Deliverable 3.4
Recommendations for New Standards to Overcome Interoperability Barriers

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EXECUTIVE SUMMARY

REViSITE is working for the European Commission to identify cross-sectoral research priorities, covering the domains of grids, manufacturing, buildings and lighting, in support of ICT for Energy Efficiency (ICT4EE). The priorities are needed to direct EC funding for Research in Technological Developments in this area.

Our initial analysis of recent and current research initiatives in the area of ICT4EE suggests that the following research areas are of high priority:

1. Technical interoperability and standardisation
2. Design for energy-efficiency in all sectors
3. Metrics and methods for quantitative assessment of ICT impacts
4. Substantiating the casual connection between research and technical development
5. Data visualisation and decision support particularly in the usage phase of each *sector*

This document provides an overview of pertinent standards for energy efficiency in each of the four sectors (chapter 2). Chapter 3 of this document contains the Cross sectoral standardisation opportunities and main barriers in interoperability standards for energy efficiency. Recommendations to bridge the identified standardisation gaps and to gain from cross-sectoral synergies are formulated in chapter 4.

Through the construction of the Strategic Research Agenda (SRA), the REViSITE Framework and SMARTT Taxonomy an overview of standardisation requirements have been compiled. In terms of rigour, this overview was put through a sanity check, a review by sector specialists and a validation workshop to add ranking and priorities. The process provided an insight into the urgency, contents and scope of standards that are widely considered to be essential for energy efficiency. The key recommendations are:

- Extension of existing ontologies for energy efficiency (eeBDM)
- Energy performance indicators (Metrics and measurement)
- Product catalogues that include energy dynamics
- Data exchange protocols
- Harmonisation and extension of the IEC Ontology

This document underpins the need for these recommendations and offers additional details for each of the suggestions from a cross-sectoral viewpoint. The recommendations have been aligned withy the members of the REViSITE expert group. We would like to thanks the REG-members for their insights and support. The concluding recommendations have been validated through the Paris workshop (see appendices for attendance and voting results). We would also like to express our gratitude towards the participants of the validation workshop for the contribution and constructive discussions.

ACRONYMS AND TERMS

Acronyms	Description
BAN	Building Area Network
BAS	Building Automation System
BMS	Building Management System
CIM	Common Information Model. Domain Ontology of the IEC TC57 Reference Architecture. Formalized through the IEC 61970-301 standard.
DER	Distributed Energy Resources
EISA	USA Energy Independence and Security Act of 2007
EMS	Energy Management Systems
ETP	European Technology Platform
HAN	Home Area Network
MDA	Model Driven Architecture
NAN	Neighbourhood Area Network
NB-PLC	Narrowband power line communications
NIST	National Institute for Standards and Technology (USA)
OLE	Object Linking and Embedding
OPC	Object Linking and Embedding for Process Control
RTD	Research & Technical Development
SGIP	Smart Grid Interoperability Panel (of the NIST)
SAE	Society of Automotive Engineering
SO	Standards Organisation
SRA	Strategic Research Agenda
W3C	World Wide Web Consortium

1. INTRODUCTION

1.1 Purpose

The REViSITE project co-ordinates co-operation and communication within the multidisciplinary 'ICT for energy-efficiency' research community in Europe. The focus is on 4 industrial disciplines: manufacturing, the built environment, lighting and grids. The core of this community are the European Technologies Platforms that represent RTD in these sectors. These industry sectors often come together in delivering infrastructures and environments for production, business and living. Together they produce and consume most energy in Europe.

Although versatile statistical information is available on energy consumption in various countries and industrial sectors, there is still limited understanding about the potentials of ICT to reduce it. Indeed the area of ICT impact assessment is immature. REViSITE had to develop a framework to assist in understanding how ICT can impact on energy consumption in the four key sectors. Based on available statistical data and, where such data is not available, estimations by experts, the project identifies the RTD priorities for ICT4EE.

The project engaged key stakeholders from the four sectors to compare and analyse sector specific RTD agendas such as Strategic Research Agendas (SRAs) of the relevant European Technology Platforms (ETPs), European and national RTD initiatives etc. A consolidated roadmap, and the associated impact potentials, was derived as a synthesis. The focus of this document is on interoperability and it provides recommendations on standards for overcoming interoperability barriers to cross-sector opportunities.

The purpose of this document is to:

- Identify the relevant existing and emerging standards that affect energy consumption in the target sectors.
- Identify the commonalities and opportunities for convergence of these standards across the four sectors.
- Identify the opportunities for enhancing interoperability between the four target sectors.
- Formulate recommendations for standards bodies and relevant organisations to facilitate convergence of standards for ICT for energy efficiency in a non sector specific way.

1.2 Contributions of partners

The consortium provides an overview over existing standards for energy efficiency in alignment with the consortium sector focus in chapter 2 according to KEMA on grids, CSTB on buildings, VTT on lighting and FHG on manufacturing. The other contributions are listed below:

FHG

- Materialisation ICTs - Cross sectoral standardisation opportunities
- Energy performance indicators (Metrics) - Key proposals for standardisation

VTT

- Specification & design ICTs - Cross sectoral standardisation opportunities
- Product catalogues that include energy dynamics - Key proposals for standardisation

CSTB

- Technical Integration ICTs - Cross sectoral standardisation opportunities
- Extension of existing ontologies for energy efficiency - Key proposals for standardisation

INTEL

- All sections of "Sectoral standards related to ICT4EE" (with LOU)
- Automation & operational decision support ICTs & Resource & process management
- Data exchange protocols - Key proposals for standardisation

LOU

- Sections of Sectoral Standards related to ICT4EE (with INTEL)
- Section on Data Exchange Protocols
- General review and edits of the deliverable

KEMA

- Trading / transactional management ICTs - Cross sectoral standardisation opportunities
- Harmonisation and extension of the IEC Ontology - Key proposals for standardisation
- Overall document edits (Executive summary; Acronyms and terms; Introduction, Conclusions, Main Findings, References, etc.)

The recommendations have been aligned withy the members of the REViSITE expert group (REG) and validated by the participants of the validation workshop in Paris.

1.3 Methodology

The standardisation recommendations in this document were prepared using the surveys for the Implementation Action Plans (IAP as documented in the REViSITE D3.3 deliverable). Specific experts provided inputs with regard to the standards that would be required to bridge gaps and overcome barriers for cross-sectoral cooperation. These inputs have been put through a sanity check in order to verify the validity in each of the specific sectors. IAP's have been defined for each of the 23 SRA research topics subsequently (See Figure 1). Most of these IAP's contain recommendations for standardisation bodies as a measure to enable the cross-sectoral interoperability. These items have been synthesized into more generic topics, five in total, that apply to multiple sectors and capture the breath of the recommendations. The 5 high-level standardisation topics were presented for validation and ranking at the REViSITE workshop which was held in Paris on 9 March 2012. The results of the validation were used for the final REViSITE recommendations that are documented in this deliverable (D3.4).

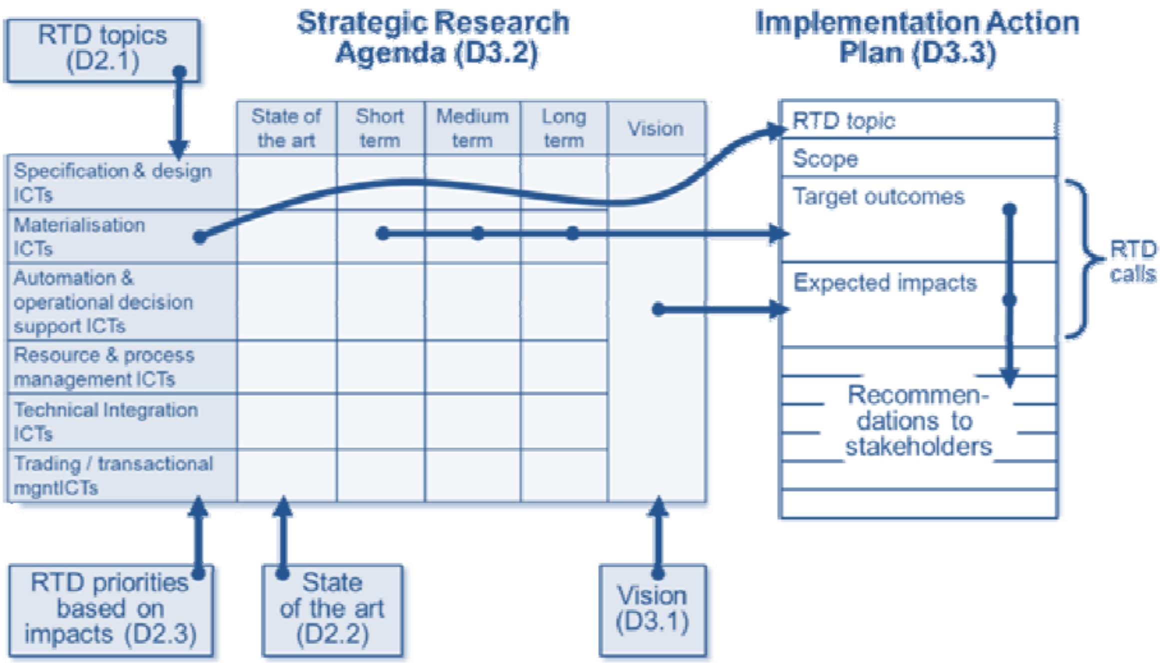

Figure 1: Information Flow from the REViSITE SRAs to IAP development

The ranked proposals for standardisation exhibit great complexity. The Paris workshop indicated that the standards and the processes that create and maintain the standards are difficult to grasp. An overview is difficult as lots of different and partially overlapping standards already exist. This is the case particularly in the area of communication protocols.

A further barrier identified was in relation to the time it would take to establish a mature international cross-sectorial standard or ontology in the ICT4EE domain. The CIM ontology took some 20 years to achieve its current maturity level. Current developments in technology however are much faster and would require a more flexible and agile standardisation creation and maintenance process.

Some of the disciplines involved in the discussions are relatively young (semantic web technologies, remote sensing, energy and carbon metrics, etc.). Some of these may require more context specific research before being stable enough for definitive standards. The subject matter knowledge that is needed for the standardisation may need further development.

2. Sectoral standards related to ICT4EE

2.1 Introduction

While the focus of REViSITE has been described as ICT4EE [Information Communication Technology For Energy Efficiency] in reality it can be described at a higher level as the interoperability of *smart energy ecosystems* which include built environments, the industries they house and the energy grids that power them.

The pivotal role standards development and structuring will have in realising a smart ecosystem vision is apparent but challenging. Smart ecosystems are complex environments with many existing and emerging standards. The Smart Grid Interoperability Panel [SGIP] of the US NIST identified greater than 100 standards with regard to smart grids alone. While Building Automation Systems, Building Information Models, Lighting Control and Manufacturing all bring additional standards with them.

But are standards that relate to Smart Grids, Buildings, Manufacturing or Lighting by association standards that relate to ICT4EE? Some might argue that they are not if viewed from a direct energy impact perspective. However, the REViSITE position has consistently argued that there are ICTs [by association standards] that are direct enablers of energy efficiency and there are ICTs that are indirect enablers. To focus on direct enablers alone would by myopic.

In the context of ICT4EE, energy efficiency can be viewed as a desirable by-product of adding ICT enabled intelligence to existing and emerging Energy Ecosystems. Standards in this space need to support more generic concepts:

- Openness
- Interoperability
- Empowerment
- Flexibility, Scalability & Extensibility
- Security and Data Privacy

The ICT sector is an inherent horizontal enabler that seeks to address these needs by promoting existing and evolving IP protocols as a core backbone of an interoperable smart-ecosystem communications network. Collectively sectors must leverage standards to enable interoperability in supporting communication between networks of devices, energy data exchange and new energy services from utilities or other service providers, empowering users while ensuring industry best practices in terms of security and privacy. The current focus is more ‘ICT’ than ‘EE’. However, the result will be more energy efficient manufacturing, built environments and energy grids.

As such the sections that follow outline some of the more important standard organisations (SOs), standards and initiatives relating to ICT enabled ‘Smart’ visions whereby energy efficiency is an envisaged inherent outcome.

2.2 Grids

The future trans-European grids must provide all consumers with a highly reliable, cost-effective power supply, fully exploiting the use of both large centralised generators and smaller distributed power sources throughout Europe [4]. The conclusions of the European Council of 4 February 2011 confirm the urgent need to adopt European standards for Smart Grids. The challenges and functionalities that connect to this energy infrastructure are commonly referred to as the “Smart Grid” vision. The smart grid will allow for a larger scale deployment of new technologies and wider varieties in the areas of (distributed) generation (wind, hydro, solar) and operations (DSM, voltage optimisation, reversal of power flows, etc.) [3]. In order to meet the shared criteria of the smart grid vision (flexibility, accessibility, reliability and economics [3]) additional technological and legislative measures are required. Because of the wide range of the participants who will be affected by this transition, some believes it’s more accurate to refer to the new utility landscape as a “smart energy ecosystem” that’s collaborative and integrated [9]. Advances in information and communication technology are expected to provide essential tools for smart grids. Establishing shared technical standards and protocols that will ensure open access and enabling the deployment of equipment from any chosen manufacturer is one of the key elements of the smart grid vision [2]. This paragraph describes the current state-of-the-art with regard to interoperability standards in the smart grid domain.

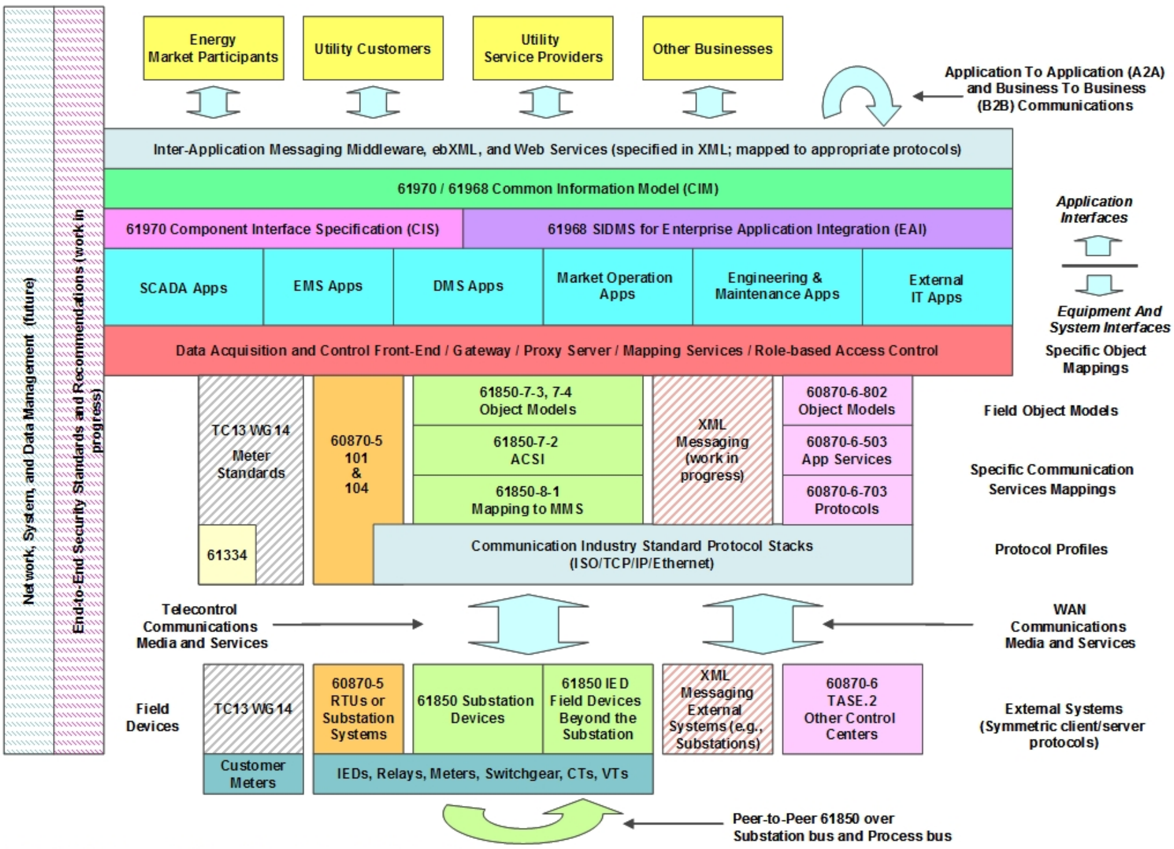

Figure 2: The IEC TC57 Reference Architecture

The IEC identified [Figure 2] a suite of standards relevant for the development and maintenance of the smart grid. Table 1 shows examples of such IEC standards as well as other standards relevant in the context of ICT4EE, while tables 2 and 3 that follow give examples of relevant standards and non-standards organisation pertinent to the smart grid domain.

Table 1: Examples of relevant Smart Grid & related standards

IEC 62357	IT Architecture Standard on Services Oriented Architectures (SAO)
IEC 61970	EMSAPI Standard (CIM, the reference architecture domain ontology)
IEC 61850	Communication, network and system standard for substation automation
IEC 61968	Interface specification of DMS
IEC 62351	Cyber Security Standard
IEC 62056	Data exchange for meter reading, tariff and load control
IEC 61508	Functional safety of electrical/electronic/programmable electronic systems
IEEE 2030-2011	Posited as the first all-encompassing standard on smart grid interoperability *'supports EISA, the NIST framework coordination efforts, IEC interests, and additional smart grid applications. It focuses on a systems-level approach to understanding and guidance for interoperability components of communications, power systems, and information technology platforms'*
ITU-T G.9955 G.9956	NB-PLC standards focused on '*…smart grid applications such as distribution automation, diagnostic & fault location, smart metering, demand response, energy management, smart appliances, grid-to-home comms. & advanced recharging systems for electric vehicles'*
SAE J2836-1	Use cases for communication between plug-in vehicles and the utility grid
SAE J2847-1	Communication between plug-in vehicles and the utility grid

Table 2: Relevant Standards Organisations, examples

Org	Scope
IEC TC08 Systems aspects for electrical energy supply	To prepare & coordinate, in co-operation with other TC/SCs, the development of international standards & other deliverables with emphasis on overall system aspects of electricity supply systems & acceptable balance between cost & quality for users
IEC TC57 Power systems management & associated information exchange	To prepare international standards for power systems control equipment & systems including EMS, SCADA, distribution automation, teleprotection, & associated information exchange for real-time & non-real-time information, used in the planning, operation & maintenance of power systems
NIST – SGIP Smart Grid Interoperability Panel	The SGIP engages [on behalf of the US NIST] stakeholders from the entire Smart Grid Community in a participatory public process to identify applicable standards, gaps in currently available standards, & priorities for new standardization activities
IEEE SCC21 Standards Coordinating Committee on Fuel Cells, PV, Dispersed Generation & Energy Storage	Oversees standards development in the areas of fuel cells, photovoltaics, dispersed generation & energy storage. Coordinating efforts among IEEE Societies & other orgs to ensure all standards are consistent & properly reflect the views of all applicable disciplines. IEEE 2030 Sponsors

Table 3: Relevant non-standard Organisations, examples

Org	Scope
GridWise Alliance	Industry coalition *'advocating for the transformation of the electric system for the public good'*. GridWise *'promotes the advancement of the electric system through thought leadership, production of white papers and reports, and legislative advocacy.'* It has 137 members include utilities, technology companies (large & small), telecommunications companies, equipment manufacturers & academia
Demand Response and Smart Grid Coalition	Trade association for companies that works to educate & provide information to policymakers, utilities, the media, the financial community & stakeholders on how demand response and smart grid technologies can help modernize our electricity system and provide customers with new information & options for managing their electricity use.
Friends of the Supergrid	A group of companies & organisations which have a mutual interest in promoting & influencing the policy & regulatory framework required to enable large-scale interconnection in Europe.

Of particular note from a standards perspective is IEC standards 61970-301 and 61968-11 which collectively are known as the Common Information Model (CIM) - the domain ontology of the Smart grid reference architecture.

Of additional interest is the Smart Grid Interoperability Reference Model (SGIRM) and methodology of the IEEE 2030 standard 'intended to present interoperable design and implementation alternatives for systems that facilitate data exchange between smart grid elements, loads, and end-use applications'. The SGIRM is 'a conceptual representation of the smart grid architecture from three Interoperability Architectural Perspectives (IAPs), namely power systems, communications and information technology. It presents a set of labelled diagrams that offer standards-based architectural direction for the integration of energy systems with communications and information technology infrastructures of the evolving Smart Grid. It aims to establish a common language and classification for the smart grid community to communicate effectively' [10] Ontology engineering and holistic data modelling in the context of smart energy eco-systems is a subject to which we will return in sections 3 and 4.

From an operational perspective the HAN / BAN / NAN standards are dealt with in detail in the built environment section. But Figure 3 below is a good illustration of the varied and interconnected ICT-standard areas that are relevant to a Smart ecosystem context [15].

From an operational maintenance perspective the argument to use Model Driven Architectures (MDA) is underpinned by the need to separate (business) logic from the technology infrastructure. Most of the Smart Grid components will rely on software. Hardware components will be largely standardized due to the massive extent of the application and are expected to be replaced by "newer" versions in rapid succession. The success of the smart grid can therefore not depend on the "boxes" currently used. The Model-Driven Architecture approach defines system functionality using a platform-independent model (PIM) and utilise automated tools to perform translation into source code. The MDA model is related to multiple standards, including the Unified Modeling Language (UML), the Meta-Object Facility (MOF), XML Metadata Interchange (XMI), Enterprise Distributed

Object Computing (EDOC), the Software Process Engineering Metamodel (SPEM), and the Common Warehouse Metamodel (CWM).

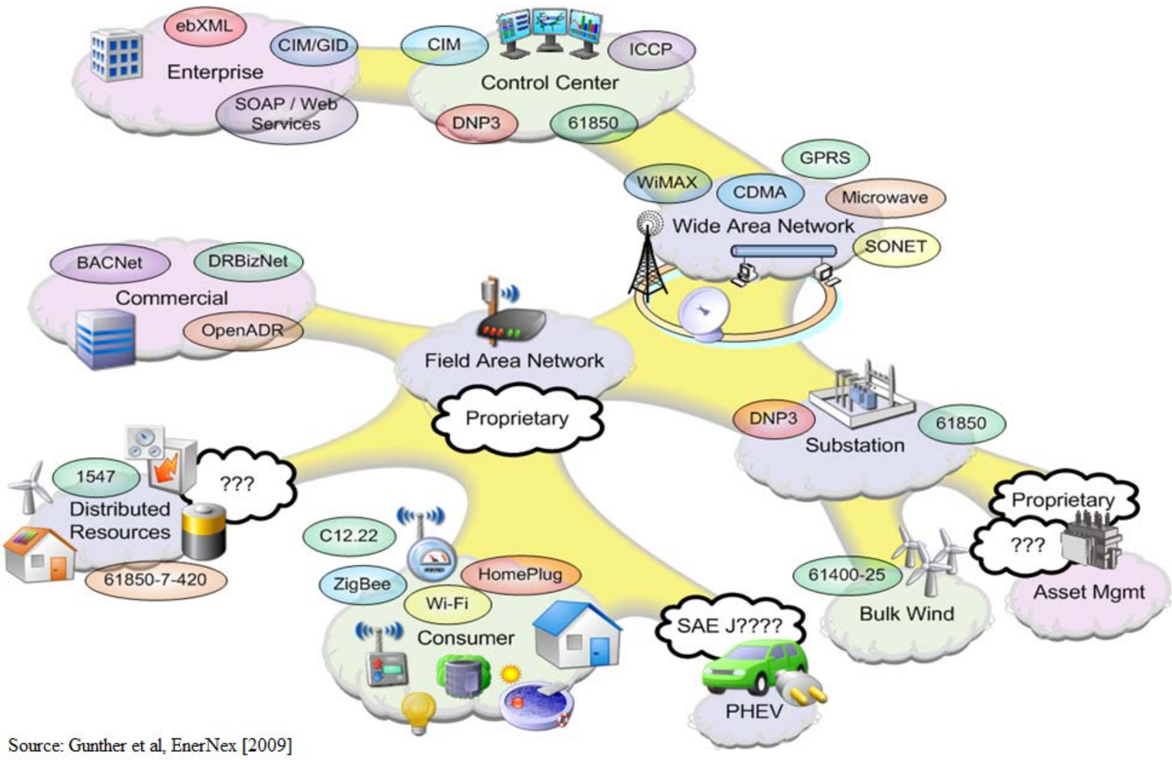

Figure 3: An illustration of the varied SmartGrid standards domain areas.

In addition to various standards and specifications there are additional mandates that pertain to the smart grid:

- **In March 2009** the European Commission issued a mandate to the European standardisation organisations (ESOs) CEN, CENELEC and ETSI to establish European standards for the interoperability of smart utility meters (electricity, gas, water and heat), involving communication protocols and additional functionalities, such as assuring interoperability between systems to provide secure communication with consumer's interfaces and improve the consumer's awareness to adapt its actual consumption. The ESOs were to provide European standards for communication in March 2010 and complete harmonised solutions for additional functions by December 2011. The first deliverables for European standards for smart meters are expected by the end of 2012.
- **In June 2010**, the Commission issued a mandate to ESOs (ETSI and CENELEC) to review existing standards and develop new standards for the interoperability of chargers for electric vehicles with all types of electric vehicles and with electricity supply points. There is a wide consensus that Europe urgently needs such standards, some of which are listed in table 1.
- **On 1 March 2011**, the Commission issued a mandate to ESOs for Smart Grids to develop standards facilitating the implementation of high-level Smart Grid services and functionalities by the end of 2012. As the mandate builds on the consensus achieved among the stakeholders participating in the Task Force and the ESO Joint Working Group on Smart Grids, this should ensure a smooth and fast process.

In summary, there is a high level of activity in the smart grid standards domain, testimony to its importance in the context of smart energy eco-systems and 2020 goals. But smart grids deployment will be a continuous learning process and standardization should include a clear set of processes to cope with this learning process [5]. For example the current IEC reference architecture (Figure 2) includes protocol standards that provide coverage for various functional interfaces without shared ontologies, semantic definitions and generic use-cases. The adaptation of the current standardisation structure will be governed by schedules and therefore have to re-use existing insights in order to ensure future-proof conventions. Due to the maturity of the current standards and the existing commitments the "learning process" for standards will have to manage "changes" as part of the life-cycle maintenance processes.

Chapter 3 of this document covers the Cross sectoral standardisation opportunities and barriers to interoperability and standards for energy efficiency. Recommendation towards bridging the standardisation gabs and enable cross-sectoral synergies are put forward in chapter 4.

2.3 Buildings

As discussed standards ensure a common definition and basis for all that leads to better quality and reliability in terms of information exchange in a heterogeneous environment. This section relates to the built environment [BE]. The text, tables and figures that follow describe some of the most relevant standards, standards organisations and organisations in the BE space. The standard and protocols described deal with data/information exchange particularly pertinent to BE design phase and on the BE exploitation / operational phase.

Figure 4 below represents a layered representation of the various concepts in relation to the BE Life cycle and specifically the energy flow throughout same. Layers closer to the Built environment represent those layers that are conceptually nearer to the physical with subsequent layers moving closer to the abstract or application layers. All grey coloured levels are essentially conceptualisations of the actual physical buildings (black coloured level).

In the figure there is significance to the direction of the shapes representing the various protocols, which levels they span and in the way they span those levels. For example, the KNX protocol is built up from the field level to the management level, but BACnet is more focused at the management level and is less defined at the field level, this is represented visually by the direction or more so the amount of area of the shape at the respective levels.

A BMS is a horizontally layered system of sensors, actuators, controllers and user interface devices orchestrated to work together over selected communication media. Additionally, a BMS may also be divided vertically across different building subsystems such as HVAC, Fire, Security, Lighting, Shutters and Elevator control systems. Today most BMSs communicate over four media; EIA-485, DALI, Ethernet and wireless. Sensors, actuators, area controllers, zone controllers, and building controllers most often connect via EIA-485 3-wire twisted pair serial media.

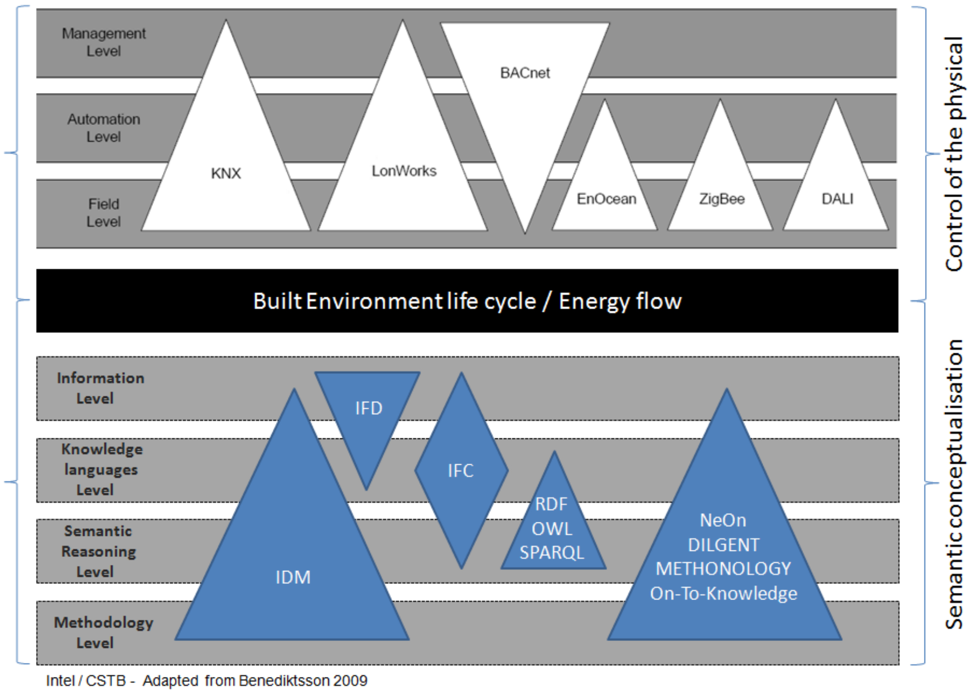

Figure 4: Mapping protocols / standards onto architectural levels of BMS / BAS

The tables that follow aim to illustrate some of the predominant standards and protocols in the BE domain, and give an indication of the ubiquitous nature and importance ICT technology and the interoperability of same has for the built environment and smart energy ecosystems.

Table 4: Relevant Building Standards Organisations, examples

Technical committee	Scope
ISO – TC 59 Building & Civil Engineering Work	Scope includes standardization in the field of building and civil engineering works, of: general terminology; organization of information in the processes of design, manufacture and construction; general geometric requirements for buildings, building elements and components including modular coordination and its basic principles, general rules for joints, tolerances and fits etc Example sub-committee - TC 59/SC 13 ‘Organisation of information about construction works’
ISO – TC184 Industrial automation systems and integration	This TC has produced a lot of standards, among which, the Construction sector is particularly interested by the work achieved by –TC184/SC4 concerning the IFC: ISO/PAS 16739:2005: Industry Foundation Classes, Release 2x, Platform Specification (IFC2x Platform).
ISO – TC205	Building environment design is also an interesting ISO TC from the REViSITE perspective. It has nine WGs e.g. WG2 Design of energy-efficient buildings and WG3 Building Automation and Control System (BACS) Design. Application of BIMs will probably be one of its future directions.
CEN-TC247 Building automation, controls and building management	Focused on the definitions, requirements, functionality and test methods of building automation products and systems for automatic control of building services installations and the primary integration measures

	including application interfaces, systems and services to ensure efficient technical building management in co-operation with commercial and infrastructure building management. Excluded from this scope are areas of building automation that are under the responsibility of other CEN/CENELEC TCs.
CENELEC-T205 Home and Building Electronic Systems	To prepare standards to ensure integration of a wide spectrum of control applications & the control & management aspects of other applications in & around homes/buildings, including the gateways to different transmission media & public networks taking into account all matters of EMC & electrical/functional safety. TC 205 will not prepare device standards but the necessary performance requirements & necessary hardware/software interfaces
CEN-TC228 Heating systems in buildings	Scope includes standardisation of functional requirements for all types of heating systems in buildings, including domestic hot water production: General requirements for performance design installation and commissioning, Requirements for preparation of instructions for operation and maintenance; - Methods for calculation of design heat loads etc

Table 5: Relevant non-standard organisational examples

Org	Title
BuildingSMART	an international organisation bringing together architects, engineers, constructors, product manufacturers and facilities managers, along with software vendors and progressive construction customers. It has created the Industry Foundation Classes (or IFCs), the Information Framework Dictionary (IFD), the Information Delivery Manual (IDM). See fig 2 regarding how these standards / protocols map onto architectural levels of BMS / BAS
OASIS oBIX TC	The purpose of oBIX (open Building Information Exchange) is to enable the mechanical and electrical control systems in buildings to communicate with enterprise applications, and to provide a platform for developing new classes of applications that integrate control systems with other enterprise functions. Enterprise functions include processes such as Human Resources, Finance, Customer Relationship Management (CRM), and Manufacturing.
eeBDM / EE4E2B forum	ICT4E2B Forum is a EU project mapping the sector-specific priorities into a common view and vocabulary, thereby enabling communication and understanding between experts indifferent sectors that need to join forces in order to achieve improvements in energy efficient buildings. A relevant aspect is covered by Data Models,which represents an enabling infrastructure for the actual implementation of future ICTs in the EeB context and that covers all relevant priority areas identified by the ICT4E2B Forum.

Table 6: Communication/control network protocol, examples

Code	Title
BACnet: CEN EN ISO 16484-5	A worldwide Standard application layer protocol designed to maximize interoperability across many products, systems and vendors in commercial buildings. BACnet supports six media types including

	Ethernet (802.3 and IP), EIA-485, Arcnet, LON, RS-232 and ZigBee. BACnet supports all expected network services including functions such as device and object discovery; unicast and broadcast messaging; full routing; flow control and fragmentation, and network security. BACnet support covers the Web Services interface enabling information exchange from BACnet networks between external ICT based systems.
LonWorks: CEN EN 14908, ISO/IEC 14908-1	A platform built on a protocol created by Echelon Corporation for networking devices over various media. It is an underlying control networking technology used for connecting products and solutions including lighting, HVAC, Security, and Automation systems. LonWorks is used for networking devices over media such as twisted pair, powerline carrier, and wireless.
KNX: CENELEC EN 50090, CEN EN 13321-1 ISO/IEC 14543-3	An OSI-based network communication protocol for intelligent buildings. KNX covers whole stack from presentation down to physical layer. KNX supports several communication media: twisted pair, powerline, radio frequency and Ethernet. Twisted pair is the most common KNX medium and is generally installed when new buildings are constructed. Powerline and radio frequency are typically used when existing buildings are retrofitted. KNX can be used for all possible functions / applications in home and building control ranging from lighting, shutter control to security, heating, ventilation, air conditioning, monitoring, alarming, water control, energy management, metering as well as household appliances, audio and lots more. KNX systems can be mapped to BACnet objects (as documented in the international standard ISO 16484-5) & can interface with the DALI technology.
oBIX	Open Building Information Xchange is a focused effort toward creating a standard XML and Web Services guideline to facilitate the exchange of information between intelligent buildings, enable enterprise application integration and bring forth true systems integration.
ModBus	*A* a serial communications protocol published by Modicon in 1979 for use with its programmable logic controllers (PLCs), it has become a de facto standard communications protocol in industry, and is now the most commonly available means of connecting industrial electronic devices. Modbus filled some of the needs of the building-automation community prior to BACnet but, coming from the industrial world, it was not originally designed for the needs of buildings data.
ACN: ANSI E1.17-2006	Entertainment Technology - Architecture for Control Networks (ACN), is a suite of documents that specifies an architecture, including protocols & language, which may be configured & combined with other standard protocols to form flexible lighting, or other control systems. Service descriptions are expressed in XML. ACN has defined the Service Data transport (SDT) for reliable communication between end-points. ACN is designed on top of UDP, SDT, SLP/IP, making it available for Ethernet, 802.11x, & potentially other media.
Wavenis	*A* a 2-way wireless connectivity platform dedicated to serving M2M applications. Wavenis operates in the major license-free ISM bands around the world. Wavenis focuses on AMR (automatic meter reading), AMI (advanced meter infrastructure), home and building automation, & industrial automation, medical & environmental UHF-active long-range RFID applications.
HomePlug GreenPhy	A specification and certification profile of IEEE 1901, that allows products to use the already installed home wiring system to connect to each other and in turn to connect to the Internet. HomePlug GreenPhy is

	specifically designed for the requirements of the smart grid market. It has peak rates of 10 Mbps and is designed to go into smart meters and smaller appliances such as HVAC/thermostats, home appliances and plug-in electric hybrid vehicles, so that data can be shared over a Home Area Network (HAN) and back to the utility. For these applications, there's not a great need for high capacity broadband; the most important requirements are for lower power, robust, reliable coverage throughout the home, smaller size and less costly Bill of Materials.
X10	An international and open industry specification for communication among electronic devices used for home automation. It primarily uses power line wiring for signalling & control, where the signals involve brief radio frequency bursts representing digital information. A wireless radio based protocol transport is also defined. Household electrical wiring (the same which powers lights & appliances) is used to send digital data between X10 devices. This digital data is encoded onto a 120 kHz carrier, which is transmitted as bursts during the relatively quiet zero crossings of the 50 or 60 Hz AC alternating current waveform.
EnOcean	A proprietary wireless, energy harvesting technology developed to enable battery less sensors & switches for building automation systems. EnOcean GmbH offers the technology & licenses for the patented features under license within the EnOcean Alliance framework.
Z-Wave	A proprietary wireless communications protocol designed for home automation, specifically to remote control applications in residential and light commercial environments. The technology uses a low-power RF radio embedded or retrofitted into home electronics devices and systems, such as lighting, home access control, entertainment systems and household appliances.
OPC and OPC UA	Object Linking and Embedding (OLE) for Process Control, is a standards specification developed in 1996 by an industrial automation industry task force. The standard specifies the communication of real-time plant data between control devices from different manufacturers. OPC UA (Unified Architecture) is the next generation OPC standard specification that provides a cohesive, secure & reliable cross platform framework for access to real time & historical data & events.

Table 7: Sensor/actuator network protocol examples

Org	Title
ZigBee	*ZigBee*: Recently sensors, area controllers and zone controllers have been deployed on wireless mesh systems. 802.15.4 based mesh systems seem to be the technology of choice by most manufacturers due to the cost point of the radio technology and communication robustness. ZigBee is a suite of high-level communication protocols to be used over the IEEE 802.15.4 standard. ZigBee incorporates device and service discovery. ZigBee Device Objects (ZDO) exhibit the functionality in a given device, introducing a set of related commands. For a given profile and device, the Zigbee standard specifies which ZDOs should be supported and which clusters they can serve. ZigBee and ZigBee Pro have specified a proprietary networking solution, using features from the underlying IEEE 802.15.4 communication medium. In order to expand the interoperability to other media such as low-power 802.11 and Powerline Communication (PLC), IP networking is being integrated, placing ZigBee over the IP stack for resource-constrained networks currently standardised at the IETF. Subsequently, ZigBee abandons networking and moves towards application profiles and device and

	service discovery.
6LoWPAN	*6LoWPAN*: The IPv6 for Low-Power Personal Area Networks (6LowPAN) working group has issued a standard RFC that allows stateless compression of IP headers before transmission. Such compression enables transmission of IP packets over low-power networks, whether they be 802.15.4, PLC, or other. The RFC also provides the mechanism to assign IPv6 address to nodes.
ROLL	*ROLL*: The Routing Over Low-power and Lossy networks (ROLL) working group is developing a standard IP-level routing protocol (RPL) targeting resource-constrained networks.
CORE	*CORE*: The CORE working group is working on an application layer protocol (CoAP) to allow efficient discovery and access to device and devices' resources. Sensor/Actuator nodes in IP-based sensor networks will need to implement the adaptation layer defined by the 6LowPAN RFC, the IP layer, the RPL routing protocol defined by ROLL, the UDP transport layer, the CoAP application layer defined by CORE and finally an application, which may be a ZigBee application profile.

As shown by the amount of standards listed above, there is a lot of standards that are suited to answer specific needs. The main concern remains about the interoperability among these standards and the semantic alignment among them.

Chapter 3 of this document discusses potential Cross sectoral standardisation opportunities and the main barriers to interoperability and standards given an energy efficiency context. Recommendations to bridge the identified standardisation gabs and to gain from cross-sectoral synergies are formulated in chapter 4.

2.4 Lighting

Lighting is most commonly thought of in terms of *space lighting and displays*, but think in terms of *photonics* and one begins to appreciate the paramount and varied cross-sectorial impact the lighting sector has. Photonic technologies are:

- at the centre of ICT infrastructure in terms of fibre optic communications
- used as a versatile industrial tool, from welding to semiconductor lithography
- utilised as remote sensing and measurement devices
- used for medical imaging and minimally invasive treatments

Nevertheless, the scope of REViSITE primarily focuses on ICT control of *space lighting and displays* from an energy efficiency standpoint, with photonics in *communication fibre optics* being a secondary consideration.

In that context there are obvious connections between lighting and the built environment in terms of standards. Regarding lighting controls standardisation as a part of the integrated building control, the actual standardisation bodies are the professional or technological organisation as shown in Table 1 below, ASHRAE SSPC 135 [BACnet], LonMark International and KNX Association.

Table 8: Lighting controls contained industrial standardisation

Technical committee	Scope
ASHRAE SSPC 135 BACnet - A Data Communication Protocol for Building Automation and Control Networks	SSPC 135 contains a specific WG for Lighting Applications (LA-WG) to take care of the development of lighting control applications. Support for lighting control applications is embedded in BACnet. New versions of BACnet standards developed within SSPC 135 will be brought as international standards through CEN TC247 and ISO TC 205.
LonMark International KNX Association	LonWorks and KNX protocols are European and international standards (Lon: CEN EN 14908 and ISO/IEC 14908-1; KNX: CENELEC EN 50090, CEN EN 13321-1 and ISO/IEC 14543-3). They both have support for lighting controls. The standards are developed within the related industrial organisations.

Behind official standardisation there can be national/professional organisations developing draft standards before the formal standardisation projects will be started. The actual development work for new standards will be made then by these liaising organisation. Regarding the lighting domain standardisation the most important organisation is CIE shown in Table *8*.

Table *9* shows a set of existing lighting related standards. The first four standards are lighting domain specific. The next ones are lighting related energy performance of buildings standards. The last one is a BACS standard in which lighting controls is supported.

Table 9: Examples on lighting specific and lighting contained standards

Code	Title
ISO 8995-1:2002 CIE S 008:2001	Joint ISO/CIE Standard: Lighting of Work Places - Part 1: Indoor
ISO 15469:2004 CIE S 011:2003	Joint ISO/CIE Standard: Spatial Distribution of Daylight - CIE Standard General Sky
ISO 30061:2007 CIE S 020:2007	Joint ISO/CIE Standard: Emergency Lighting
EN 12665:2002	Light and lighting - Basic terms and criteria for specifying lighting requirements
EN 15193:2007	Energy performance of buildings - Energy requirements for lighting.
CEN/TR 15615: 2008	Explanation of the general relationship between various European standards and the Energy Performance of Buildings Directive (EPBD) - Umbrella Document
EN 15603:2008	Energy performance of buildings - Overall energy use and definition of energy ratings
EN 15459:2007	Energy performance of buildings – Economic evaluation procedure for energy systems in buildings
EN 15217:2007	Energy performance of buildings - Methods for expressing energy performance and for energy certification of buildings
EN 15232:2007	Energy performance of buildings – Impact of Building Automation, Controls and Building Management
EN ISO 16484-5: 2010	Building automation and control systems. Part 5 Data communication protocol (BACnet)

In addition to the above standards lighting related standardisation committees and their scopes are show below in *Table 10* and *Table 11*, again the connection to the built environment and by extension the wider energy eco-system is apparent.

Table 10: Lighting domain specific standardisation

Technical committee	Scope
CEN TC 169 Light and lighting	WG 1 Basic terms and criteria; WG 2 Lighting of work places; WG 3 Emergency lighting in buildings; WG 4 Sports lighting; WG 6 Tunnel lighting; WG 7 Photometric data for luminaires; WG 8 Photobiology; WG 9 Energy performance of buildings; WG 10 Performance of Optical Materials for Luminaires
CLC TC 34Z Luminaires and associated equipment	To prepare harmonized standards based on concluded international standards in the lighting field, but excluding lamps.
IEC TC 34 Lamps and related equipment	SC 34A Lamps; SC 34B Lamp caps and holders; SC 34C Auxiliaries for lamps; SC 34D Luminaires.
CIE –International Commission on Illumination A worldwide independent, non-profit organization organisation on all matters relating to the science and art of light and lighting, colour and vision, photo-biology and image technology. Presenting the best authority on the subject and as such is recog-nized by ISO as an international standardization body.	Division 3 (/7): Interior Environment and Lighting Design Sample of 13 TCs: TC 3-52 Energy Performance of Buildings – Energy Requirements for Lighting; TC 3-50 Lighting Quality Measures for Interior Lighting with LED Lighting Systems; TC 3-49 Decision Scheme for Lighting Controls for Tertiary Lighting in Buildings; TC 3-47 Climate-Based Daylight Modelling; TC 3-46 Research Roadmap for Healthful Interior Lighting Applications; TC 3-45 Luminance Based Design Approach; TC 3-44 Lighting for Older People and People with Visual Impairment in Buildings; TC 3-42 Indoor Work Space Application Guide; TC 3-39 Discomfort Glare from Daylight in Buildings; TC 3-34 Protocols for Describing Lighting.

Table 11: Lighting contained official standardisation

Technical committee	Scope
ISO TC 205 Building environment design	Lighting specific WG contained: *WG7 Indoor visual environment*. Integration of lighting controls with Building Automation and Control Systems (BACS) covered through BACnet contained in *WG3 Building controls design*.
CEN TC 163 Thermal performance & energy use in the built environment	Lighting specific WG contained in *SC 2 Calculation methods*: *WG 14 Daylight in buildings*
CEN TC 247 Building automation, controls and building management	Integration of lighting controls into BACS covered through BACnet, LonWorks and Konnex contained in *WG4 3 Open Data Transmission*. Integration of lighting controls into BACS energy efficiency standards contained in the project team *WG6/PT5 Calculation methods for energy efficiency by the application of integrated BACS.*
CEN TC 89 Thermal performance of buildings and building components	Incorporation of lighting systems in methods for expressing energy performance and for energy certification of buildings (EN 15217).
CEN TC 228 Heating systems in buildings	Incorporation of lighting systems in methods for Economic evaluation procedure for energy systems in buildings (EN 15459).
CEN BT/TF 173 (Task Force 173 of CEN Technical Board)	Incorporation of lighting systems in the description of overall energy use and definition of energy ratings (EN 15603) as well as in explanation of the general relationship between various European standards on Energy Performance of Buildings (TR 15615).

Chapter 3 of this document discusses potential Cross sectoral standardisation opportunities and the main barriers to interoperability and standards given an energy efficiency context. Recommendations to bridge the identified standardisation gaps and to gain from cross-sectoral synergies are formulated in chapter 4.

2.5 Manufacturing

The major potential for energy efficiency in manufacturing by using sophisticated ICT concepts can be seen in the early phases of the product development process, namely the product design and materialization-planning. These phases determine how much energy the product will consume during its lifecycle. On the one hand they define the product properties and on the other hand the design of the manufacturing process. If there is detailed data available describing the energy consumption of machines, processes and other loads, the product design and the manufacturing process can be optimized in order to decrease the needed energy. These improvements can be made on different levels of the production system from layout planning to machine control.

There are currently few standards of typical sources like ISO/EN, IEEE or DIN that directly focus on the ICT4EE agenda. However, tables Table 12 and Table 13 below give examples of standards and SO technical committees/sub-groups that need to be considered in broadened smart energy ecosystem context. While few energy specific standards have emerged as yet, tools and frameworks are more readily available. Such tools and frameworks are useful approaches to support energy efficiency of production systems using information technology. A selection of concepts is shown in the following:

- TEEM ("Total Energy Efficiency Management") is a system developed by the Fraunhofer Institute IPA (Fraunhofer Institute for Manufacturing Engineering and Automation). The basic aim of this model is the detection of energy consumption on the process level and a following determination of possible potentials for improvement.
- The EPE ("Embodied Product Energy") Framework was developed by the "Centre for sustainable manufacturing and Reuse/Recycle Technologies" at the Loughborough University. This approach tries to increase energy efficiency by a detailed model of the required energy at process and factory level from a product perspective. Contrasting to the TEEM concept EPE considers also "indirect" energy which creates the environment for the process (e.g. light or heating). The result which can be achieved with this framework is a systematic search for inefficiencies but proposals for solutions or improvements are not delivered.
- The "EnergyBlock"-planning-system, developed at the Technische Universität Berlin, describes a planning system where resource and energy-consumption profiles of machines and facilities can be displayed dependent on time and operating conditions. Therefore an analysis and prognosis of future energy consumption gets possible.
- The "Process Chain Modeler", developed by Rünger et al focuses on a bidirectional interface between product development and production planning in order to include efficiency considerations in the product specifications. Mathematical models of the process steps are used to determine energy efficient process chain variations. By including specific machine and product data the necessary time, cost and energy

consumption of the process can be calculated. The energy-data is based on LCA-databases.

These frameworks show different approaches for the same problem all with their particular advantages, disadvantages and technology readiness. Since the development is still on-going a dominant standard could not be defined yet and further research is necessary. Furthermore, the primary focus of these methods is on planning and no special ICT standards for measuring or databases are used. Accurate and meaningful energy-prognosis, as a basis for production planning decisions, requires real-time measurements of the production system's performance. However this data can only be valid by considering the system's constraints and boundaries that lead to complex interrelations.

Therefore one of the major challenges connected to these models is the way how energy data can be generated and saved. This problem could not be adequately solved yet and therefore a clear need for standards is visible.

In current automation technology (see Figure 5) machine data is recorded through various sensors at the field level and the signals are processed using PLC (Programmable Logic Controllers). The recorded data can only be used to control the process because real time energy measurement on the machine level is not yet state of the art. Adjustments to the process can be made using SCADA (Supervisory Control and Data Acquisition) interfaces. MES (Manufacturing Execution Systems) analyse the captured data in real time and can be used to monitor and control the complete production process. Usually MES systems are integrated in ERP (Enterprise Resource Planning) Systems which can be used for planning activities. At this level the energy consumption of the system gets defined for several hours or days. If energy consumption is considered, several scenarios for the process can be compared regarding the highest degree of energy efficiency. However, the data transfer between ERP and MES systems does not proceed in real time which can lead to incorrect assumptions in the planning phase.

In addition to this way of capturing and analyzing data, EMS (Energy Management Systems) can be used to monitor energy - provision, distribution and usage. These systems can be integrated with every level of the automation pyramid to provide an overview about energy consumption over time of the production system. EMS can be used to optimize energy procurement and to identify systemic inefficiencies. Nevertheless, it is not possible to use the data for process control, since the usual interval for measurements is too large.
It is also very common in current planning activities to use secondary data from LCA databases. The problem of this approach is the high imprecision of this data because it focuses primarily on material creation and product disposal. The energy consumption of manufacturing processes are often neglected what can lead to planning failures. This problem can be diminished by using data generated by CO2PE! CO2PE - Cooperative Effort on Process Emissions in Manufacturing operates within the EREE working group of the International Academy of Production Engineering [16]. This initiative recognized the problem with current LCA data and systematically analyzed ecological impacts of current production processes.

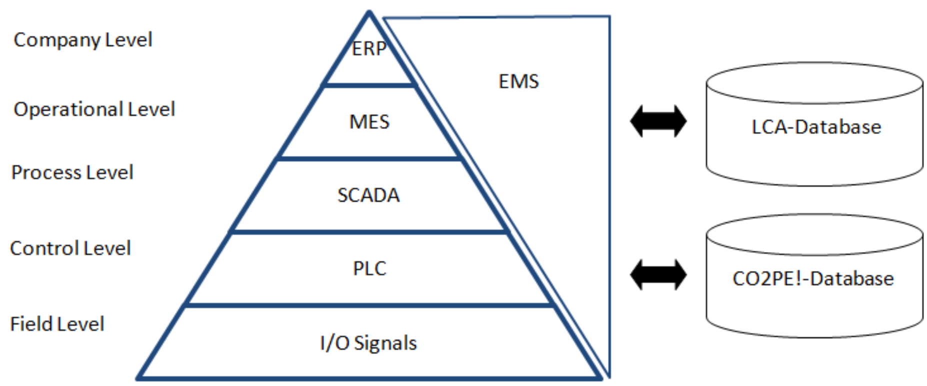

Figure 5: Energy-data generation options and management in manufacturing

As stated few specifically ICT4EE related standards are currently available from typical SO's like ISO/EN, IEEE or DIN. However, Table 12**Error! Reference source not found.** & Table 13 below give examples of standards and SO technical committees/sub-groups that needs to be considered in a broadened smart energy ecosystem context.

Table 12: Examples of potentially relevant standards

Code	Title
ISO 50001 / EN 16001	ISO & EN Energy Management Standard - specifies requirements for establishing, implementing, maintaining and improving an energy management system, whose purpose is to enable an organization to follow a systematic approach in achieving continual improvement of energy performance, including energy efficiency, energy use and consumption
ISO 14040	ISO 14040 describes the principles and framework for life cycle assessment (LCA) including: definition of the goal and scope of the LCA, the life cycle inventory analysis (LCI) phase, the life cycle impact assessment (LCIA) phase, the life cycle interpretation phase, reporting and critical review of the LCA, limitations of the LCA, the relationship between the LCA phases, and conditions for use of value choices and optional elements
ISO/CD 20140	Environmental and energy efficiency evaluation method for manufacturing systems [currently under development by TC 184/SC5]
ANSI/ISA95 ISO/IEC 62264	ISA-95 is the international standard for the integration of enterprise and control systems. ISA-95 consists of models and terminology. These can be used to determine which information, has to be exchanged between systems for sales, finance and logistics and systems for production, maintenance and quality. This information is structured in UML models, which are the basis for the development of standard interfaces between ERP and MES systems. The ISA-95 standard can be used for several purposes, for example as a guide for the definition of user requirements, for the selection of MES suppliers and as a basis for the development of MES systems and databases.
ISO 10303	STEP [Standard for the Exchange of Product Model Data] is a comprehensive suite of standards that describes how to represent and exchange digital product information. While not directly linked to Energy efficiency ISO 10303 is an example of the type of standards being examined in terms of including energy related data with respect to product eco-design and design for manufacturing efficiency.
ISA100.11a-2011	The ISA100 family of proposed standards focus on the use of wireless sensor

	systems to help industry - use energy and materials more efficiently, lower production costs, and increase productivity. ISA100 is recognised as a Publically Available Standard [PAS] by the IEC, as opposed to an IEC standard

Table 13: Examples of potentially relevant committees/work groups

Technical committee	Scope
ISO TC242 – Energy Management	Standardization in the field of energy management, including for example: energy efficiency, energy performance, energy supply, procurement practices for energy using equipment and systems, and energy use as well as measurement of current energy usage, implementation of a measurement system to document, report, and validate continual improvement in the area of energy management.
ISO TC184 – automation systems and integration	Standardization in the field of automation systems and their integration for design, sourcing, manufacturing and delivery, support, maintenance and disposal of products and their associated services. Areas of standardization include information systems, robotics for fixed and mobile robots in industrial and specific non-industrial environments, automation and control software and integration technologies. Example sub-committee - TC 184/SC 5 Interoperability, integration, and architectures for enterprise systems and automation application Example working group - TC 184/SC 5/WG 1 Evaluation of energy efficiency and other relevant factors of a manufacturing system with respect to its environmental influence.

Chapter 3 of this document discusses potential Cross sectoral standardisation opportunities and the main barriers to interoperability and standards given an energy efficiency context. Recommendations to bridge the identified standardisation gaps and to gain from cross-sectoral synergies are formulated in chapter 4.

3. Cross sectoral standardisation opportunities

3.1 Specification & design ICTs

Specification and design requires basic boundary conditions or models from the other sectors, including geographical location and spread, energy consumption and production characteristics, and economical parameters such as cost of energy production and cost of delayed or avoided consumption. This information would typically be across all sectors although the scale of energy exchange would vary. It includes energy demand patterns, or estimated energy patterns and where applicable energy generation patterns and is required for the development of optimisation models, simulation models and control algorithms. The interface descriptions, to interface between different control systems would typically include the technical communication interface, but also the commercial market related aspects, and technical limitations.

The usage of design tools (e.g. CAD) is very similar across sectors. ICTs that support the specification process such as material databases with ‘energy-properties’ information are to a degree currently utilised. An extension and integration of such databases is one possible area for cross-collaboration. Advanced model-based CAD tools and intelligent product libraries, including semantic data, are applicable to all sectors. At the same time, there is a need for convergence of standards for semantic data in order to enable cross-sectorial communications.

Advanced Virtual Reality and Digital Mock-up ICTs used in the product design domain can be utilised to verify a building's design in early stages, however it is recognised that ICT technology in this space in buildings is already at a sophisticated level, whereby the building is effectively treated as a product.

Simulation ICTs can prove useful in many contexts and phases. It provides useful insights and provides planning data for both energy providers and manufacturers tasked with improving energy consumption and efficiency as part of the overall design process. Realistic simulation of waste heat of production equipment will help to dimension HVAC systems precisely and to investigate heat re-use opportunities in usage phase. Such simulation is akin to the augmented building vision for BIM’s.

The design phase is very important for the life cycle energy performance of the building during the operational stage. It is crucial to be able to perform analysis based on the digital model of the building. The better the model is, the more accurate the results of these priori analyses will be. Therefore the need is for shared models (geometry, materials, HVAC systems, lighting systems, embedded energy, etc.) and communication buses or interoperability among sectorial solutions (i.e PLM/PDM based on Smart Manufacturing side) are of high importance. Holistic building simulation is needed to estimate energy consumption.

Information about smart grid services influences selection of the building’s control system concept. The detail design of control system needs to be adopted to the transactional protocol with the grid. Generic requirement management tools, product libraries and some CAD tools are adoptable to all sectors for the design stage. PLM/PDM technologies from the manufacturing sector are potential to the building sector for enabling a smoother transition from document-based to model-based (BIM) approaches.

Availability of cross sectorial standards in the usage contexts above covering e.g. harmonised interoperable data exchange protocols, energy performance metrics and measurement, CIM /

BACS collaboration, energy related BIM extensions product catalogues, and eeBDM etc. would enable various energy performance improvements.

3.2 Materialisation ICTs

'Materialisation' follows the design phase and is a non-sector specific term understood within REViSITE to encompass construction, grid infrastructure and production-system development i.e. realisation of the physical. ICTs in this space are similar, identical in most cases to decision support ICTs in the operational phase. What is different is the context, which undoubtedly has greater significance for, but is not limited to, the construction sector. In short, benefits for EE stem from the optimisation of in-the-field work and coordination of different stakeholders, enabling abatements in terms of overruns and unnecessary logistical runs etc. The REViSITE vision sees:

- usage of control mechanisms at various scales to optimise financial results as well as environmental parameters and stability,
- ICTs to support optimal materialisation / procurement decisions (e.g. onsite v off-site production),
- ICTs to rationalise materialisation processes in terms of planning and control (e.g. logistics, sequence etc.)
- easily deployable mobile communications, tracking and visualisation of materialisation processes etc.

As indicated in the previous chapter the establishment of standards is quite heterogenous and isolated from each other in the four sectors of the project scope. Especially, the materialisation phase lacks an approach in guiding construction and planning-activities in a more energy efficient direction.

One of the key-problems in this field is the lack of energy performance targets which would provide incentives to design buildings, production systems etc. in a more energy efficient way. For this purpose energy indicators are required. Otherwise targets without continuous monitoring of its constituting parameters may be of no great use. Since there is a variety of different indicators available it needs to be clarified which of them are suitable for simulation of different layout scenarios. In this context, the potential of synergies of the four target sectors by using a common and harmonized set of metrics needs to be examined. In the same area, there is a need to define the whole chain of measurement in order to ensure the reliability / accuracy of the data collected, its meaning and the level of privacy. This point will be further highlighted in chapter 4.

Comprehensive targets and indicators are only the first step of optimizing energy consumption in the materialisation phase. It is also a great challenge to implement the correct measures for reaching these targets. Mistakes in this phase lead to suboptimal results which can influence the energy efficiency of the system for its complete lifecycle. In order to meet the defined targets standardized best practices, process models and criteria need to be developed which can be used as guidelines and basis for decision in planning activities of buildings/factories, grids or lighting systems. These guidelines could be generic for many applications and would need to be adapted to the special use-cases. An example for the manufacturing sector could be a catalogue of different factory layouts/machine arrangements which proved as energy efficient in the past.

Another important point is the coordination between the different sectors using interoperable communication tools, protocols and formats. Information barriers within the supply chain and between the sectors may lead to a waste of resources due to unnecessary transport, inefficient usage of production facilities or creation of junk. Therefore, information exchange without gaps is needed in order to ensure optimal coordination of tasks.

Once the building/production system etc. is established a continuous validation of the planning scenarios using simulation and metrics as described above is necessary and serves as a base for benchmarking. From this point automation and operational decision support ICTs are primarily used to spot and solve inefficiencies. Nevertheless, systematic inefficiencies can occur when certain constraints of the observed system change. In these cases, there could be a need to go back to the materialisation phase and change the layout of the system. Standardized procedures for EE management like ICT driven regular efficiency checks, benchmarking etc. need to be put in place to ensure a systematic prevention of systemic inefficiencies.

For supporting these processes workgroups and expert forums could be established in order to facilitate company comprehensive exchange of information and experience.

3.3 Automation & operational decision support ICTs

REViSITE research has confirmed a holistic approach is required to realise 202020 objectives. As described above built environments, the industries they house and the energy grids that power them, all interlink to form smart energy ecosystems.

'Automation and operational decision support' ICTs given their direct relationship to the operational phase of the respective sector life cycles, is probably the most obvious in considering the energy efficiency of such ecosystems, especially in the context of existing buildings, lighting systems, production systems and grid infrastructure.

Central is the need for actors within such ecosystems to 'sense', 'understand', 'decide' and 'act' in resource efficient ways. Wired and wireless communication and sensor networks offer significant potential in aiding the first step, 'sensing'. Such ICTs will be paramount to monitoring resource efficiency from district level down to individual home and citizen level. Technical integration is of course fundamental to development in this space and this is where open standards and harmonisation of existing standards can play a significant role, more so at the data exchange and web service level.

Data accusation, aggregation, processing and analytics technologies coupled with intuitive, easily deployable, easily-usable, dynamically adaptable visualisations incorporating streamed and asynchronous data, will undoubtedly prove crucial in terms of 'understanding' and deciding' where to improve. Again, harmonisation and interoperability of data exchange protocols will be central.

Additionally, technological development with respect to decision support will require significant behavioural-science input in ensuring the enabling value of ICT is appropriately channelled. As such frameworks and forums for sharing cross-sectorial use-cases and best practice should be promoted.

With respect to 'acting' intelligent energy based algorithms, control logic and actuation will prove pivotal in maximising potential energy efficiencies by automating those elements and choices that can be taken outside the human decision loop. For example, ICT control could ensure service level agreements whereby ventilation or air-conditioning of a factory is dynamically aligned to machine operation. 'Context aware' ICTs could be used to spin-up down work cells or building environments based on user requirements, market signals, defined service level agreements etc. Such algorithms can often prove universally applicable and standardised means of cataloguing together with knowledge sharing platforms should be established whereby openly developed algorithms can be shared.

3.4 Resource & process management ICTs

The efficient use of resources in horizontal processes is of universal appeal. The general consensus would suggest that productivity gains can quiet easily be translated into energy efficiencies but that holistic thinking and incentive is required. ICTs have a paramount role to play in this regard.

Business process improvement methodologies and supporting ICTs could be utilised in this space also. Sector practices around ERP systems would need closer study to ascertain cross-sectoral leveraging; closer study would also be required to ensure energy efficiency resulted from performance related efficiency through the supply chain.

It is often the case that from an energy perspective another sector is the beneficiary of changed practices and technology, for example process scheduling efficiencies in manufacturing may result in energy savings in the transport sector. ICT can play a part in ensuring a holistic view is taken and credit given where one sector makes changes that result in indirect energy savings in another. Standard means of accrediting such initiatives should be investigated.

It is often the case now that businesses do not compete but rather supply chains or networks compete, this needs to be extended to energy efficiency whereby a life cycle approach to energy consumption and efficiency is taken. The role of policy will be crucial here in incentivising such approaches while ICT will be paramount in ensuring effective, transparent accountability in measuring and reporting on same and as such standard metrics and means of measuring should be established.

In the built environment there is a need to increase the semantic level of data [BIM and eeBDM] in making it openly available to different enterprises, while improving IPR protection. A possible development into this direction could be to provide intelligent object libraries with embedded but protected knowledge.

Knowledge sharing repositories in general should be leveraged extensively in sharing best practices. Other valuable common ICTs in this space are collaboration technologies such as - group-work tools, electronic conferencing, distributed and virtual team systems for process management and information sharing platforms.

3.5 Technical Integration ICTs

Several ICTs standards have been identified in each of the four Sectors. But we identified at the same time that they have been developed following a siloed / sectoral approach. As a first consequence, there are no gateways among these sectoral standards even if they are overlapping each other.

At this stage, it is worth mentioning The European Interoperability Framework (EIF[1]) provides the following definition about "Interoperability":

"Interoperability is the ability of disparate and diverse organisations to interact towards mutually beneficial and agreed common goals, involving the sharing of information and knowledge between the organizations via the business processes they support, by means of the exchange of data between their respective information and communication technology (ICT) systems."

Therefore, in terms of technical integration, it is mandatory to consider at least two folds as enablers for this integration:

[1] See: http://ec.europa.eu/idabc/en/document/2319/5644

- Interoperability of the data and data models
- Interoperability of the protocols and processes.

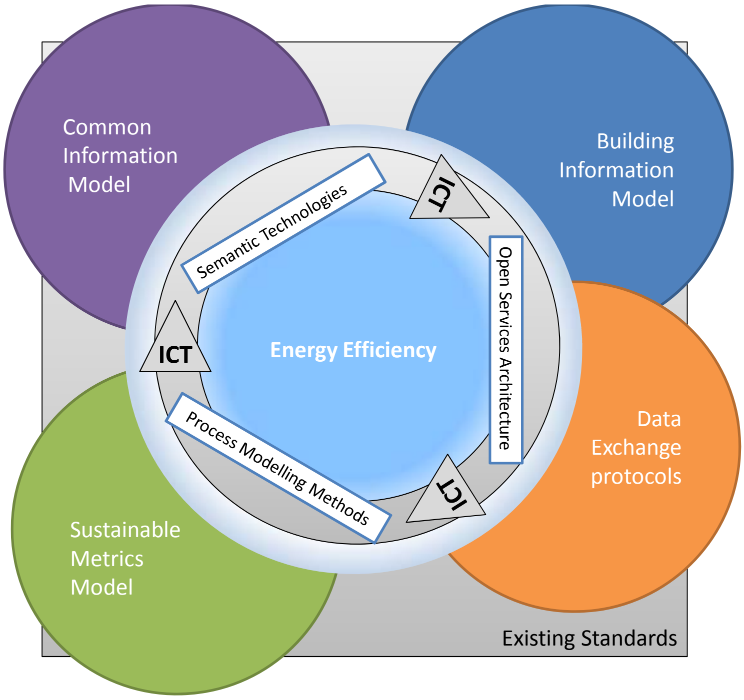

Figure 6: Current interoperability situation

The figure above shows the current situation: In order to come with EE management solutions, it is mandatory to develop bridges among the different models developed in each of the considered sectors. Mainly it means to develop common understanding between the Construction models (encompassing also the Manufacturing and the Lighting concerns) and the Grid models. This convergence of models is needed and will make the first step towards the identification and shared understanding about concepts that are common to the two parties and relevant in the scope of Energy Efficiency. As a result of such convergence, a dictionary of common concepts could be jointly defined by the sectors. As suggested, one neutral approach could rely on semantic web technologies.

The second fold to be taken into account is the acquisition / dynamic / transactional aspects of the data exchange. The main need seems to be the definition of cross sector processes formalizing the different scenarios around the acquisition / management of data, energy consumption/ production, dynamic pricing, etc…

3.6 Trading / transactional management ICTs

It is envisioned that energy consumers, generators and those who do both, cooperate with traders and suppliers and establish their participation in any kind of market places under contractual arrangements pre-defined with the related DSOs. This will resemble how “large” market participants and generators participate in the energy wholesale markets and cooperate with the TSOs today. They will have to deliver information on their planned market activities, with regard to energy consumption and generation, to the DSO and/or the TSO, depending on their kind of participation [7]. This structure requires information exchanges with all energy flow participants and will have to manage the external stimuli from large numbers of stakeholders in a transparent and controlled manner (as shown in Figure 7).

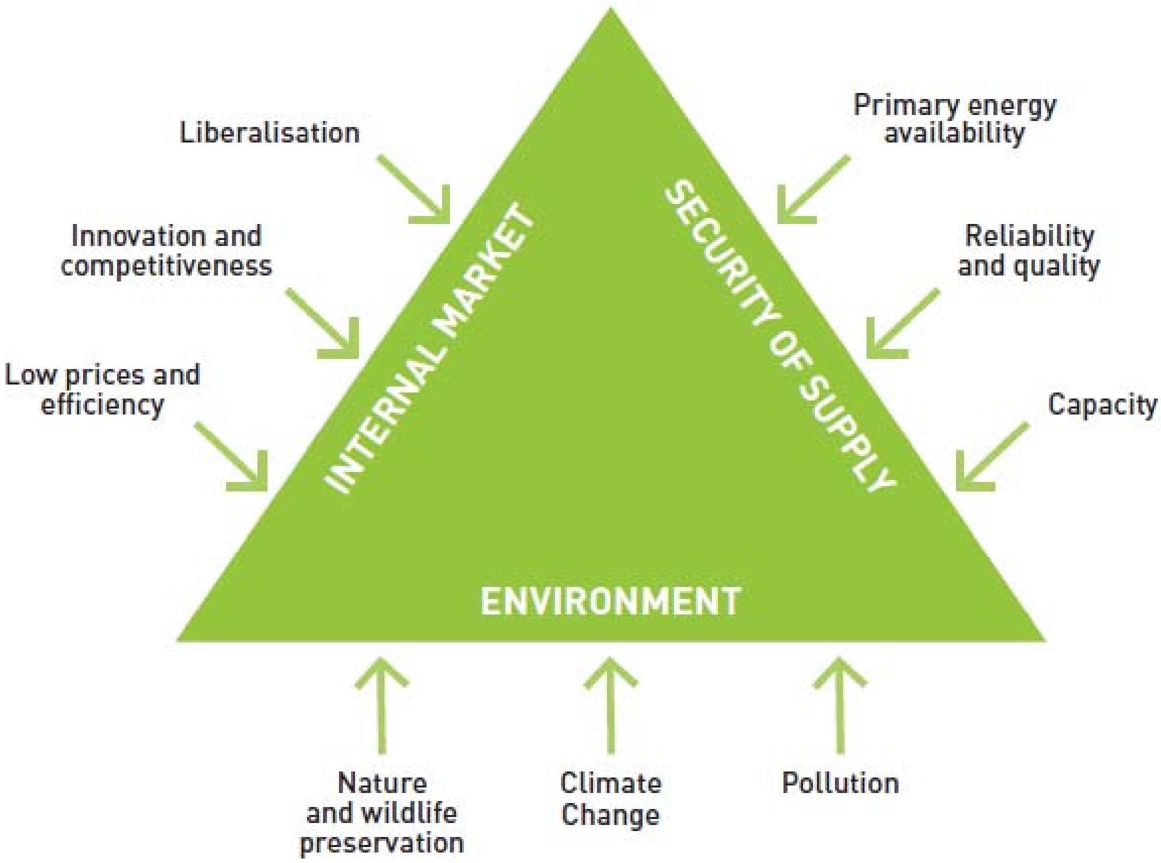

Figure 7: Scope, themes and influences on energy management [2]

Energy Management systems (EMS) have been in use for regional energy optimisation and network operation for many years. These systems operated within confined regional responsibilities and are not tightly interconnected. The conformance to interoperability standards of these systems is limited and further connectivity may not be easily achieved. Developments with regard to Distributed Energy Resources (DER) and renewables will create the need to apply energy management functions to greater extents of the energy flow. Tools that will support this function are required to exchange information with far greater number of counterparts on many more topics than the current generation of EMS is designed for.

On the short term Energy Management Systems will be fitted with data acquisition functions that register data on energy consumption and generation on all grid voltage levels. This will typically include the roll out of large scale remote meter reading infrastructures and the ability to easily utilise local logic and local interfaces. Local decisions making software is envisioned to be required as centralised “solvers” of energy management will not be feasible over certain levels of complexity. Data of energy consumption will be used to drive the central and decentralised decisions on energy management and to provide information of the energy flow for invoicing and settlement to end-users and other participants in the energy market.

In the medium term the information infrastructure will acquire measured usage data and optimise the local generation against energy market conditions. This would typically include optimisation of the production of a manufacturing facility against product order, storage, market conditions, energy market conditions and energy production or generation constraints. This type of optimisation will be fully automated for residential end-use. Prosumers will than allow the automated infrastructures to control energy consumption and generating equipment.

Local optimising systems will –autonomously– negotiate with peer systems on optimal consumption and generation patterns. The main challenges in this model are to ensure that the functionality on all levels conforms to the requirements of all stakeholders and ensures that the transport and distribution networks remain in a secure and reliable operational state. Due to social support it might be essential to ensure transparency on these automated decisions and its consequences.

In order to construct support ICT for the market model described above a certain generic concept on actors and use-cases must be developed. The current standards organisations recommend [11] to perform an investigation of the most promising market data systems as "this … is vital for an extension of the Smart Grid with market information". The use of open international interoperability standards and ontologies may be a more lasting strategy than the use of current state-of-the-art and de-facto standards. Regulatory authorities and trade associations should be involved in this effort to ensure stakeholder coverage.

4. KEY PROPOSALS FOR STANDARDISATION

4.1 Extension of existing ontologies for energy efficiency

The current models developed in each sector are too vertical and even if there is some overlapping among the ontologies, there is no alignment between the concepts that overlap. The need is therefore to find an efficient approach to identify these overlapping areas.

The suggestion here is to rely on the notion of Virtual Power Plant (VPP).

This concept of VPP is not new. It comes from the Grid sector and has been advanced as a generic model or modeling approach to represent all elements or devices concerned in the field of Energy production (Pudjianto et al, 2007).

The REViSITE proposal is to extend that notion of VPP to all “artifacts” concerned both the production and the consumption of energy.

This dedicated model has to be seen from the building sector point of view as a specific facet of the BIM and eeBDM ontologies.

The concept of VPP is a very interesting tool. It allows for a defined model (the VPP model) that contains a generic set of characteristics to allow connection and interaction between the smart grid and the building sector. On the Construction side, this model could be seen as a subset of BIM and eeBDM.

This approach applies also at different scales as it can be imagined and defined a VPP model well suited to represent the needs from the most “atomic” VPP (a generating device, i.e: a battery) to the most complex like the energy grid as a whole. In between these two extreme elements, we can already think of relevant steps regarding our needs like the definition of a VPP for buildings (aggregation of smaller VPP like washing machines, CHP, Electric Vehicles, Solar Panels, etc…), a VPP for the districts (aggregation of buildings), a VPP model for so called “smart cities” (aggregation of District VPP…). The figure below illustrate different representation of VPPs.

Figure 8: Illustration of a Virtual Power Plant (Electric Power Research Institute).

A VPP from the building point of view is a kind of “identity card” that should contain information in a structured manner in order to allow interconnection of ontologies from the Grid and the construction sectors.

In a recent report (“ICT Applications for the SmartGrid” – 2012), OECD mentioned also the VPP approach as an enabler to reshaping the energy system by giving rise to scenarios and transactions that can only be solved by digital continuous integrated exchanges among prosumers. The VPP modeling approach is an answer to tackle the gradual decentralization of power generation, by providing a simplifying instrument to deal with the complexity of energy systems.

4.2 Energy performance indicators (Metrics)

Performance targets, driven by politics or company standards, are required in order to provide incentives to design buildings and production systems etc. in a more energy efficient way. The parameters which constitute a target are defined by certain metrics which need to be continuously monitored to ensure that target values are reached. As already introduced in chapter 2 there are no cross sectoral standards available for EE metrics and even within the sectors the maturity of standards is on a generally low level. There is still ongoing research about the statistical advantages and drawbacks of different indicators and evaluation methods leading to several frameworks used to measure the EE of a building or a “device”. It is very hard to compare two solutions that have been assessed by two different frameworks.

Therefore concrete objectives consistent for different companies or even different sectors are difficult to find. These methodology barriers also prevent benchmarking and the diffusion of best practices since it is not possible to find who has the most efficient technologies. Thus in order to have an integrated approach, it is necessary to come to a common and harmonized set of metrics. There is also a need to define the whole chain of measurement in order to ensure the reliability / accuracy of the data collected but also their meaning and their privacy. In this context, the potential of synergies for the four target sectors also needs to be assessed.

There are two major ways for assessing energy efficiency. An overview about these methodologies is presented in the following paragraphs.

Energy Indicators are ratios of energy consumption/emissions of carbon dioxide equivalent in relation to a physical or economical dimension.“There is no unequivocal quantitative measure of ‘energy efficiency’. Instead, one must rely on a series of indicators relevant to the context…”[16] The “International Energy Agency” (IEA) developed a hierarchical overview how energy indicators can be structured according to the level of their respective aggregation (Figure 9).For this standardization proposal only metrics which granularity is in line with the REViSITE scope are relevant.

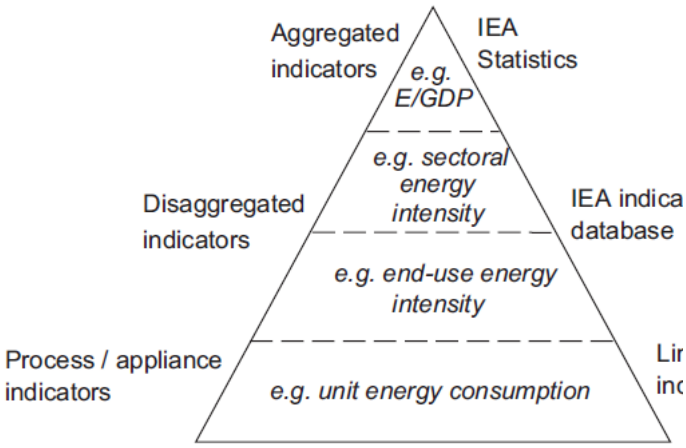

Figure 9: Hierarchy of aggregation for EE Indicators[17]

Highly aggregated indicators usually reflect the economical perspective of energy use in order to compare different sectors, countries etc. regarding energy efficiency, e.g. kwh/GDP. On the lowest level of aggregation indicators are measuring the efficiency of machines, processes different subsystems of buildings, etc.[17]. Within the REViSITE scope performance measurement on plant/building level seems sufficient. Nevertheless, indicators at this level of aggregation are usually based on a physical unit related to a special sector. The “Energy Use Intensity” is the most often used example in this category. It simply relates energy consumption to the unit of outcome e.g. kwh/square meter in the building sector or Gj/ton of product produced in manufacturing [21].

Whereas the efficiency of buildings, lighting and grids can be determined using the same indicator manufacturing cannot be integrated easily since the most significant ratios are related to physical units of their respective sectors (kwh/square meter vs. kwh/unit produced). Nevertheless there may be some indicators applicable to both (e.g. energy saved per year) [21]. A selected number of indicators defined in different research projects can be found in Table 14 below.

Table 14: Examples of EE Indicators

Reference	Indicator	Indicator type	Application	Formula/Unit
(Phylipsen et al., 1997)	Energy Intensity	Economic	Aggregated level	Energy consumption/economic term
	Specific energy consumption	Physical	Disaggregated level	GJ per t
(Irrek and Thomas, 2006)	Energy intensity	Macro-economic	Aggregated level	Energy consumption/monetary variables (GDP)
	Degree of efficiency	Engineering view	Aggregated level	Net energy/used primary energy
	Final energy efficiency improvement	Physical	National level	Energy savings per year
(Patterson, 1996)	Thermodynamic energy efficiency	Thermodynamic	Measurements derived from the science of thermodynamics	Actual energy usage related to an 'ideal' process
	Physical-thermodynamic energy efficiency	Hybrid	Measure the service or delivery of the process	Actual energy usages/tonnes or passenger miles
	Economic-thermodynamic energy efficiency	Hybrid	Measure the service or delivery of the process	Energy usage in conventional thermodynamic units/output in terms of market price
	Economic energy efficiency	Economic	Measure in terms of market value	Energy input in monetary terms/output in monetary terms
(Farla et al., 1997)	Energy efficiency measurement	Economic	Activity of a sector	Energy consumption/value added or value of shipments
	Specific energy consumption	Physical	Process level, cross country comparison	Energy use/physical unit of production
(IEA, 2008a)	Thermal energy efficiency of equipment	Physical	For single equipment	Energy value available for production/input energy value
	Energy consumption intensity	Physical	Broader than thermal indicator: companies, etc.	Energy consumption/physical output value
	Absolute amount of energy consumption	Physical	With indication of production volumes	Energy value
	Diffusion rates of equipment	Physical	Focusing on specific energy efficient technology	Rate of deployment of technology
(IEA, 2007a)	Industrial energy intensity	Physical	Comparison of efficiency data on a sub-sector level between countries.	Energy use/unit of industrial output, e.g., GJ/t
	Specific energy consumption	Physical	On sector level	e.g., GJ/t
(Boyd et al., 2008)	Energy performance indicator	Statistical	On plant level	Percentile ranking of the energy efficiency

As an alternative to indicator-based evaluation schemes rating systems can be used to evaluate EE. Contrasting to indicators they do not produce real values or ratios as a result. An own metric is produced which consists of different EE classes/categories. Prominent examples in the building sector is “LEED”[19] developed by the US green building council and the English governmental program ”Code for sustainable homes”[20]. Since the result is not directly linked to a sector, rating schemes offer a good potential for integrating multiple sectors in Energy efficiency assessment. Because of the result’s independence from physical values rating systems may have a higher potential for cross sectoral efficiency evaluation. The criterion which lead to an efficient outcome of the sectors (like electrical efficiency of power supply, efficiency of machines and production facilities etc.) could be integrated in catalogues evaluating the performance of the building itself.

Although the composition of indicators/rating schemes seems simple it is the result of a complex measuring process. Different methodologies are used (e.g. embodied/operational energy assessment, calculating with on-site or off-site energy, different system boundaries etc.) which makes comparisons difficult and often leads to misunderstandings. Therefore there is a clear need for standardization. Harmonization of metrics, test procedures and integration of frameworks for different sectors may lead to an EU-wide or preferably global methodology to assess energy efficiency and thus enable energy benchmarking.

Cross-sectoral approaches to benchmarking lack the support of applicable conventions. The building sector excels in methods for the assessment of energy performance for comparative analysis. The need for multiple codes and standards for residential and non-residential buildings benchmarks is caused by the differences in context and life-cycle conditions. New standards for benchmark assessments may be needed to overcome these limitations. These conventions should typically address the relationship between energy usage and the functional features of the objects and processes under scrutiny and the statistics that are required to define “normal operating conditions”. This would set the conditions that apply for the benchmark in defining the measurement standard. The “occupant density” and “climate” standards would be needed for the assessment of residential buildings efficiency for instance.

International working groups and expert forums need to be formed in order to support dialogues in best practices and standardization opportunities. An example for efforts in this direction is the “Common Carbon Metric”[22] programme in the building sector developed by the UNEP. It is currently evaluated by the ISO regarding applicability as a new standard and could be an example for other sectors.

4.3 Product catalogues that include energy dynamics

Information on available real products is needed during the design stages when specifying the actual components or modules which implement the designed functional units. If the design tools are CAD based then the product information has to be modelled into the format compatible with the CAD tool in use.

Usually CAD tool providers have taken care of the development extensive add-on product catalogues/libraries to their tools to improve the usability and attractiveness of the tools. These add-ons have a great competitive importance for tool provider companies.

Alternatively, product manufacturers can develop data models for such CAD tools they want to get support for their products. These product models can be published on the web so that their users (tool providers and end-users) can download and install them in their design environments.

Examples on existing product catalogues mostly on the building sector are shown as follows.

- ArchiCAD http://www.graphisoft.com/products/archicad/parametric_objects GDL (Geometric Description Language) based Parametric object technology contains all the information necessary to completely describe building elements as 2D CAD symbols, 3D models and text specifications for use in drawings, presentations and quantity calculations; tens of thousands of intelligent objects available and in use around the world.
- The *Autodesk® Seek* http://seek.autodesk.com web service enables designers to discover, preview, and download BIM models, drawings, and specifications covering the following product libraries: *Revit MEP*, *AutoCAD MEP*, *Revit Structure, Revit Architecture and AutoCAD Architecture*
- *SMARTBIM Object Catalog* http://www.smartbim.com is a collection of over 45,000 generic and manufacturer product BIM families and types (Autodesk® Revit® based) Where appropriate, they are parametric, representing different types of the same product. Objects are available FREE.
- MagiCAD http://www.magicad.com/en/content/design-real-products building services design tool on AutoCAD and Revit MEP having database containing hundreds of thousands of 3D models of real products. The models have correct dimensions and the technical data needed to make accurate calculations.
- Edibatec (in France): basic parts being dictionary, database and web service interface; the dictionary contains more than 250 classes of products (heating, cooling, ventilation, electrical equipment, insulation, doors, windows, glazing); a public on line database of more than 50000 products with their technical data, pictures and documentations; updated by the manufacturers; web services facilitating the use of technical database for buildings professionals having in 2011 more than 10 000 connections.
- Modelica https://modelica.org is a non-proprietary, object-oriented, equation based language to conveniently model complex physical systems containing, e.g., mechanical, electrical, electronic, hydraulic, thermal, control, electric power or process-oriented subcomponents. Libraries with a large set of dynamic models are available. The open source Standard Library contains about 1280 model components and 910 functions from many domains. Modelica represents an extension to the pure data modelling.

Main standardisation committee in the field of product libraries (building domain) is ISO TC 59 / SC 13 Organization of information about construction works having several BIM related activities going on. The working group WG 11 Product data for building services systems model with the work item ISO/CD 16757 Product Data for Building Services Plant Models is directly related to product libraries. Its work is based on the German VDI 3805 standard describing catalogue information for Building Services products. VDI 3805 has been developed over the last 20 years having specifications available for a big number of product groups. A parametric product modelling approach is used with computational properties. Another new work item in TC59/ SC 13 is related to the French building products industry's approach Technical Dictionary of Harmonised Properties (DTH). That approach is based on product description via properties.

Standard based product data catalogue systems have in principle two different data repositories: product data dictionary and product data library. The data dictionary contains the metadata of the type product such as attribute names and the data library contain the instantiated product types i.e. attribute values. Figure 10 below illustrates the concept.

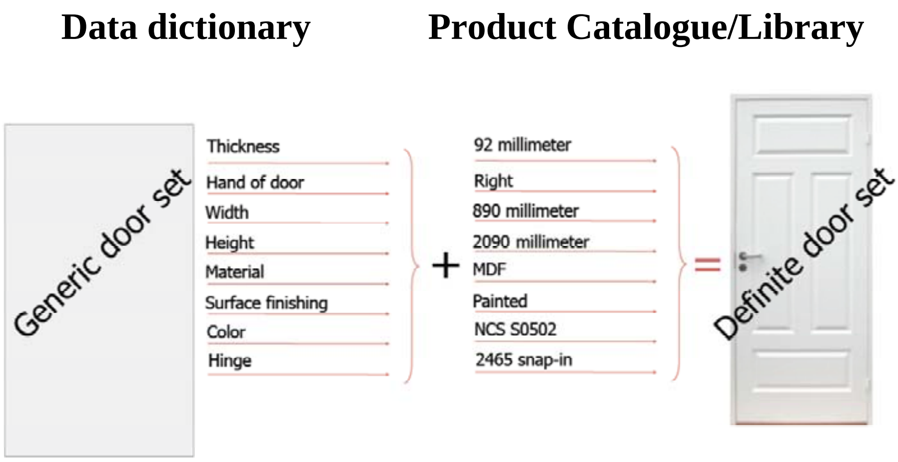

Figure 10: Illustration of data dictionary and product library concepts [23]

The data dictionary attributes (their values) are mapped directly to the attributes of the product type. In addition to these attributes directly inherited from data dictionary, the product catalogue item can have additional attributes to be computed or used as input to generate other attributes. The following alternatives were identified.

- The library and directory types have exactly the same attributes.
- The library type has computational attributes. These are the additional attributes to those inherited from the directory product type.
- The library type has computational attributes. Some of the inherited attributes are computational and generated from additional attributes through parameterisation.
- The library type has computational attributes. Some of the inherited attributes are computational and generated from additional attributes rule based.
- The product type contains dynamic model(s).

A specific requirement for the contents of product data models concerns energy related attributes of the products. The new energy efficiency standards will increase demand for technical data. Each manufacturer or professional organization must also use the same standard and the same method to describe construction product data.

Proposed standardisation concerns 1) the contents of the product data models for attributes needed for standardized energy performance evaluation, 2) standardisation application areas related to directory/library/1-1 mappings, 3) standardisation application areas related to mature parametric applications.

4.4 Data exchange protocols

Any information exchange requires a set of conventions shared by the sender of data and its recipient: both must know when the communication begins, what procedure it follows, and when it ends. Such sets of conventions are called protocols. A data exchange protocol is a standardised format for transmitting data between two devices. The type of protocol used can determine such variables as the error checking method, the data compression method, and end-of-file acknowledgements. If all networks and devices were constructed in the same manner and all networking software and equipment behaved similarly, only one protocol would be necessary to handle all of our data transmission/exchange needs. In reality, the ICT industry includes millions of different networks running a wide array of hardware and software combinations.

The issue is that most mechanical and electrical systems have embedded digital controls, these lower-level devices are low cost and/or low power and typically cannot support a full OSI stack i.e. they are not directly controllable. At this physical layer data exchange is handled by dedicated communications wiring or a wireless equivalent. Typically, these individual devices operate separately, without exchanging information and, as a consequence, the building or factory is not considered and controlled as one single system, but as a number of individual subsystems. This leads to sub-optimal results in terms of energy flow, comfort, cost and controllability. The world of lower level protocols is essentially a jungle of heterogeneous often competing offerings and standards harmonisation at this level is extremely onerous and highly unlikely.

The most appropriate solution is the use of interoperable control systems, governing all HVAC, lighting and other electrical applications, and related sub-systems installed in a facility. However, as described above integrating the myriad of sub-systems and devices, which are manufactured and often installed by different companies with different data interfaces and communication protocols, is an arduous process. There is a big challenge to effectively and efficiently integrate all these sub-control systems into one intelligent application.

Section 2 above details several well established protocols [e.g. BACnet, KNX, LonTalk etc] utilised in BAS BMS type systems that attempt to do just that, essential acting as aggregators allowing for homogeneity in terms of controlling lower level heterogeneous devices. However, while these data exchange protocols can be used over TCP/IP networks they themselves have challenges when dealing with other network applications with respect to interoperability, routers, firewalls and security etc.

REViSITE would suggest that while feasible and very much needed harmonisation is not, all things considered, likely at the lower level. When considering connection from aggregators to the network typically IP / TCP compatible solutions are available but more-often-than-not this requires adaptive coding because the structures of the messages exchanged are not standardised.

The most obvious way forward is one many in the built environment have already set out to employ. That is the development and standardisation of common ontologies, open interfaces, XML and web-services based mechanisms whereby one abstracts away from the jungle of lower level and less crowded data exchange protocols [such as BACnet, KNX etc.] enabling integrated communication between building systems and enterprise applications. As such, REViSITE would suggest there is a research and standardization need with respect to:

- Non-alignment of open solutions, above the IP layer, as the structure / content of messages is not commonly defined.
- Defining a uniform approach towards application with respect to building control systems.
- Investigating the interoperability of different information sources in buildings i.e. further consideration with respect to harmonisation of data models between BIM and BACS.
- Understanding the advantages and disadvantages of traditional data exchange approaches [BACnet, LonTalks, KNX etc.] and web-service based mechanisms, so industry can find the right balance in developing an optimised and standardised approach that addresses interoperability while allowing for heterogeneity and innovation.

But effort in this regard would not be starting anew and any effort should consider existing initiatives, which include but are not limited to:

- W3C
- OASIS Open Building Information eXchange [oBIX]
- CABA
- BuildingSmart
- BACNet XML working group
- LonMark interoperability association
- The XPL project
- BuildingSmart

4.5 Harmonisation and extension of the IEC Ontology

Applications of the IEC 61970 and IEC 61968 Common Information Model (CIM) have been expanding from its traditional usage in power system modelling and data exchange into the role of a standardized semantic model for the Smart Grid. The Smart Grid Interoperability Road Map has identified the need for a semantically consistent framework on which to base the Smart Grid and has selected the CIM as a central element across many functional areas of the Smart Grid not traditionally addressed by the CIM. One such area relates to how CIM works with the IEC 61850 power system communications standard that has also become an important part of the Road Map for both substation communications and as the basis for other Smart Grid oriented communications. This has made harmonization of CIM and IEC 61850 critically important to the goal of interoperability. [12]

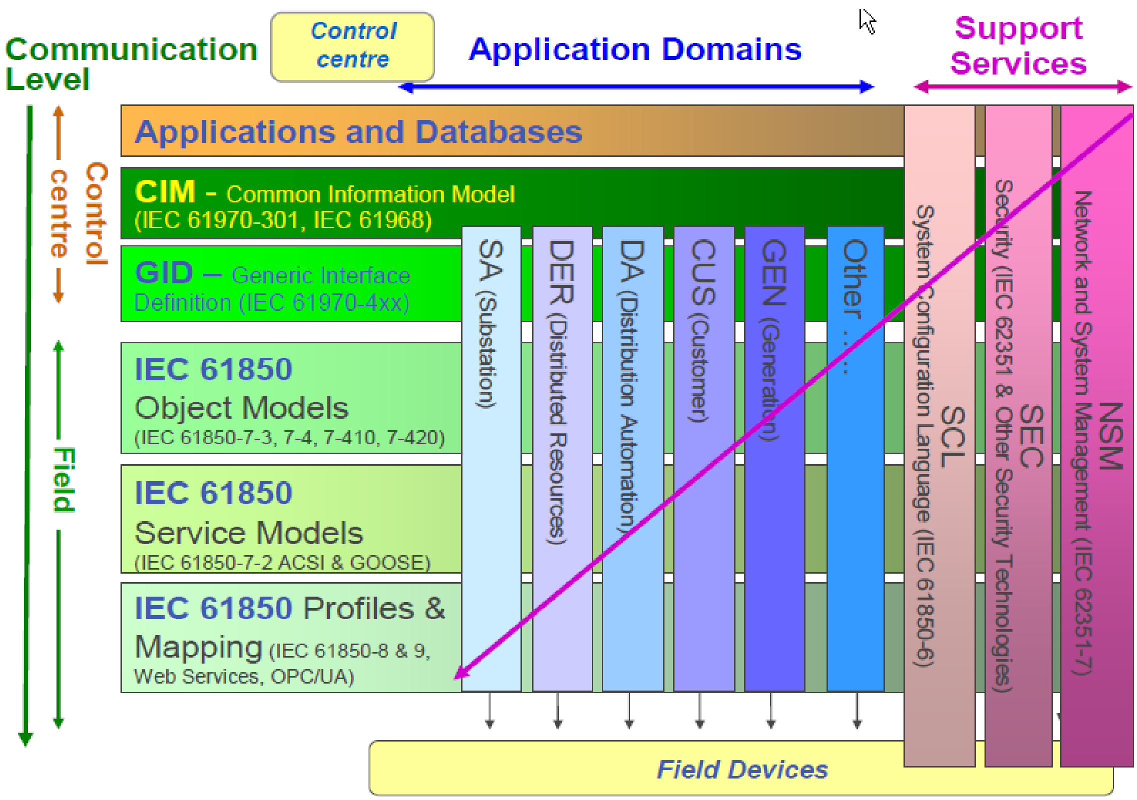

Figure 11: IEC 61850 models and the Common Information Model (CIM) [11]

The IEC reference architecture finds it origin in the technical operation of transport and distribution grids and therefore lacks support for more recent roles and responsibilities. Although ontology packages for competitive market roles have been designed these are regarded to represent a different maturity level than the core packages. In the smart grid vision even newer roles and tasks such as the “Aggregator” have been identified that are not yet represented in the existing ontologies [7]. The main items for expansion of the current ontologies include support for the use-cases listed:

- Flexible energy prices, flexible grid tariffs and the interfaces between consumers and producers, TSOs, DSOs and suppliers/traders/aggregators
- Clearing & settlement and interaction with data collection, data exchange, and electricity flows
- Products and features fostering producers and consumers’ flexibility in relation to capacity management, communication needs, etc.
- Efficient ways to communicate with customers, such as e-mail, SMS, signals to the meter, In-Home display, digital TV etc.
- Ensuring that consumers receive accurate, timely, understandable and usable information on consumption.

A set of tools and rules is needed for cross domain information exchange and representation. Activities that have been happening in parallel in various sectors need to be able to converge in a controlled fashion. Standards already exist across the semantic and pragmatic boundaries. The challenge is to formalize these into an ontology that covers the Energy Efficiency applications domain.

The semantics of the built environment and the grid are connected at a functional level as both domains are part of the same energy flows. The smart grid projects already defined domain ontologies that have become part of an IEC standard. These ontologies have limited support for the built environment however. In that respect both ontology domains could benefit from each other on shared topics such as energy efficiency measures. Ontology mappings may be required to effectively exchange information between the grid domain (infrastructure operators, energy market and such) and the built environment (developers, owners, occupants etc.). A mutual approach of grid and build environment experts could help interconnect the semantic definitions of the two sectors and prepare for collaboration in the field of energy efficiency [13]. The new emerging standards on energy efficiency of buildings, general energy terminology, the carbon footprint standard (the future ISO 14067) and energy management systems (the future ISO 50001) will help establish global conventions [14].

5. Conclusions

5.1 Compliance with the DoW

This document is part of the list of deliverables and part of the DoW of the REViSITE project. This document is part of Task 3.4 “Interoperability Frameworks and Standards” and its findings are also based on the tasks 2.1, 2.3 and 2.4 of the project and their corresponding deliverables.

5.2 Main Findings

This document identifies the needs and opportunities for enhanced interoperability in the four focus areas and suggests actions forward based on a consolidated view as part of the roadmap. It highlights areas where data exchange should be defined, or where projects concerning this definition should be integrated.

The ranked proposals for standardisation exhibit great complexity. The REViSITE validation workshop held in Paris indicated that the standards and the processes that create and maintain the standards are difficult to grasp. An overview is difficult as lots of different and partially overlapping standards already exist. This is the case particularly in the area of communication protocols.

A further barrier was identified relating to the time it would take to establish a mature cross-sectoral international standard or ontology. The CIM ontology took some 20 years to achieve its current maturity level. Current developments in technology however are much faster and would require a more flexible and agile standardisation creation and maintenance process.

Some of the disciplines involved in the discussions are relatively young (semantic web technologies, remote sensing, energy & carbon metrics, etc.). Some of these may require more context specific research before being stable enough for definitive standards. The subject matter knowledge that is needed for the standardisation may need further development.

The recommendations in this document focus on the selection, extension and harmonisation of existing standards or development of new standards in order to overcome the barriers listed in this paragraph. This underpins the suggestions to further develop the following areas:

- The extension of existing ontologies for energy efficiency
- Energy (and carbon) performance indicators (Metrics)
- Product catalogues that include energy dynamics
- Generic data exchange and communication protocols
- Harmonisation and extension of the IEC Ontology

The overall conclusion would indicate that energy efficiency requires a cross-sectoral and life-cycle perspective to achieve energy efficiency in its full potential. The design stage requires faithful insights in energy requirements of processes and buildings while the operational phase includes information exchanges across sectoral boundaries that require common semantic definitions. The recommendations of the REViSITE project cover the actors in the full scope of the energy flows and support monitoring, assessment and control.

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ANNEX 1: PARIS WORKSHOP SUMMARY

ICT for Energy Efficiency – Cross-Sectoral Interoperability Workshop

The workshop was held in Paris, France, March 9th 2012, hosted by CSTB.

Since this workshop represented the most important of the five organised by the project a detailed and accurate preparation has been conducted.

The consortium aimed to provide the audience beforehand with a short document related to the Strategic Research Agenda, both to offer them a background of the priority research topics identified up to now, and also to gather feedback on them.

Furthermore, to prepare the audience for the scheduled work group exercises, the consortium provided also a short version of the Implementation Action Plan.

The Consortium met on the day before the workshop and defined the scope and the most suitable strategy to gather the most out from all participants about the following items:

- D3.3 – Feedback on The Implementation Action Plan, previously sent to the participants
- D3.4 – Recommendation for Standardisation proposals.

The full day saw the consortium and experts working together in groups developing some validation exercises in relation to the results developed among the Implementation Action Plan and about the standardisation proposals.

After the welcome and the brief presentation of the project, the partners gave explanation about the work developed up to date by REViSITE and explained in details the aim of the day and what we did expect from the audience.

The audience has been represented by 10 external experts.

During the workshop the consortium also organised some quick poll questions to gather points of view about:

- REViSITE Framework validity
- Recommendations about standardisation proposals
- Barriers for standards implementation

Through the use of an electronic voting tool the consortium has been able to gather feedback in real-time and then to develop an analysis to define important inputs for the upcoming closure of the project.

The day ended positively, both the consortium and experts were satisfied about the work done.

The Consortium had the chance to validate, improve and finally define its inputs both in relation to the IAP and to the standardisation proposals.

ANNEX 2: RECOMMENDATION FOR STANDARDISATION PROPOSALS EXERCISES

Paris Workshop Results

During the workshop held in Paris the following proposal were discussed between the REViSITE consortium and the audience:

- Extension of existing ontologies for energy efficiency
- Harmonisation and extension of the IEC Ontology
- Energy Performance Indicators
- Data exchange protocols
- Product catalogues that include energy dynamics

For each of the following proposal, the audience was asked to express the level of importance according to their view from 1= Low importance to 5=High importance using the keypads of the electronic voting tool

The following table summarises the outcome of the voting exercise:

Results					
	1	2	3	4	5
Extension of existing ontologies for energy efficiency	7%	7%	14%	43%	29%
Harmonisation and extension of the IEC Ontology	0%	13%	40%	7%	40%
Energy Performance indicators	6%	0%	19%	31%	44%
Data exchange protocols	0%	6%	13%	31%	50%
Product catalogues that include energy dynamics	20%	7%	40%	27%	7%

Table 1: Polling exercise results for the standardization proposals

To evaluate the order of importance for each single proposal we assigned weight to the various grades. In specific we used used the following weight in correspondence to the grades:

Grade	Weight
1	0.2
2	0.4
3	0.6
4	0.8
5	1

The results obtained after calculation are shown in the following graph:

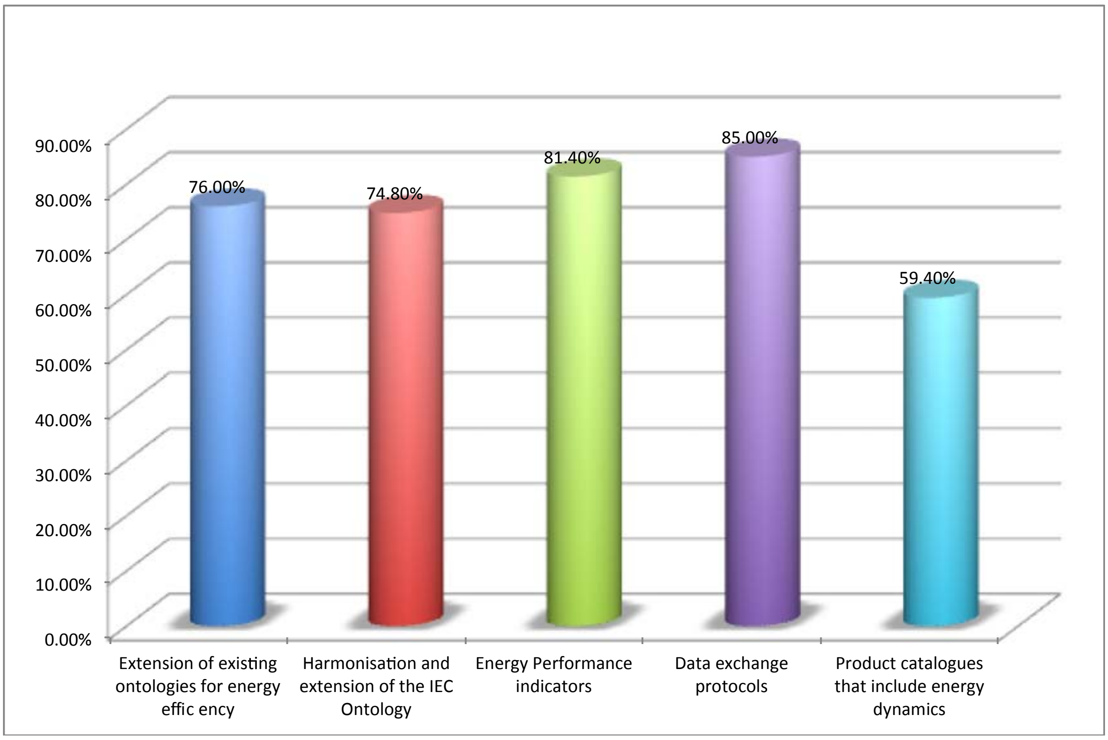

Figure 1: Weighted results for Standardisation Proposals

Hence the positioning for importance according to the workshop audience was:

1. Data exchange protocols
2. Energy Performance indicators
3. Extension of existing ontologies for energy efficiency
4. Harmonisation and extension of the IEC Ontology
5. Product catalogues that include energy dynamics.

Web Consultation:

During the project course the consortium developed a voting tool embedded into the REViSITE website.

Such quick poll investigates about what is the most significant barriers to integration/interoperability between the built environment and smart grids.

The results are following reported:

Barrier	**Voting Percentage**
Technical	7.7%
Economic	23.1%
Regulatory	38.5%
Political	30.8%

From such survey it comes out that the most critical barriers to face with are represented by the Regulatory aspects (38.5%) and Political aspects (30.8%).