary energy factors Reference area Measurement of Electricity/ other fuel consumptions sub metered per 'energy' type
			kWhEP/(m².[X=year, month, day for opening days or day for day off])	
		Total primary energy consumption (without other uses of electricity)	kWhEP	Type of energy involved (electricty, gas, etc.) National primary energy factors Reference area Measurement of Electricity/ other fuel consumptions sub metered per 'energy' and 'usage' type
			kWhEP/(m².[X=year, month])	
		Primary energy consumption per application (heating, cooling, lighting, DHW, etc)	WhEP and WhEP/(m².[X=year, month])	Type of energy involved (electricty, gas, etc.) National primary energy factors Measurement of Electricity/ other fuel consumptions
		Energy consumption per energy type (electricity, gas, etc.)	Wh and Wh/(m².[X=year, month])	Type of energy involved (electricty, gas, etc.) Measurement of electricity/ other fuel consumptions
	Renewable energy	**Renewable energy Ratio RER (pr EN 15603)**	%	Type of renewable energy involved Renewable primary energy factor Measurement of electricity/ other fuel consumptions and Renewable energy generation submetered by generation sources
		Renewable primary energy	kWhEP	
	Greenhouse gaz emission	**CO2 emission**	kgCO2/m²/year	Type of energy involved (electricty, gas, etc.) National CO2 emission factors Reference area Measurement of Electricity/ other fuel consumptions
	Water	**Hot water consumptions /year**	m3/year/X	Measurement of hot and cold water consumptions X= employee for office/ student for school/guest for hotel
		Cold water consumptions /month	m3/month/X	
SOCIAL 	Thermal comfort	**PMV/PPD (predicted percentage dissatisfied) (NF EN ISO 7730 and ASHRAE 55)**	%	For more details look at PERFORMER primary KPIs description in D1.1
		Adaptative operative temperature (ASHRAE de Dear and Brager definition)	°C	
		Time of deviation from comfort zone (NF EN 15251 for buildings without cooling systems)	hours	
	Indoor Air quality	**Pollutant concentration : C02 concentration (NF EN**	ppm	
ECONOMIC 	Economic KPIs	**Annual running costs (for building and/or per building zone)**	€ or £ per year and/ or € or £ per zone, per year	For more details look at PERFORMER primary KPIs description in D1.1
		Asset value	€ or £ per m2	
		Investment payback	Number of years	
		Increased profit margin	€ or £ or a % of income or turnover	
		Income/saving generated bu renewable energy	€ or £ saved or generated	
		Energy Tax/Carbon allowance expenditure (for UK)	Generally based on energy consumption of MWh/year or electricity costs of € or £/year	

Figure 6 – PERFORMER primary KPIs

METRIC	INDICATOR		UNIT	PRIORITY	COMMENTS
KPIs for intrinsic performance of envelope	BLC (Building loss coefficient) and HLC (Heating loss coefficient)		W/K	2	Description and methods to assess those indicators available in D1.2
	Air permeability [NF EN 13 829]		m3/h.m²	2	
KPIs for Building usage	% time of Occupation : % of occupancy time per day		%	1	This indicator can be compared to an expected %
	% of Movable Equipment rate (W/m²) : real/predicted		(W/m²)	1	Moveable equipment: desktop computers, printers, TV sets, electronic devices and other small electronic appliances like coffee machines, etc.
	Building zoning per main homogeneous zone of activity (room zone, classroom zone, catering, meeting rooms, corridors etc)	Total primary energy consumption for the zone of activity	WhEP/X/month and year	1	For each of this zone of activity, it is useful to monitor ratio taking into account the specificity of the activity (X). For example: X = Number of employees for an office zone in an office building X= Number of guest for a room zone in a hotel X= Number of students for a classroom zone in a school X= Number of meals for catering zone etc.
		Area ratio : area of the zone of activity / total reference surface	%	1	
	for each thermal zone	Amount of time when a windos is open while the heating or the cooling system is on	hours/month	2	

Figure 7 - PERFORMER secondary KPIs for intrinsic performance of envelope and building usage

METRIC	INDICATOR		UNIT	PRIORITY	COMMENTS
KPIs for global performance of systems and FDD	HEATING SYSTEM	System efficiency	-	1	To be adapted allowing involved heating system (efficiency or COP - if relevant take into account distribution and emision level of the system involved)
		Pumps energy consumptions for distribution	Wh	1	Relevant for heating system with hydraulic distribution
		Indicator for optimal start test (EN NF12098-1)	OK/NOK	2	Description of the indicator available in D1.4
		% of successfull starting of heating	%	2	Description of the indicator available in D1.4
		Local hourly average operative temperature for the first hour of occupancy	K	2	Description of the indicator available in D1.4
		Temperature differential between local hourly average operative temperature and local setpoint temperature	K	2	Description of the indicator available in D1.4
	COOLING SYSTEM	System efficiency	-	1	To be adapted allowing involved cooling system (EER – if relevant take into account distribution and emission level of the system involved).
		Pumps energy consumptions for distribution	Wh	1	Relevant for cooling system with hydraulic distribution
		Indicator for optimal start test	OK/NOK	2	Description of the indicator available in D1.4
		% of successfull starting of cooling	%	2	Description of the indicator available in D1.4
		Local hourly average operative temperature for the first hour of occupancy	K	2	Description of the indicator available in D1.4
		Temperature differential between local hourly average operative temperature and local setpoint temperature	K	2	Description of the indicator available in D1.4

Figure 8 – PERFORMER secondary KPIs for global performance of systems and FDD – Part A: heating & cooling systems

METRIC	INDICATOR		UNIT	PRIORITY	COMMENTS
KPIs for global performance of systems and FDD	DHW SYSTEM (KPIs recommender for hotel only)	DHW system efficiency (efficiency or COP)	-	1	To be adapted allowing involved DHW system (Efficiency or COP – if relevant take into account distribution and emission emission level of the system involved).
		Thermal solar collector efficiency	-	2	If relevant – description of the indicator available in D1.4
		Supply temperature from hot water tank	K	1	Description of the indicator available in D1.4
	AHU / VENTILATION	Fans energy consumptions	Wh	1	
		Status of the fans	V	1	Use the fan command to check if fans are off (or reduced speed) during non-ocupancy) Description of the indicator available in D1.4
		Pumps batterry consumptions	Wh	2	
		Ratio of supplied flow rate and hygienic ventilation flow rate	%	1	
		Pressure drop across AHU filters	Pa	2	Description of the indicator available in D1.4
	LIGHTING	% of time when the lights are on during non-occupancy periods	%	1	Use the light command (V) to assess this indicator - Description availbale in D1.4
		% of time when the lights are on during occupancy periods	%	2	Use the light command (V) to assess this indicator
	LIFT	Lift energy consumption (including lighting) per month and year		1	
		Working time during non-ocupancy per month	hours/month	2	

Figure 9 – PERFORMER secondary KPIs for global performance of systems and FDD – part B: DHW, HVAC. Lighting and Lifts

1.3.2 Critical measurement identification and sensor gap analysis methodology

BRE, with support from SMS, ECG and DRA, have developed a spreadsheet-based tool that can be used to determine the sensors and meters needed to measure the specific KPIs chosen from the KPI library by a PERFORMER client. A separate template is available to capture the existing sensors / meters within a building (see below 1.3.4). Once the 'required' and 'existing' sensor lists are available, they can be compared to identify the metering 'gaps' that will need to be filled with the purchase of new equipment in order to assess the chosen KPIs. This approach is linked to the PERFORMER KPIs library (see 1.3.1) and gives a standardised, repeatable method to help clients / building managers self-assess the sensor requirements and / or monitoring equipment needed to obtain key energy KPI information. The spreadsheet-based tool has been developed and is usable.

1.3.3 Cost optimised sensor selection support tool

SMS and ECG, with contributions from other partners have developed a tool (Excel spreadsheet) which includes a database of sensor / meter solutions for parameters commonly measured in buildings for both building and energy management purposes. Sensor / meter properties can be filtered out according to client building requirements to identify feasible solutions to fill sensor / metering gaps in buildings. The tool will save time and money for customers by supporting the identification of cost-optimal solutions that would suit their needs. It will also aid sensor / meter suppliers by recommending solutions for different sets of requirements. The tool will also support sensor / meter and BEMS system designers, installers & consultants through the easier access to data for design, purchase and implementation activities. The tool includes a methodology for qualitative characterisation of sensors / meters (that has been made objective through impact factors assessment) and allows for future updates.

For illustration purposes, the sensor properties, costs assessment and impact factors are given in **Figure 10** and **Figure 11** on the following pages for the measurement of some primary KPIs relating to thermal comfort and indoor air quality. The impact factor threshold values proposed for indoor air temperature sensors are reported in **Figure 12**.

General properties					
Parameter	Use (Meter/submeter/Only sensor/Sensor and set-point control/other/not applicable)	Type	Measurement range	Accuracy range	Resolution
Room Air temperature	Sensing and set-point control	RTD - Platinum 1kohm	0-50 °C	±0.3°C	N/A
	Sensing and set-point control	10 kohm Thermistor	13-35 °C	±0.28°C	N/A
	Sensing and set-point control	RTD PT100, NTC Thermistor	(-10)-60 °C	±0.2°C	N/A
	Sensing and set-point control	RTD PT100, NTC Thermistor	(-10)-60 °C	±0.2°C	N/A
	Sensing and set-point control	Digital sensor integrated circuit	13-35 °C	±1°C	N/A
	Sensing and set-point control	NTC Thermistor	(-10)-60 °C	±0.3-0.5°C	N/A
	Sensing and set-point control	NTC Thermistor 10kohm	(-10)-70 °C	±0.2-0.3°C	N/A
	Sensing and set-point control	10 kohm Thermistor	13-35 °C	±0.28°C	N/A
	Sensing only	RTD - Platinum 1kohm	0-50 °C	±0.3-0.5°C	N/A
	Sensing only	T1 PTC Thermistor	0-50 °C	±0.6°C	N/A
	Sensing only	RTD PT100, NTC Thermistor	(-10)-60 °C	±0.2°C	N/A
	Sensing only	NTC Thermistor	(-10)-60 °C	±0.3-0.5°C	N/A
	Sensing only	Digital sensor integrated circuit	13-35 °C	±1°C	N/A
	Sensing only	RTD - Platinum 100ohm	4-32 °C	±0.3°C	N/A
	Sensing only	NTC Thermistor 10kohm	0-50 °C	±0.3°C	N/A
	Sensing only	NTC Thermistor 10kohm, 100 kohm	12-35 °C	±0.3°C	N/A
	Sensing only	NTC Thermistor 10kohm, 100 kohm	12-35 °C	±0.3°C	N/A
	Sensing only	RTD - Platinum 1kohm	12-35 °C	±0.6°C	N/A

Figure 10 – Sensor properties for measuring room air temperature

Manufacturers	Impact factors										Solution
Main manufacturers and models	Measurement accuracy	Intrusiveness	Compatibility	Reliability	Networkability	Sensor cost	Additonal devices cost	Installation/ replacement cost	Running costs (On-going cost)	Maintenance cost	Type of solution
Siemens QAA2312.FWNN	1,5	2,5	2,5	2,5	2,5	2,5	2,5	2,5	2,5	2,5	Cost-optimal
Siemens 587-189	1	2,5	2,5	2,5	2,5	3	2,5	2,5	2,5	2,5	Cost-optimal
Sontay TT1000 series	0,5	2,5	2,5	2,5	2,5	1	2,5	2,5	2,5	2,5	Cost-optimal
Sontay TT1000 series	0,5	2,5	2,5	2,5	2,5	0,5	2,5	2,5	2,5	2,5	Cost-optimal
Siemens QAA2062.FWU	4,5	2,5	2,5	2,5	2,5	4,5	2,5	2,5	2,5	2,5	Hybrid
Sontay RF-RS-T, Titan Wireless Room temperature sensors	2	0,5	2	2,5	1,5	1,5	2,5	1	1	4	Non-intrusive
Siemens QAA2330.EWNN, Titan Room temperature sensors	1,5	2,5	2,5	2,5	2,5	0	2,5	2,5	2,5	2,5	Cost-optimal
Siemens 587-189	1	2,5	2,5	2,5	2,5	2,5	2,5	2,5	2,5	2,5	Cost-optimal
Siemens QAA2312.EWNN, Vaisala TMW82	2	2,5	2,5	2,5	2,5	1	2,5	2,5	2,5	2,5	Cost-optimal
Siemens QAA2040	3	2,5	2,5	2,5	2,5	2,5	2,5	2,5	2,5	2,5	Cost-optimal
Sontay TT1000 series, Titan Room temperature sensors	0,5	2,5	2,5	4	1,5	0	2,5	2,5	2,5	2,5	Hybrid
Sontay RF-RS-T, Titan Wireless Room temperature sensors	2	0,5	2,5	2,5	2,5	1,5	2,5	1	1	4	Non-intrusive
Siemens QAA2062.WU	4,5	2,5	2,5	2,5	2,5	3	2,5	2,5	2,5	2,5	Cheap but less accurate
Siemens 536-752, Siemens 536-753	1,5	2,5	2,5	2,5	2,5	3,5	2,5	2,5	2,5	2,5	Cost-optimal
Siemens QAA2230.FWNN	1,5	2,5	2,5	2,5	2,5	2,5	2,5	2,5	2,5	2,5	Cost-optimal
Siemens 540-520, Siemens 536-784, Siemens 536-994, Siemens QAA1031	1,5	2,5	2,5	2,5	2,5	2	2,5	2,5	2,5	2,5	Cost-optimal
Siemens 540-995, Siemens 536-7984, Siemens 540-984	1,5	2,5	2,5	2,5	2,5	0,5	2,5	2,5	2,5	2,5	Cost-optimal
Siemens 544-374	3	2,5	2,5	2,5	2,5	2	2,5	2,5	2,5	2,5	Cost-optimal

Figure 11 - Cost assessment and impact factors for indoor air temperature sensors

Measured parameter	Impact factor	Related properties (Properties that affect the impact factor)	Relevance (High, Medium, Low)	Proposed threshold value for IF=2.5 (that corresponds to reasonable minimum requirements for the PERFORMER solution)	Notes, observation, explanations for the suggested values
Room air temperature	Measurement accuracy	Accuracy range	High	±0.5°C	Using European Standards and accuracies of the models on the market
		Measurement range	Low	4-35°C	It may slightly affect the measurement accuracy IF. Widest ranges have lower impact factors
	Intrusiveness	Need for additional devices	Low	Additional devices generally include a controller, an analog/digital transformation device and a transmitter	Most sensor solution requires additional devices to send the information to the collector or BMS. If the solution requires more devices than those listed in the proposed threshold values the IF is greater than 2.5 and viceversa
		Wireless	High	-	A wireless device has a sub-IF < 1
		Power system	High	-	A battery powered device has a sub-IF <1
		BMS compatibility	Low	Compatible with most BMS on the market	It depends on the number of Communication protocols used by the sensor belonging to the same sensor solution and from manufacturers' information
	Compatibility	Need for additional devices	Medium	Additional devices generally include a controller, an analog/digital transformation device and a transmitter	Most sensor solution requires additional devices to send the information to the collector or BMS. If the solution requires more devices than those listed in the proposed threshold values the IF is greater than 2.5 and viceversa
		BMS compatibility	High	Compatible with most BMS on the market	It depends on the number of Communication protocols used by the sensor belonging to the same sensor solution and from manufacturers' information.

Figure 12 - Impact factor threshold values for room air temperature sensor properties

1.3.4 *Building information collection standard for energy performance assessment*

ECG and DRA have developed a standard spreadsheet based-tool to facilitate building information collection for energy performance assessment. All the gathered information (e.g. building envelope characteristics, mechanical and electrical plant and equipment, occupancy data, minimum energy consumption data, acceptable sources of information – design models, drawings, etc.) could be incorporated into a Building Information Model. This tool/methodology will significantly reduce the resources needed to carry out initial energy performance assessments. The template developed is already usable, although it requires tailoring to any new building types which were not used in PERFORMER (adding extra fields).

1.3.5 *Building energy performance visualisation tool*

ECG has developed a building performance monitoring visualisation tool that can be integrated with any pre-existing hardware (EMS, BEMS, sensors, etc.) in a building. To do this, the different tools that compose the visualisation application are populated using a standard simple data format. This data can be obtained and adapted from any other data format from most of the existing EMS or BEMS on the market. The tool extracts data from the building's data server and structures all this information to present it to the user in an intuitive way. This simple layout allows the user to understand the energy performance of the building. In addition to charting actual energy consumption, the tool displays information about gaps between actual and expected energy consumption in a clear and comprehensible way, facilitating the identification of areas where action should be taken to improve the overall consumption of the building. The tool has been validated and is currently being used at all four PERFORMER pilot buildings. It can be used either as part of the global PERFORMER solution or as a stand-alone tool. A screenshot of the visualisation tool is shown in **Error! Reference source not found.** below.

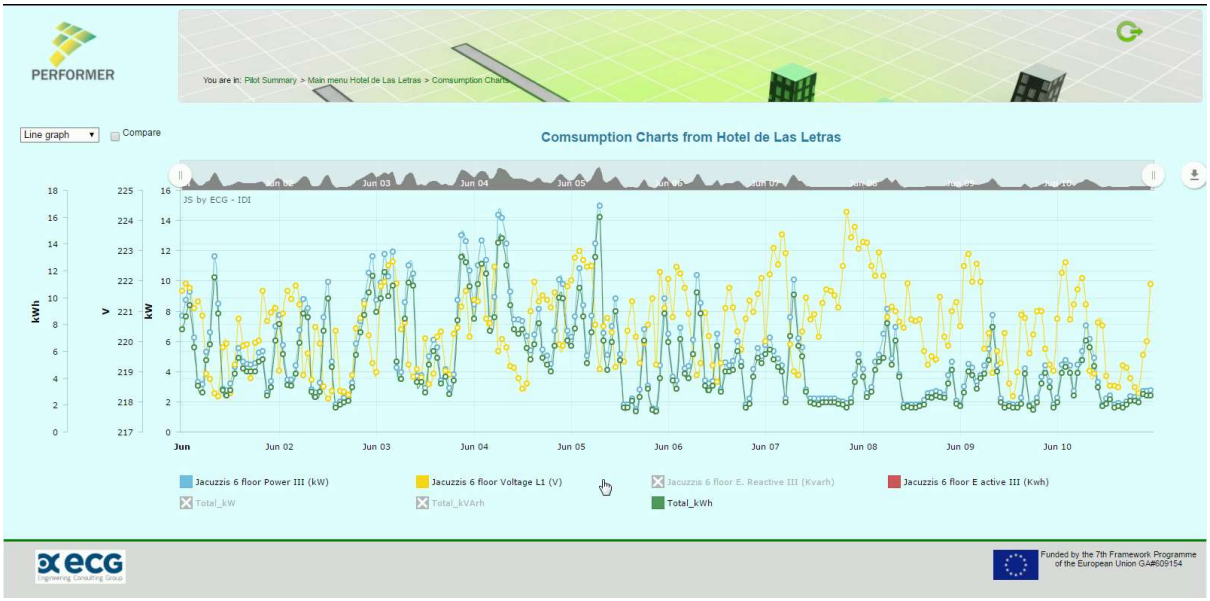

Figure 13 –Example of consumption chart (screenshot)

1.3.6 *Expert rules database for building energy performance and users' comfort*

Existing BEMS can only control consumption and comfort conditions by changing set points of various building parameters. No BEMS is currently able to carry out intelligent analysis to explain the reason for gaps between actual and expected consumption, or the reasons for poor thermal comfort. A group of partners (ENGIE, CSTB, SMS, CU and CEA) have collaborated to address this by defining a set of expert rules based on gap identification and Fault Detection and Diagnostics (FDD). These rules are the result of translating human knowledge into technical knowledge expressed in the form of tables, diagrams, flow charts, mathematical formulas, or any other relationships between operational parameters that can be expressed logically. These

expert rules are then converted into algorithms and coded into expert system software which actively "learn" from the building's data and thereby identify any energy gaps that still exist.

However, even when not integrated into the expert system tool, whenever abnormal readings or performance gaps are identified by building managers, the rules can be used on their own as support information in order to determine the source of any data gaps that are visible using the Visualisation Tool (see 1.3.5). The Expert Rules database has been tested within PERFORMER together with the Expert System (see below 1.3.10). Expert rules for data gap identification have been tailored for St Teilo's High School, UK and have been validated. FDD rules have been defined for the WOOPA offices, France and tested during the final part of the project.

1.3.7 Building data warehouse

This software platform, developed by CSTB, allows for data time series from building monitoring systems to be collected, stored and managed whilst ensuring security and privacy. Based on open source tools, it provides a set of generic web services for loading data whilst also allowing third-party applications to query and retrieve the stored data. Dictionaries and quality rules can be defined to filter, clean and check the consistency and the quality of the data series. The platform can be installed locally (at the monitored site) or as a cloud service, which could be offered to several building sites.

If used as a cloud service, the server should provide all the functions required to guarantee data security and privacy. This generic solution provides large interoperability with other ICT tools through the web service approach. It is highly flexible and allows for the customisable control of data quality. In addition to being easily extensible (since it is based on widely available open tools), it is well suited for integration as an added-value cloud service for smart buildings or smart cities where monitoring, collecting and storing data is a core requirement.

In its current form, the PERFORMER Data Warehouse (PDW) is potentially a core component of any PERFORMER-like platform providing energy management services to building owners / managers, where monitoring, collecting, storing and postprocessing data are core functionalities. Two kinds of data are managed in the PDW: structured data (for the pilot data models) and unstructured data (for the time series). Specific Open Source solutions have been chosen to manage each kind of data. For structured data, it is a standard relational database; for unstructured data, KairosDB over Cassandra has been chosen for its high performance in managing large sets of time series.

Access to the PDW is provided through a Web Service layer. An API has been provided that specifies the services available and standardises the way third-party applications can connect to the PDW. In practice, a script should be written and implemented at the level of each pilot site to gather their data and upload it on the PDW on a regular basis. The PDW offers two main types of services: services for managing the definition of variables and services for data upload and retrieval. **Figure 14** illustrates how pilot sites (BMS, PERFORMER Box…) and external applications can interoperate with the PDW.

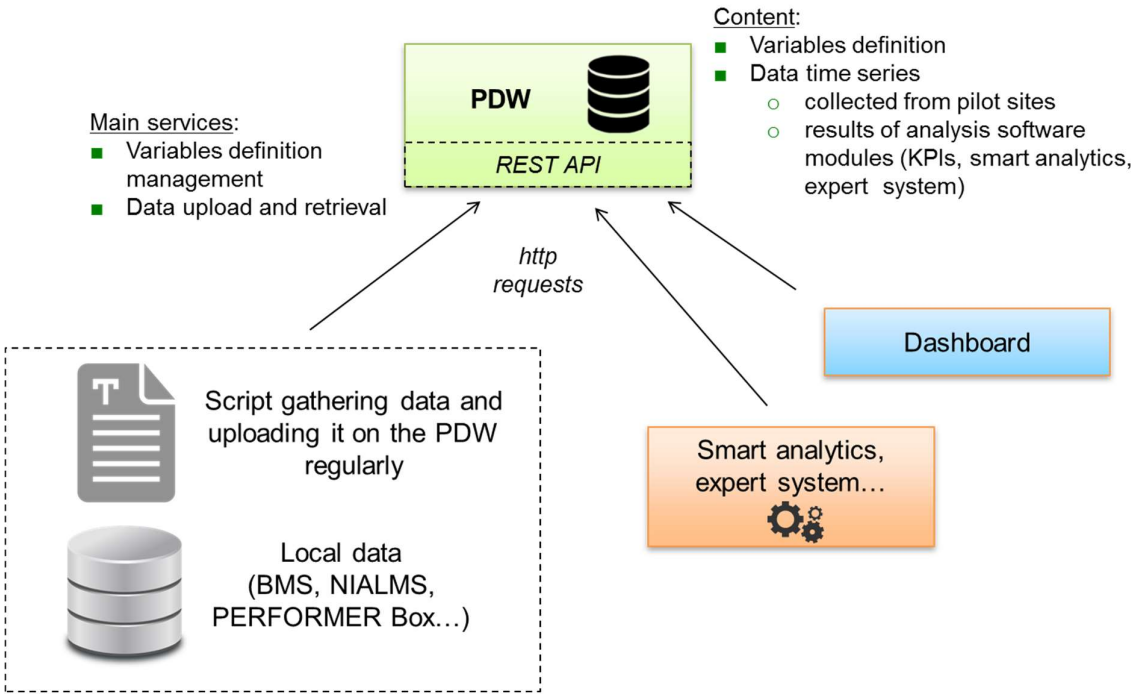

Figure 14 - Interoperability with the PERFORMER Data Warehouse

1.3.8 Building intrinsic performances assessment software[2]

With the increasing uptake of energy performances contracts, there is a need for building performance assessment tools that are able to determine the causes for possible deviations from anticipated energy performance.

CEA has developed a software tool which can reliably assess the thermal performances of all / part of the thermal envelope based on measures collected in a specific part of a building over a limited period of time. The software relies on short periods of measurement (an order of magnitude of 2 weeks). It is relatively low-cost, non-intrusive and requires limited instrumentation. Reliability is ensured by the combination of a global, wide spectrum approach and of a local, more detailed method.

A research prototype has been developed and validated based on actual data from a specific space in St. Teilo's High School, UK.

1.3.9 Energy performance monitoring algorithms

These algorithms developed by CEA are based on fine-tuned state-of the-art statistical analysis algorithms sourced from the most up to date models in the current 'Deep Learning' domain. They perform an analysis of time-based data series collected from the meters and sensors deployed in a building. They allow for the assessment of the building energy baseline and for the on-going assessment of energy performance (including deviations awareness). The ability of these algorithms to detect deviations in energy performance links in well with the Expert System (see 1.3.10) which can also detect variations between actual and predicted energy consumption. The algorithms chosen and validated are able to provide more accurate anticipation of future sensor behaviour than more classical statistical methods. They have been tuned and packaged into a fully integrated module communicating with both the data acquisition part of the PERFORMER solution and its data storage / analysis part. Forecast accuracies have been compared to classical

[2] It should be noted that other methodologies for in-situ fabric performance assessment (Isabele, QUB…) have also been analysed and tested in the timeframe of the project. Their results are available in project deliverables.

statistical methods for time-series prediction and published in an academic journal[3]. A second paper is being written in collaboration with CU to provide a performance comparison with more elaborated methods.

It should be noted that these algorithms need to be trained using historical data and that the performance of the prediction highly depends on the quality of the training data sets. So, in order to improve the quality of the prediction models, a software module dedicated to the detection of anomalies in the history baseline was also developed.

Figure 15 below illustrates the use of prediction models. In this example, the predicted values (green points) for the energy consumption in one of the PERFORMER pilot sites are compared with the actual measured values (blue points). Large gaps between predicted and actual values are highlighted with red lines. It can be seen that the global dynamics are well anticipated by the models even if hourly peaks are not clearly covered. The identified gaps may come from real problems on site, but this can also indicate that the history for this variable was not clean enough or not representative enough to allow the models to extract the variable's dynamics.

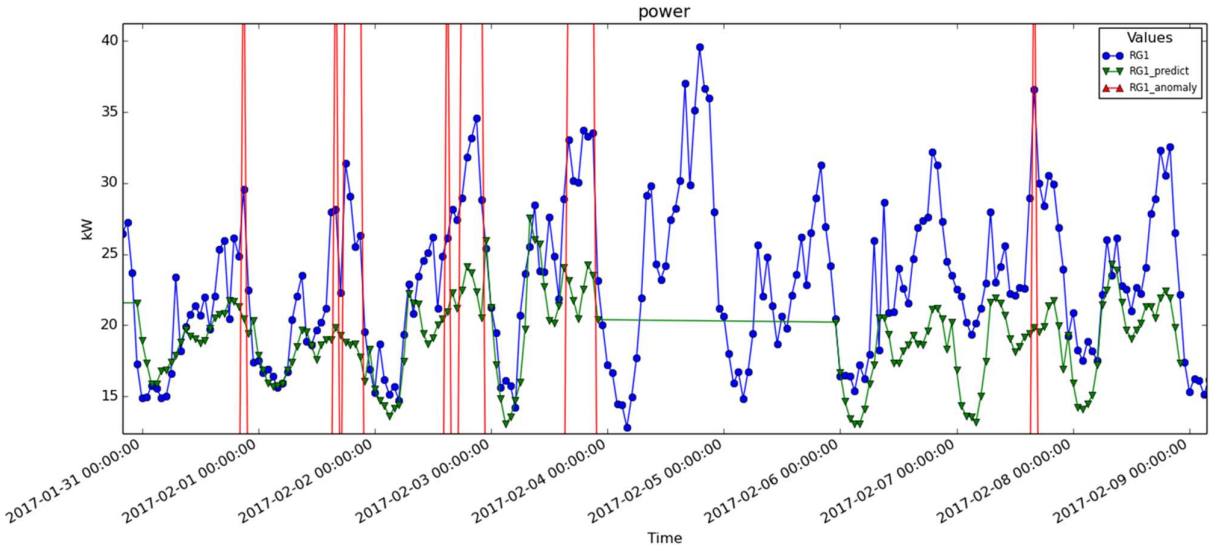

Figure 15 – Example of gap detection between predicted and actual values

1.3.10 Expert system for building energy performance and fault detection and diagnosis

CU has worked on the development of an expert software system to automatically detect faults and diagnose any performance gap, providing recommendations to reduce the performance gap by taking into account the actual and predicted energy consumption. The system relies on expert rules (see above 1.3.6) to explain the reasons behind a gap or fault. The module will help the building owners / managers to understand behaviour of the building and to make more informed decisions. The module has been tested using actual and predicted (from smart analytics module) values. Once the module has been run for some time on the pilot buildings, it can be updated by new rules based on the feedback from the building owner / manager.

Figure 16 shows the functional architecture of the expert system module.

[3] Innovative time series forecasting: auto regressive moving average vs deep networks. Entrepreneurship and Sustainability Issues; v4; n3; March 2017.

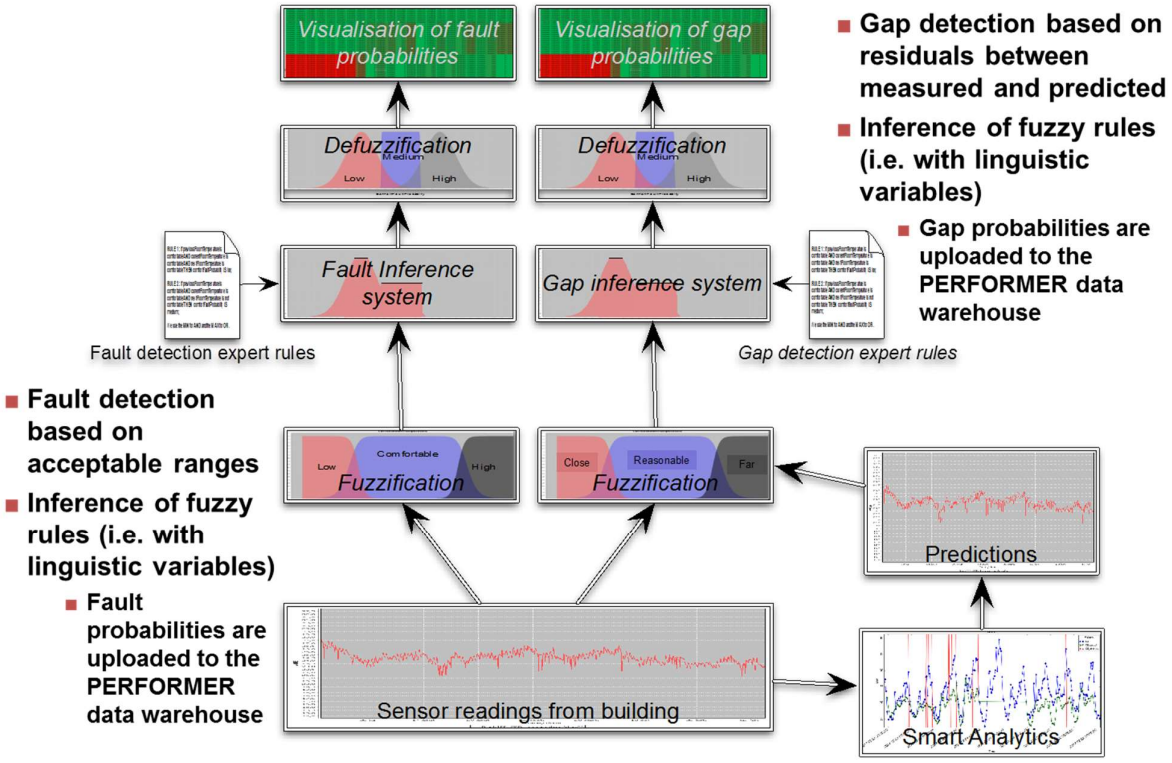

Figure 16 - Architecture of the expert system module

Gaps can be visualised through "Heat Maps" as previously introduced in **Figure 5**. Another example is provided below in **Figure 17**.

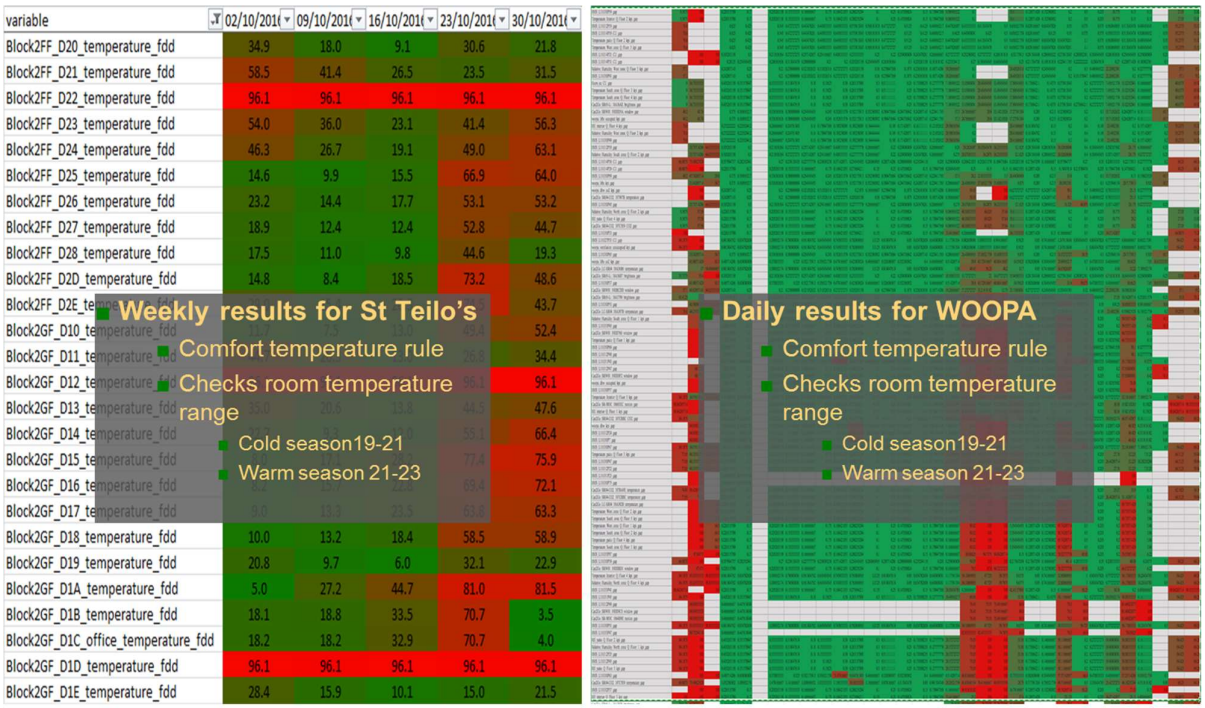

Figure 17 - Example (2) of a "Heat Map"

1.3.11 PERFORMER Box

The PERFORMER Box is an enhanced version of the CSTBox (CSTB Sensing and Tele-monitoring Box), a software toolkit developed by CSTB for creating embedded applications for smart buildings. The CSTBox core system and additional components are open source. In the framework of the PERFORMER project, this toolkit has been extended by including additional communication protocols, connection with the PDW (see 1.3.7), and specific local data processing (computation of indicators related to building usage). The main role of the PERFORMER Box, as part of the PERFORMER solution, is for it to be used as a gateway between the sensors network of a pilot building and the PDW, especially for those sensors that are not connected to the existing BEMS. It also provides local processing of the raw data collected from the sensors, before sending them to the PDW e.g. basic filtering and checking, advanced consolidation computation improves transfer speeds, while aiming at producing high level indicators, etc.

The PERFORMER Box is easy to deploy and can be tuned or extended to cover specific needs. Integration of new protocols (it can deal with different communication protocols) and supplying of edge analytics (data aggregation, incident detection, occupant awareness, etc.) are the two main capabilities that differentiate the PERFORMER Box from other products available on the market. The PERFORMER Box has been deployed and assessed in two pilot sites: St Teilo's High School (UK) and WOOPA (France). In both cases, data is collected from sensors that characterise building usage related to windows, electric blinds, artificial lights, or mobile devices. During that time, a set of indicators was computed locally and then uploaded to the PDW. This solution is well adapted to collect and process data at buildings not yet equipped with BEMS (e.g. residential buildings), or to complement existing installations like in the case of the PERFORMER pilot sites (tertiary buildings) for specific tasks (e.g. audits).

Figure 18 below illustrates how a PERFORMER Box has been deployed to complement the sensing infrastructure at two of the PERFORMER pilot sites. A set of KPIs related to building usage are computed locally (in the PERFORMER Box) or in the cloud (at level of the PERFORMER Data Warehouse). The PERFORMER Box packaged for Woopa is shown in **Figure 19**.

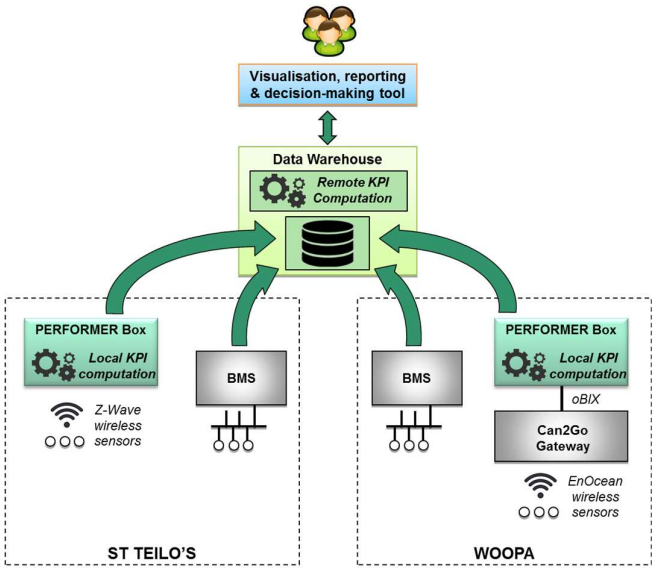

Figure 18 - Technical integration of a PERFORMER Box

Figure 19 - PERFORMER Box for Woopa

Aside from the ability to provide new sensors without the need to integrate them with the existing BEMS, the benefits of a PERFORMER box can be summarised as follows:

- Local processing of simple KPIs if data collected locally;
- Reduces quantity of information passed to the PDW;
- Reduces processing burden at PDW level;
- Faster processing – potential for more immediate feedback for users;
- If active control based on real-time data was pursued, local processing would have clear advantages.

1.4 POTENTIAL IMPACT

PERFORMER has developed a prototype technology platform to facilitate improved energy management in buildings, whilst ensuring occupant comfort. The consortium has validated the performance of the PERFORMER solution at four pilot sites to test the various components and demonstrate their usefulness. Identification of energy saving opportunities in the pilot buildings offers the possibility to close the performance gap, thus reducing energy consumption and associated CO_2 emissions. As Buildings are responsible for 40% of energy consumption and 36% of CO2 emissions in the EU[4] the deployment of PERFORMER across the EU presents significant economy of scale opportunities.

The project's advancement of analytical techniques goes beyond simple data visualisation by using prediction algorithms and anomaly / fault reporting that will help users target on-going opportunities for improvements effectively. This is a key enhancement over traditional energy visualisation packages, making the magnitude of deviation from predictions apparent. These functions should help users move beyond overall savings in the range of 5% from improved awareness of energy use, to more substantial savings of between 15-45%, by the identification of numerous on-going energy management and commissioning opportunities. (Scope of savings according to the US DoE, Federal Energy Management Program.)

Examples of the scale of savings experienced across the pilot buildings include:

- St. Teilo's High School (UK) – 10% reduction in annual electricity demand by addressing high out-of-hours electricity base load use. Similarly, eliminating excess out-of-hours heating base load could save approximately 38% of heating energy per year, equating to a total combined saving of 22%.
- Woopa office (France) – changing the heating schedules for the high-lag heating distribution system improved occupant comfort and will save 38% of the heating energy demand.
- Iberostar las letras (Spain) – 5% electricity savings by identifying an improved ventilation strategy for the hotel (65% of ventilation energy) plus a further 5% saving from reducing cooling energy demands outside the heating seasons, in line with energy simulation model forecasts (19% of the total cooling energy demand).

These, along with other various energy saving opportunities identified, suggest that total savings would fall within the higher range mentioned above, which could have a significant impact at an EU level if the roll out of PERFORMER enabled this in other buildings across Europe.

Another major impact of the project is the creation of a protocol to setup the export of BEMS data without the need for external access to the BEMS, which is a notoriously difficult hurdle to overcome for data security reasons. The benefit of this approach is that the solution will have a wider market scope by being able to make use of existing BEMS data in virtually any native format, from any brand of BEMS. This is important as even the ubiquitous BacNet global standard (ISO 16484) can be interpreted differently when implemented by major BEMS manufacturers. It has been shown that this is achievable for a wide number of varied data sources during the pilot demonstration phase, including BEMS from two international market leaders; which sets a positive outlook for compatibility across the wider industry. Having unified multiple data sources in the PERFORMER Data Warehouse (PDW), provides an opportunity for the wider market to potentially create new applications and rules for energy management and control that could then be applicable to many buildings, unified by use of the PDW intermediary.

The optional element of including the PERFORMER box as part of the overall solution could have a major impact on SME building owners and service providers in particular. The box serves as a gateway to the PDW and the PERFORMER analysis services for any sensors / meters not connected to the existing BEMS. This can allow smaller companies to readily supplement any shortage of sensors in a building without employing a BEMS supplier to integrate them to the existing BEMS, which can often be expensive for 'locked-in' technologies of some existing systems. The PERFORMER box therefore provides added flexibility to the

[4] http://ec.europa.eu/energy/en/topics/energy-efficiency/buildings

solution, which can widen its reach amongst SME clients and SME third parties (such as energy consultancies) supporting building owners and managers.

The project has also contributed towards the development of European standards related to intrinsic building performance assessment via CEN/TC89/WG13, by trialling innovative testing protocols during the piloting phase with results feeding into the Working Group discussions.

The PERFORMER solution will assist building owners and managers to optimise their assets, while also supporting energy consultants and energy service providers (i.e. ESCOs) to assist their own clients with energy management opportunities. The solution will be applicable to any building with an existing BEMS that warrants some degree of sub-metering to differentiate between energy uses by zone or service. So, although it is not likely to be suitable at an individual dwelling level, or buildings without a number of zones and services, the majority of commercial, public, leisure and centrally managed multi-residential buildings could benefit from the use of PERFORMER.

The solution will be of particular interest for buildings being considered for refurbishment or services upgrades to reduce energy use, for which PERFORMER can help to identify how efforts would be best targeted. The renovation of existing buildings is seen by the EC as an important element towards achieving future EU energy reduction targets. As part of this, policies have been introduced that will require EU countries to make energy efficient renovations to at least 3% of buildings owned and occupied by central governments per year (average renovation rates across the EU are currently around 1%). Demonstrating the successful use of PERFORMER to identify energy saving actions in a UK school being managed by the Local Authority (City of Cardiff Council) and French office building show how the solution is relevant to help facilitate this goal for public buildings.

Immediate impact would be expected in the countries where the solution has been initially piloted (i.e. France, Spain, UK and Poland), as the demonstration buildings will act as tangible case studies in these local markets and the market opportunities in these regions have already been considered through the project. The pilot organisations themselves offer an opportunity for immediate impact as they could look to replicate the PERFORMER solution across their own assets; for example, City of Cardiff Council are responsible for many buildings beyond the pilot school that could benefit from similar energy management, including other schools, offices and public buildings. ENGIE have numerous office buildings across their main organisation and subsidiary companies, which opens further doors to a wider building market through their energy services arm - Cofely. The hotel chains, Iberostar and SEA Developments, both own numerous hotels that may benefit similarly from the installation of the PERFORMER solution to help reduce energy use while ensuring occupant comfort. In order to deliver knowledge transfer and embed related activities, a “Project Handbook” has been developed for each pilot site, not only to enable continued use of PERFORMER by the pilot sites beyond the project end date, but also to act as a replication tool by providing case studies in support of potential uptake by industry across Europe.

From successes in the pilot countries, it is proposed that the solution could readily branch out into Belgian, Swiss and Portuguese markets due to common languages to the pilot regions and similar climatic conditions. The solution will be widely applicable thanks to the option to offer it at different levels (varying functionality and degrees of customer support) and with different prices and payment routes, which will also make the tool competitive compared to other solutions currently in the energy management market.

The most significant societal impacts from PERFORMER are likely to arise from the public sector, where any savings that can be made on energy expenditure in buildings will help to extend the budgets that can subsequently be made available for other public services. This is not a factor that has been directly explored by the project but is a beneficial consequence of PERFORMER’s energy saving purpose. Another major focus of the project was ensuring health and comfort parameters are delivered in buildings. Most people spend a significant amount of time within buildings and hence PERFORMER can help to deliver healthy indoor

environments to improve the quality of life for the occupants. This aspect can be particularly influential in offices, schools, or hospitals, where people may spend extended periods of time, with the latter usually including more vulnerable occupants (young, elderly, infirm).

1.4.1 Dissemination

A series of workshops have been organised during the project in cooperation with SIG members and other key stakeholder groups. The objective of these workshops was to promote a bidirectional information flow between PERFORMER and the workshop participants relating to the exploitation potential of PERFORMER achievements and results. In order to obtain a balanced EU perspective on exploitation opportunities, the workshops were organised in different countries by partners in Spain, Poland, the UK and France. The three following workshops have taken place:

- On 26th March 2014, a workshop at Euroconsult's facilities in Madrid was celebrated as part of the Exploitation and Dissemination activities of PERFORMER. The project consortium was represented by SMS Plc (project coordinator), Euroconsult (meeting host) and Dragados (WP6 leaders). The objective of the workshop was to present the objectives and current progress of PERFORMER to a group of companies involved in the energy management sector so that they could provide feedback related to the potential exploitability of the outcomes expected from the project. The objective of the workshop was to present the objectives and current progress of PERFORMER to a group of companies involved in the energy management sector so that they could provide feedback related to the potential exploitability of the outcomes expected from the project.
- The workshop in Poland was held on 4th February 2016 in Poznań as a part of BUDMA fairs, the biggest construction industry meeting in Poland and an event considered to be the largest international trade meeting of the construction industry in Central and Eastern Europe. The project consortium was represented by SMS (project coordinator), ASM-Market Research and Analysis Centre (meeting host) and SEA Developments (owner of the Polish demo building). The objective of the workshop was to present the objectives and current progress of PERFORMER and then discuss the business possibilities with external stakeholders.
- The UK workshop took place on the 28th June 2017 within the framework of the Sustainable Places 2017 Conference (SP17) held at Teesside University, Middlesbrough. PERFORMER was one of the main sponsors of SP17. The majority of consortium partners were present at the conference and thus the workshop, namely SMS, CU, BRE, CCC, CSTB, CEA, ASM and DRA. The objective of the workshop was to discuss the perceived market appetite for the project's exploitable results with external stakeholders and to capture any recommendations that could further strengthen the PERFORMER solution going forward.
- The fourth workshop was advertised through professional networks of the French project partners. An email invitation was prepared and sent to a CSTB contact list of 115 national buildings stakeholders. In total, 32 external participants were registered and 16 actually came to the event representing design offices (design consultants) and building operators. A further 8 project participants were in attendance to co-organise, present and engage in workshop activities. The objective of the workshop was to communicate project objective and obtain participant feedback on emerging outcomes.

PERFORMER has also been co-organising Sustainable Places since 2014; which has proved to be very valuable for project dissemination, engagement of experts and clustering activities. The project has helped the conference to grow from its inception to technology-clusters defined by the EU according to the construction-related research and innovation value chain from the EeB PPP Roadmap. Every year the event attracts around 200 scientists, researchers and engineers from research institutes and industry across Europe and internationally. The conference facilitates knowledge sharing around innovative solutions to ensure long-term and sustainable performance in buildings and cities.

The PERFORMER consortium initially aimed to deliver 12 to 16 presentations on the project objectives and (planned/achieved) results at leading national and international workshops, seminars and conferences during the lifetime of the project. A total of sixteen events relating to energy efficiency, construction and ICT have been attended to disseminate PERFORMER objects and results, with further participation in at least three more events planned beyond the project end date.

All partners committed to present, individually or collectively, contributions to scientific journals and technical magazines, based on their work in the project. A total number of 12 such contributions were expected over the project lifetime. This target has been exceeded as PERFORMER has provided 16 contributions, with further publications planned after the end of the project.

The widest possible dissemination of the project's image, its purpose and key developments to stakeholders was ensured by the project website. It was specified at a very early phase of the project and put online at M2. Throughout the project, any public content (including deliverables) has been made available on the website. The 'Newsroom' section is updated at least once each month and keeps visitors fully informed on project developments including organisation of, and contribution to, events. Apart from the public area, the project website also includes a restricted area that can only be accessed by consortium partners by password. Each partner can enter the area and view private documentation including deliverables with a confidential dissemination level. Partners were required to upload all project documents, agendas, minutes, presentations and reports to ensure effective communication. The following table presents the most important achievements in terms of number of website users.

Table 2 – Number of views through PERFORMER and Sustainable Places websites

WEBSITES	PERIODS	USERS	NUMBER OF PAGE VIEWS
PERFORMER	October 2013-August 2017	10 538	37 064
SUSTAINABLE PLACES	October 2013-August 2017	8 047	36 651
ALL (both websites)	**October 2013-August 2017**	**18 585**	**73 715**

In addition to the defined activities described within this deliverable the project consortium has completed many other dissemination activities. Information on PERFORMER has been published via partners through their social media accounts (Facebook, LinkedIn, Twitter) and websites e.g. a description of the PERFORMER project is included on the ASM website: http://asm-poland.com.pl/badania-i-projekty-miedzynarodowe/performer/.

Information on PERFORMER has also been disseminated during internal meetings of consortium partners e.g. Dragados gave a presentation to ACS Construction Companies and ECG presented PERFORMER and their activities within the project to personnel from national subsidiary companies of ECG. Activities such as these are important, as it allows people who are not directly involved in the project (although they represent the same sector and are often employed by the same entity) to have an opportunity to learn about PERFORMER results.

1.4.2 Exploitation

Following the development and demonstration period of the PERFORMER project, a number of key steps have been identified that are relevant to the future exploitation and rollout of the solution. All relevant licensing issues have been identified to ensure that partners' IP is duly acknowledged and rewarded when utilised by others. Anticipated fees for such licensing have been incorporated into the overall PERFORMER business model and subsequent implementation strategies.

The business model capitalises on the technical advancements of PERFORMER compared to existing tools and will target building owners and managers as well as carefully selected professionals from the construction and services sector (e.g. ESCOs) to support and promote the implementation of PERFORMER.

Research for the model has confirmed that the retrofit market is likely to be the best target audience to get the most from the solution and different 'levels' of offering will allow the solution to be competitive amongst the range of energy management tools already on the market. The costing exercise carried out for the business model has shown that PERFORMER can be offered via different pricing plans. Each plan should help to align with competitor's differing levels of service in order to remain competitive. It can also be demonstrated that enhanced capital commitment by clients investing in more substantial measurement solutions such as PERFORMER can help to reap greater savings.

A critical mass of users has been identified which would need to be secured for the PERFORMER solution to be profitable in the short term and hence truly sustainable. This requires 15 active sites to use the solution on an on-going basis; an average of four buildings in each of the pilot partner regions.

Regional communication strategies have been produced, highlighting the most important users, partners and communication routes for successful dissemination of the solution in each pilot country. Key points have been extracted from pilot experiences to give gravity to promotional communications, i.e. for the production of case studies. A route map has been created to guide users through the various supporting tools and materials for implementation of the PERFORMER solution. This draws together the various technical outputs from the project in a structured way so clients may implement the solution to best suit their needs and aspirations.

The consortium has also considered and pre-empted a number of risks with the aim to reduce their potential detrimental effect on the rollout of the PERFORMER solution. A range of future considerations identified from the pilot phase that would strengthen a commercial offering going forward have also been collated.

PERFORMER has developed a number of tools that can be used in isolation or as part of the overall PERFORMER solution. Separate to the development of the business model for the complete PERFORMER solution, in order to facilitate short term exploitability, an exercise has been carried out based on deconstructing the solution (system) into its constituent parts or 'exploitable results' (ERs) and assessing them individually. Due to the different levels of development of each of those parts, involved project partners will be able to use, exploit, license, or sell some of those ERs before others, thus enabling early recovery of part of the investment in PERFORMER.

Discussions were held amongst partners during the second half of the project to raise the maximum possible awareness about the many difficulties and obstacles involved in the commercialisation of R&D results and to search for common exploitation paths and commercial agreements (licensing agreements, payment of fees for use of patented results, discounts for use if useful deployment and use feedback is provided, etc.). In cases where overlapping interests have been identified, the work done in the exploitation tasks of the project will serve as a starting point for the commercial or research agreements among partners once the project is finished.

Table 3 on the following page shows the different Technology Readiness Levels (TRLs) and expected times for marketability for each of the results.

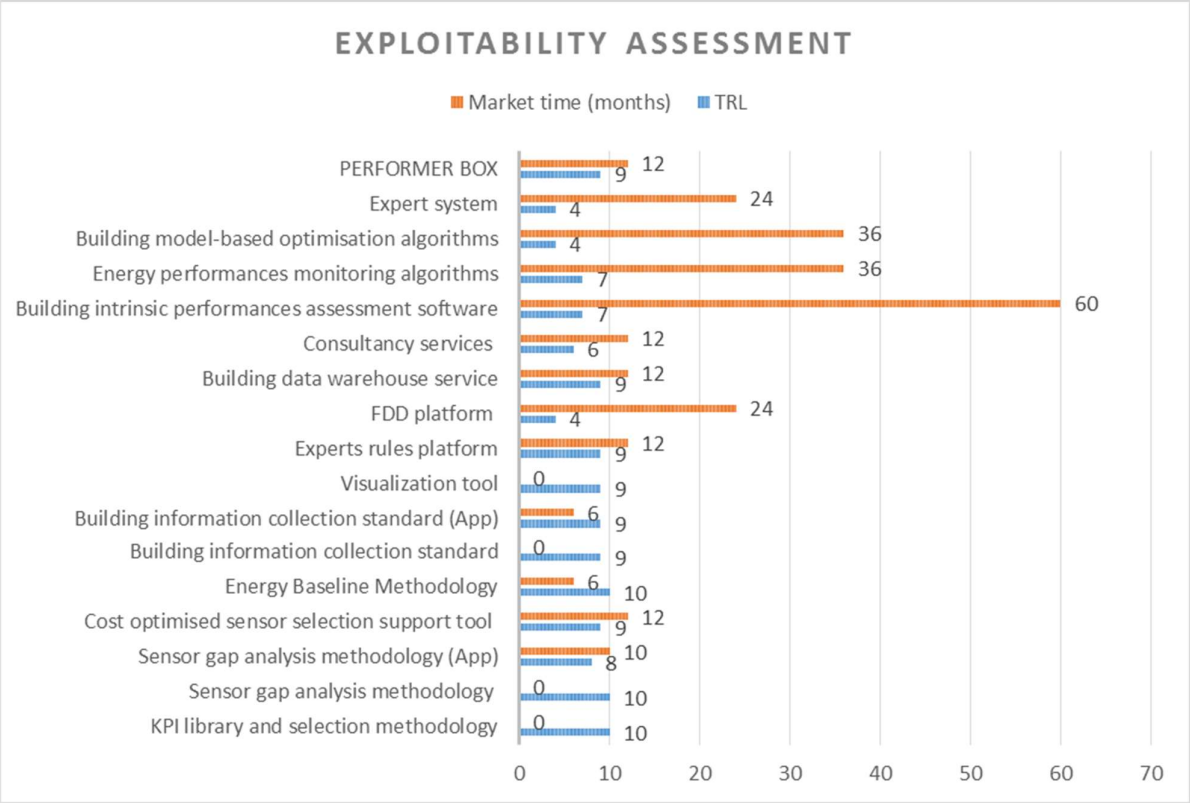

Table 3 - Exploitability summary of key project results, TRL and time to market

The table demonstrates that a large group of results can be exploited in the short term (between 6 and 12 months), including some that will be usable at the end of the project (even if advanced prototype stage, such as is the case with the Visualisation tool). This is not always the case in large integrated R&D projects, so it represents a significant achievement for partners hoping to benefit from PERFORMER in the short term.

Another group of results should become usable in the medium term (between 12 and 24 months), such as the final version of the Building / PERFORMER Data Warehouse system and the fault detection and diagnosis (FDD) platform. Those are important parts for the PERFORMER solution as they provide the highest benefits to its users. The level of investment associated with this time frame is manageable according to the developing partners.

The final group of results are more technologically challenging, such as the Building Intrinsic Performance assessment software and the different sets of algorithms developed in WP2. These will take longer to become usable and marketable. Most of the remaining work for these results will involve further validation in real buildings and fine-tuning based on the feedback received.

1.5 PUBLIC WEB SITE AND RELEVANT CONTACT DETAILS

Please follow the link http://performerproject.eu/ for more information about PERFORMER.

The beneficiaries in the PERFORMER consortium are as follows:

Beneficiary	Description
smsplc	***Project Coordinator – James Sharman – James.Sharman@sms-plc.com*** SMS is the UK's only independent utility infrastructure, smart metering and energy management solutions provider to both the public and private sectors, offering a complete and fully integrated management solution
CSTB le futur en construction	***Technical Coordinator – Marc Bourdeau – marc.bourdeau@cstb.fr*** CSTB is a public organization for innovation in the building sector. With about 900 employees, CSTB performs four key activities: research, expertise, evaluation and dissemination of knowledge, organized to satisfy sustainable development challenges.
cea	A leader in research, development and innovation, CEA is particularly active in low-carbon energies and information technologies. Key figures include 150 start-ups since 1984, a 4.3 billion € yearly budget and more than 530 FP7 projects since 2007.
CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD	The BRE Institute of Sustainable Engineering (ISE) is a multidisciplinary research group at Cardiff University specialising in informatics for resource efficient smart buildings and cities, enabled by integrated design and construction with a total lifecycle approach.
bre	BRE is an independent research-based consultancy, testing and training organisation, offering expertise in every aspect of the built environment. BRE helps clients create better, safer and more sustainable products, buildings, communities and businesses.
DRAGADOS	Dragados (ACS Group) is a general contractor specialized in all types of buildings and infrastructures. Currently, more than 57% of the company's business activities take place outside Spain. The company's turnover in 2012 was over 4,000M€ and the number of employees was 13,474.
EUROCONSULT	EUROCONSULT GROUP is one of the leading Spanish market providers of engineering consultancy in civil works and building construction. With 450 employees, we are also one of the world leaders in road and highway pavement survey services.
ENGIE	ENGIE is a global energy player and an expert operator in the three key sectors of electricity, natural gas and energy services. ENGIE employs 152,900 people worldwide, including 900 researchers and experts at 11 R&D centres.
SAINT-GOBAIN	Saint-Gobain, the world leader in the habitat and construction markets, designs, manufactures and distributes high-performance building materials, providing innovative solutions to the challenges of growth, energy efficiency and environmental protection. With 2012 sales of €43.2 billion, Saint-Gobain operates in 64 countries and has nearly 193,000 employees.
ASM	ASM is a Polish R&D centre founded in 1996, specialised in a wide range of national and European level research & management consultancy in the areas of surveys and analysis for the construction market and other sectors as well as social issues.
CARDIFF CAERDYDD	Cardiff is the capital of Wales & the focal point for devolved Government & decision-making. The city's population is 346,100 but it is at the heart of a city-region of 1.4 million. The City of Cardiff Council is the largest local authority & largest employer in Wales.
SEA Development	Sea Development focuses on developing of three main areas: ecology, health and tourism. They are all implemented in Baltic Plaza Hotel medi SPA & fit., a brand new and modern hotel located in Kolobrzeg, Polish sea-side resort.
IBEROSTAR	Iberostar Las Letras Gran Vía is located in Madrid and belongs to anima hotels group. It was opened in 2005 and it is a tribute to the world of literature. It comprises 109 rooms, Library, Gym, Restaurant, 360 sqm of meeting rooms, Lounge Bar and Penthouse.

2 USE AND DISSEMINATION OF FOREGROUND

This section describes the plan for use and dissemination of foreground. This plan updates the initial plan included in Annex I of the PERFORMER grant agreement relating to use and dissemination of foreground and is consistent with the report on societal implications on the use and dissemination of foreground (Section 3 – H). The plan consists of:

- **Section A: Dissemination measures.** This section describes the dissemination measures, including scientific publications relating to foreground. Its content either has or will be made available in the public domain thus demonstrating the added-value and positive impact of the project on the European Union.

- **Section B: Exploitable foreground.** This section specifies the exploitable foreground and provides the plan for exploitation. The report clearly marks non-publishable (confidential) parts that should be treated as such by the Commission. It is understood that information under Section B that is not marked as confidential will be made available in the public domain thus demonstrating the added-value and positive impact of the project on the European Union.

2.1 SECTION A: DISSEMINATION MEASURES

2.1.1 A1: List of scientific (peer reviewed) publications relating to the foreground of the project

RESPONSIBLE PARTNER	ARTICLE	JOURNAL / MAGAZINE	DATE	REFERENCE
SCIENTIFIC PUBLICATIONS				
Cardiff University	*OPTIMISING THE SCHEDULED OPERATION OF WINDOW BLINDS TO ENHANCE OCCUPANT COMFORT*	Proceedings of BS2015: 14th Conference of International Building Performance Simulation Association, Hyderabad, India	December 2015	http://www.ibpsa.org/proceedings/BS2015/p2683.pdf
Cardiff University and SMS Plc	*Building energy metering and environmental monitoring – A state-of-the-art review and directions for future research*	Energy and Buildings	May 2016	http://www.sciencedirect.com/science/article/pii/S0378778816302158
Cardiff University	*Computational intelligence techniques for HVAC systems: A review*	Building Simulation	August 2016	https://orca-mwe.cf.ac.uk/87217/1/Final_version%20(2)%20(1).pdf
Cardiff University	*Optimizing the Scheduled Operation of Window Opening and Blind to Enhance Indoor Air Quality and Visual Comfort*	Proceedings of IAQ 2016 Defining Indoor Air Quality: Policy, Standards and Best Practices	September 2016	https://www.researchgate.net/publication/292784245_Optimising_the_scheduled_operation_of_window_blinds_to_enhance_occupant_comfort
Cardiff University	*Trees vs Neurons: Comparison between random forest and ANN for high-resolution prediction of building energy consumption*	Energy and Buildings	July 2017	http://www.sciencedirect.com/science/article/pii/S0378778816313937
Cardiff University	*Random Forests And Artificial Neural Network For Predicting Daylight Illuminance and Energy Consumption*	Proceedings of BS2017: The 15th Conference of IBPSA. San Francisco, California, USA	August 2017	http://buildingsimulation2017.org/
ENGIE and CSTB	*Rule based Fault Detection & Diagnosis for high performance buildings: application to a positive energy building in France*	Proceedings of the CLIMA 2016 - 12th REHVA World Congress	May 2016	https://hal-cstb.archives-ouvertes.fr/hal-01312760/file/CLIMA_2016_submission.pdf
ENGIE	*Performance Validation of a Positive Energy Building in France using Advanced Data Analytics and Calibrated Simulation*	Proceedings of the CLIMA 2016 - 12th REHVA World Congress	July 2016	http://vbn.aau.dk/files/233775402/paper_471.pdf
CSTB / SG / CEA	*Short methodologies for in-situ assessment of the intrinsic thermal performance of the building envelope*	ENTREPRENEURSHIP AND SUSTAINABILITY ISSUES	2014	https://www.researchgate.net/publication/287923318_Short_methodologies_for_in-situ_assessment_of_the_intrinsic_thermal_performance_of_the_building_envelope

RESPONSIBLE PARTNER	ARTICLE	JOURNAL / MAGAZINE	DATE	REFERENCE
CEA	*Innovative time series forecasting: auto regressive moving average vs deep networks*	ENTREPRENEURSHIP AND SUSTAINABILITY ISSUES	March 2017	http://jssidoi.org/jesi/papers/papers/view/105
SCIENTIFIC PUBLICATIONS (planned)				
Cardiff University and CEA	*Predicting energy consumption using Deep Highway Networks, Support vector machines and Extremely Randomized*	Energy & Buildings	To be published in 2018	-
NON-SCIENTIFIC PUBLICATIONS (technical magazines, etc.)				
Dragados	*3 articles in M24, M30, M36*	R&D&I Newsletter	August 2015, February 2016 and August 2016	the newsletter is circulated periodically (twice a year) among all the ACS group construction companies worldwide (internal source)
ASM	*Exploitation potential of one of PERFORMER results recently assessed by stakeholders*	BuildUp The European Portal For Energy Efficiency In Buildings	March 2017	http://www.buildup.eu/en/news/exploitation-potential-one-performer-results-recently-assessed-stakeholders
ASM	*Monitoring protocol - a guide accompanying users of PERFORMER solutions*	BuildUp The European Portal For Energy Efficiency In Buildings	January 2017	http://www.buildup.eu/en/news/monitoring-protocol-guide-accompanying-users-performer-solutions
ASM	*PERFORMER project: Deployment Experience Feedback from 4 pilot sites*	BuildUp The European Portal For Energy Efficiency In Buildings	January 2017	http://www.buildup.eu/en/news/performer-project-deployment-experience-feedback-4-pilot-sites
NON-SCIENTIFIC PUBLICATIONS (planned)				
Dragados	*a full article summarizing the project's main outcomes*	R&D&I Newsletter	After the end of the project	-
BRE	*a full article summarizing the project's main outcomes*	Building 4 Change	After the end of the project	-

2.1.2 *A2: List of dissemination activities*

No.	Lead partner	Event description	Medium description	Place	Date	Focus	Coverage	Reference
1	ASM	BUDMA - INTERNATIONAL CONSTRUCTION AND ARCHITECTURE FAIR	Performer fact sheets were available at ASM exhibition stand and distributed by the project representatives. Project aims and results were disseminated during the networking session.	Poznan, Poland	March 2014	Four major groups of visitors: architects, contractors, traders and developers.	Int.	http://www.budma.pl/en/, http://performerproject.eu/asm-exhibiting-budma-march-2014/
2	SIGMA ORIONIS	A meeting on "EU-China Pilot City Exchange" within the EU-China Green smart city cooperation	PERFORMER described in presentation: EU Approaches to Promoting Energy Efficient Buildings and Districts	Beijing	28-30 April 2014	Cooperation meeting	Int.	http://eu-chinasmartcities.eu/?q=node/105
3	CEA	Energy Efficient Building Association General Assembly	Participation & networking	Bruxelles Belgium	October 2014	Approximately 100 attendees (industry & academic domains)	Int.	http://www.e2b-ei.eu/
4	ASM&SEAD	"The region, city, company, society - smart growth in a new perspective of EU funds 2014-2020". The subject of the conference is to provide knowledge audience about the opportunities arising from the development of the 2014-2020 budget perspective in the area of sustainable development, in particular in the area of environment.	Presentation: How to write effective proposals for EU projects in 2014-2020. Horizon 2020 Project Applications. (Performer recalled as a successful idea). Performer fact sheets were distributed by the project representatives and its aims and results were disseminated during the networking session.	Kolobrzeg, Poland	27-28 October 2014	Baltic Cluster sEaNERGIA, enterprises, incl. business institutions, members of the scientific community and local government	Regional	http://konferencja.seanergia.pl/
5	ASM	"Monitoring of Polish Construction Sector" is an annual conference organized by ASM. The purpose of the meeting is to summarize the results gained by construction sector and presentation of current trends and forecasts of construction market development.	Performer was introduced to the gathered audience with the support of promotional materials (project fact sheets) available for the conference members at the ASM stand where the project team was present.	Warsaw, Poland	28 October 2014	Forum bringing together the whole Polish construction society - 175 participants attended the conference	National	http://asm-poland.com.pl/wydarzenia/konferencja-monitoring-rynku-budowlanego/

No.	Lead partner	Event description	Medium description	Place	Date	Focus	Coverage	Reference
6	DRA	CONAMA	DRAGADOS made a presentation related to R&D initiatives to foster EE in buildings and PERFORMER was presented as one of the examples	Madrid, Spain	24-27 November 2014	CONAMA is Spain's most important congress about sustainability.	National	http://www.conama2014.conama.org/web/index.php
7	ASM	XII Regional Conference "Science for the Economy"	ASM presented their experiences of applying for projects and their implementation - PERFORMER was discussed as an example of a successful project, its aims and results were disseminated during the presentation and ASM contribution to the project was described.	Central Museum of Textiles in Łódź, Poland	10th December 2014	Small and medium-sized enterprises, research institutions	Regional	http://www.kpk.gov.pl/?event=xii-konferencja-regionalna-nauka-dla-gospodarki
8	ENGIE (GDF Suez before)	The Village is a whole week event organised by Gdf Suez to gather all the employees and present the projects of the whole Group, The main purpose of this event is to understand how GDF Suez is undertaking a new path into the future of Innovation and the impacts on its activities.	PERFORMER was represented and the team hold a stand and also presented PERFORMER to the audience. As the event mainly focuses on the new technologies developed within the projects, the presentation showed what was developed in PERFORMER and how it was implemented over the pilot sites.	Paris, France	26/01-30/01 2015	Gdf Suez employees, Board of Directors, and other guests.	National	-
9	CSTB	2015 IEEE International Conference on Data Mining Workshop (ICDMW 2015)	Paper entitled "Emergence of Regularities in the Stochastic Behaviour of Human"	Atlantic City, USA	November 2015	Academic - Annual event	Int.	http://icdm2015.stonybrook.edu/
10	CSTB	7th International Work-conference on Ambient Assisted Living (IWAAL 2015)	Paper entitled "Influence of Seasons on Human Behaviour in Smart Environments"	Puerto Varas, CHL	December 2015	Academic - Annual event	Int.	http://mami.uclm.es/ucami-iwaal-amihealth-2015/

No.	Lead partner	Event description	Medium description	Place	Date	Focus	Coverage	Reference
11	Cardiff University	Building Simulation conference (BS2015)	Paper presentation (OPTIMISING THE SCHEDULED OPERATION OF WINDOW BLINDS TO ENHANCE OCCUPANT COMFORT)	Hyderabad, India	7-9 December, 2015	Science & industry	Int.	http://www.bs2015.in/
12	Cardiff University	ASHRAE IAQ conference	Paper presentation (Optimizing the Scheduled Operation of Window Opening and Blind to Enhance Indoor Air Quality and Visual Comfort)	USA	12-14 September, 2016	Science & industry	Int.	https://www.ashrae.org/membership--conferences/conferences/ashrae-conferences/iaq-2016
13	SMS PLC	Energy Innovation Cardiff	PERFORMER description presentation	Cardiff, UK	19th October 2016	Government, Public & Private Sector, Building Owners	National	http://cardiffinnovation.wales/presentations-2016/
14	IBEROSTAR, ECG, DRA	International HVAC & R Exhibition	Presentation: summary of the demonstration activities carried out in the Hotel de las Letras and the outcomes of these activities in terms of improved energy efficiency vs investment.	Madrid, Spain	March 2017	HVAC sectors professionals	Int.	www.cr.ifema.es
15	SMS PLC	Edie Live 2017	Presentation on self-sustaining systems: making energy management activity resilient to changes in the external environment	National Exhibition Centre, Birmingham, UK	23rd May 2017	Energy, sustainability and resource efficiency professionals	National	http://exhibition.edie.net/visit/edie-live-show-features/theatre/energy-efficiency-theatre
16	Cardiff University	Building Simulation conference (BS2017)	Random Forests And Artificial Neural Network For Predicting Daylight Illuminance and Energy Consumption	San Francisco, USA	7-9 August, 2017	Science & industry	Int.	http://www.buildingsimulation2017.org/
PLANNED ACTIVITES								
17	SMS PLC	RWM Exhibition 2017	Exhibition stand and interactive panel discussion on exporting data services for smart city applications	National Exhibition Centre, Birmingham, UK	12-14 September, 2017	National networking event for Waste, Energy, Recycling and Water sectors.	National (although aimed at int. export).	https://www.rwmexhibition.com/welcome#/

No.	Lead partner	Event description	Medium description	Place	Date	Focus	Coverage	Reference
18	SMS PLC	UK construction week 2017	Exhibition stand and two speaker slots.	National Exhibition Centre, Birmingham, UK	10-12 October 2017	Architectural & design firms, developers, contractors, housing groups, associations, local authorities, etc	National	http://www.ukconstructionweek.com/energy-show
19	SMS PLC	TRIBUTE final conference: Closing the Building Energy Performance Gap	Dissemination of PERFORMER project outcomes to sister FP7 project TRIBUTE.	La Rochelle, France	2017-09-20	TRIBUTE project partners, TRIBUTE SIG members	European	http://www.tribute-fp7.eu/FINALCONFERENCE/

2.2 SECTION B: EXPLOITABLE FOREGROUND

2.2.1 Part B1: List of applications for patents, trademarks, registered designs, etc

Type of IP Rights	Confidential (Yes/No)	Foreseen embargo date dd/mm/yyyy	Application reference(s) (e.g. EP123456)	Subject or title of application	Applicant(s) (as on the application)
Patent application	No		FR1750903	Building intrinsic performances assessment software	CEA

2.2.2 Part B2: List of exploitable foregrounds

Type of exploitable foreground	Description of exploitable foreground	Confidential (Yes/No)	Foreseen embargo date dd/mm/yyyy	Exploitable products(s) or measure(s)	Sector(s) of application	Timetable, commercial or any other use	Patents of other IPR exploitation (licences)	Owner & Other beneficiary(s) involved
Methodology + library	Methodology to allow a smart selection of building energy KPIs using predefined libraries.	NO		Methodology to allow a smart selection of building energy KPIs using predefined libraries.	Energy efficiency assessment on the building sector	Right after the ned of the project	Publicly available	CSTB (support from GDF, SMS, BRE, ASM and DRA)
Methodology + product	Methodology for critical measurement identification and sensor gap analysis	NO		Excel-based tool for KPI and sensor selection.	Energy efficiency assessment on the building sector	Spreadsheet - Right after the ned of the project – App – 1 year after end of project if developed	No protection unless an app is developed.	BRE (with support from SMS, ECG and DRA)

Type of exploitable foreground	Description of exploitable foreground	Confidential (Yes/No)	Foreseen embargo date dd/mm/yyyy	Exploitable products(s) or measure(s)	Sector(s) of application	Timetable, commercial or any other use	Patents of other IPR exploitation (licences)	Owner & Other beneficiary(s) involved
Methodology + product	Cost-optimised sensor/meter selection methodology and support tool	NO		Database of sensor/meter solutions with a methodology for qualitative characterization (that has been made objective through impact factors assessment) and allows for future updates.	Energy efficiency assessment on the building sector	1 year after end of project	No protection envisaged	SMS – ECG – Support from all partners
Methodology	Methodology for assessing the minimum data requirements for the assessment of building energy performance baseline	NO		Methodology for the identification and collection of all relevant energy inputs and energy consumption drivers required to establish an accurate building energy baseline against which future energy performance can be compared	Energy efficiency assessment on the building sector	March 2018 (for commercial buildings)	Internal know-how for SMS	SMS
Methodology + product	Building Information collection standard for energy performance assessment	NO		Standard outlining methodology for collecting the critical information required from any building to allow for accurate energy performance assessment	Energy efficiency assessment on the building sector	Template - 2017 (at least for buildings of similar use to pilot buildings). 2018 for the software/App if decided to develop.	Internal know-how for ECG and DRA	ECG- DRA

Type of exploitable foreground	Description of exploitable foreground	Confidential (Yes/No)	Foreseen embargo date dd/mm/yyyy	Exploitable products(s) or measure(s)	Sector(s) of application	Timetable, commercial or any other use	Patents of other IPR exploitation (licences)	Owner & Other beneficiary(s) involved
Software product	Building energy performance tool for the visualization of monitoring data and fault detection	NO		Building performance monitoring visualization tool not dependent on installed hardware.	Energy efficiency assessment on the building sector	It will be operative at the end of the project in beta version. Definitive version, 1 year after project	Internal use for ECG and license agreement for third parties	ECG
Knowledge-based Product	Expert Rules Data Base for building energy performance and users' comfort	No		Set of recommendations to reduce the gap and achieve the expected energy and comfort performance values.	Energy efficiency assessment on the building sector	Approx. 2 years after project's end.	Exclusive rights, license agreement for third parties	SMS, ENG
Product Service	Building data warehouse service	No		Software platform, based on open source tools, allows storing and managing data series collected from a building monitoring system and allows for third-party applications to query and retrieve stored data.	Energy efficiency assessment on the building sector	1 year after end of the project	Internal know-how for CSTB and license agreement for third parties	CSTB

Type of exploitable foreground	Description of exploitable foreground	Confidential (Yes/No)	Foreseen embargo date dd/mm/yyyy	Exploitable products(s) or measure(s)	Sector(s) of application	Timetable, commercial or any other use	Patents of other IPR exploitation (licences)	Owner & Other beneficiary(s) involved
Product	Building intrinsic performances assessment software	NO		software relying on short periods of measurement (an order of magnitude of 2 weeks) and on low-cost, non-intrusive, limited instrumentation to assess buildings' intrinsic performances	Energy efficiency assessment on the building sector	3-5 years after the end of the project	Internal know-how Patent applied during the summer 2016. Currently the international part of the patent is under assessment.	CEA
Product	Energy performances monitoring algorithms	No		Fine-tuned state-of the-art statistical analysis algorithms that can perform an analysis of time series collected from the meters and sensors deployed in a building.	Energy efficiency assessment on the building sector	1-3 years after the end of the project	Internal know-how for CEA and License agreement for 3rd parties	CEA
Product	Building system schedule model-based optimisation algorithms	NO		Set of software modules will use input data from building's sensors and meters, and simulation models of the building to compute optimal schedules of various systems that optimise high-level objectives simultaneously	Energy efficiency assessment on the building sector	3 years after project end at least.	Internal know-how for CU. Algorithms will not be shared until publications are made. No protection is planned apart from that. They will be open source.	CU

Type of exploitable foreground	Description of exploitable foreground	Confidential (Yes/No)	Foreseen embargo date dd/mm/yyyy	Exploitable products(s) or measure(s)	Sector(s) of application	Timetable, commercial or any other use	Patents of other IPR exploitation (licences)	Owner & Other beneficiary(s) involved
Product	Expert system for building energy performance and fault detection and diagnosis	NO		Expert system software module that will automatically detect faults, diagnoses any performance gap and provides recommendations to reduce the performance gap by taking into account the actual and predicted energy consumption.	Energy efficiency assessment on the building sector	2 years after project end at least.	Internal know-how for CU	CU
Product	PERFORMER Box	NO		Software toolkit developed for creating embedded applications for smart building, which is technology agnostic	Energy efficiency assessment on the building sector	1 year after project end at least.	Internal know-how for CSTB and License agreement for 3rd parties	CSTB

3 REPORT ON SOCIETAL IMPLICATIONS

A General Information	
Grant Agreement Number:	609154
Title of Project:	PERFORMER
Name and Title of Coordinator:	James Sharman

B Ethics	
1. Did your project undergo an Ethics Review (and/or Screening)?	No
If Yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final project reports?	N/A
2. Please indicate whether your project involved any of the following issues (tick box) :	
RESEARCH ON HUMANS	
· Did the project involve children?	No
· Did the project involve patients?	No
· Did the project involve persons not able to give consent?	No
· Did the project involve adult healthy volunteers?	No
· Did the project involve Human genetic material?	No
· Did the project involve Human biological samples?	No
· Did the project involve Human data collection?	No
RESEARCH ON HUMAN EMBRYO/FOETUS	
· Did the project involve Human Embryos?	No
· Did the project involve Human Foetal Tissue / Cells?	No
· Did the project involve Human Embryonic Stem Cells (hESCs)?	No
· Did the project on human Embryonic Stem Cells involve cells in culture?	No
· Did the project on human Embryonic Stem Cells involve the derivation of cells from Embryos?	No
PRIVACY	
· Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	No
· Did the project involve tracking the location or observation of people?	No
RESEARCH ON ANIMALS	
· Did the project involve research on animals?	No
· Were those animals transgenic small laboratory animals?	No
· Were those animals transgenic farm animals?	No
· Were those animals cloned farm animals?	No
· Were those animals non-human primates?	No
RESEARCH INVOLVING DEVELOPING COUNTRIES	
· Did the project involve the use of local resources (genetic, animal, plant etc)?	No
· Was the project of benefit to local community (capacity building, access to healthcare, education etc)?	No
DUAL USE	
· Research having direct military use	No
· Research having the potential for terrorist abuse	No

C Workforce Statistics

3. Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).

Type of position	Number of women	Number of men
Scientific Coordinator	0	1
Work package leaders	1	6
Experienced researchers (i.e. PhD holders)	7	47
PhD Students	0	1
Other	8	54

4. How many additional researchers (in companies and universities) were recruited specifically for this project?	3
Of which, indicate the number of men:	1

D Gender Aspects

5. Did you carry out specific Gender Equality Actions under the project?	x	Yes
	✓	No

6. Which of the following actions did you carry out and how effective were they?

	Not at all effective		Very effective
o Design and implement an equal opportunity policy	o	o o o o	
o Set targets to achieve a gender balance in the workforce	o	o o o o	
o Organise conferences and workshops on gender	o	o o o o	
o Actions to improve work-life balance	o	o o o o	
o Other:			

7. Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?

o Yes- please specify

✓ No

E Synergies with Science Education

8. Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?

o Yes- please specify

✓ No

9. Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?

✓ Yes- please specify: At St.Teilo's new weather station data can be used as an educational tool as the graphical display has been designed to be child friendly.

o No

F Interdisciplinarity

10. Which disciplines (see list below) are involved in your project?

o Main discipline: NATURAL SCIENCES (Mathematics and computer sciences)

o Associated discipline: ENGINEERING AND TECHNOLOGY (Electrical engineering, electronics)

G Engaging with Civil society and policy makers

11a. Did your project engage with societal actors beyond the research community? (if 'No', go to Question 14)	✓	Yes
	x	No

11b. If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?

o	No
o	Yes- in determining what research should be performed
✓	Yes - in implementing the research
✓	Yes, in communicating /disseminating / using the results of the project

11c. In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?	x	Yes
	✓	No

12. Did you engage with government / public bodies or policy makers (including international organisations)

o	No
o	Yes- in framing the research agenda
o	Yes - in implementing the research agenda
✓	Yes, in communicating /disseminating / using the results of the project

13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers?

o	Yes – as a primary objective (please indicate areas below- multiple answers possible)
✓	Yes – as a secondary objective (please indicate areas below - multiple answer possible)
o	No

13b If Yes, in which fields?

Agriculture		Energy	✓	Human rights	
Audiovisual and Media		Enlargement		Information Society	
		Enterprise		Institutional affairs	
Budget		Environment	✓	Internal Market	
Competition		External Relations		Justice, freedom and security	
Consumers		External Trade			
Culture		Fisheries and		Public Health	
Customs		Maritime Affairs		Regional Policy	
Development		Food Safety		Research and	✓
Economic and Monetary Affairs		Foreign and Security Policy		Innovation	
				Space	
Education, Training, Youth		Fraud		Taxation	
		Humanitarian aid		Transport	

13c If Yes, at which level?

o	Local / regional levels multiple answers possible)
o	National levelmultiple answer possible)
✓	European level
o	International level

H Use and dissemination

14. How many Articles were published/accepted for publication in peer-reviewed journals?	6
To how many of these is open access provided?	6
How many of these are published in open access journals?	6
How many of these are published in open repositories?	6
To how many of these is open access not provided?	0
Please check all applicable reasons for not providing open access:	N/A
☐ publisher's licensing agreement would not permit publishing in a repository	
☐ no suitable repository available	
☐ no suitable open access journal available	
☐ no funds available to publish in an open access journal	
☐ lack of time and resources	
☐ lack of information on open access	
☐ other	

15. How many new patent applications ('priority filings') have been made? *("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).*		1
16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark	0
	Registered design	0
	Other	0
17. How many spin-off companies were created / are planned as a direct result of the project?		0
Indicate the approximate number of additional jobs in these companies:		N/A

18. Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project:

☐	Increase in employment, or	☐	In small & medium-sized enterprises
☐	Safeguard employment, or	☐	In large companies
☐	Decrease in employment,	☐	None of the above / not relevant to the project
✓	Difficult to estimate / not possible to quantify		

19. For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (FTE = one person working fulltime for a year) jobs:	Indicate figure:
Difficult to estimate / not possible to quantify	✓

I Media and Communication to the general public

20. As part of the project, were any of the beneficiaries professionals in communication or media relations?

✓	Yes	o	No

21. As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?

✓	Yes	o	No

22.Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?

☐	Press Release	☐	Coverage in specialist press
☐	Media briefing	☐	Coverage in general (non-specialist) press
☐	TV coverage / report	☐	Coverage in national press
☐	Radio coverage / report	☐	Coverage in international press
✓	Brochures /posters / flyers	✓	Website for the general public / internet
✓	DVD /Film /Multimedia	✓	Event targeting general public (festival, conference,

23. In which languages are the information products for the general public produced?

☐	Language of the coordinator	✓	English
☐	Other language(s)		