Roadmap Enabling Vision and Strategy for ICT-enabled Energy Efficiency

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D3.2 Multi-disciplinary Strategic Research Agenda for ICT-enabled Energy Efficiency

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RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

SEVENTH FRAMEWORK PROGRAMME

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Table of Contents

Executive summary

Project: REViSITE

Roadmap Enabling Vision and Strategy for ICT-enabled Energy Efficiency (www.revisite.eu)

Title: Multi-disciplinary Strategic Research Agenda for ICT-enabled Energy Efficiency (Deliverable D3.2, 2012-05-03)

Executive summary:

The report suggests a RTD roadmap on ICT for energy efficiency divided into 6 research areas:

1. **Specification & design ICTs:** Design conceptualisation; Detailed design; Modelling; Performance estimation; Simulation; Specification and product/ component selection.
2. **Materialisation ICTs:** Decision support & visualisation; Management and control; Real-time communication.
3. **Automation & operational decision support ICTs:** Automated monitoring & control; Operational decision support and visualisation; Secure Wired / Wireless sensor networks; Quality of service.
4. **Resource & process management ICTs:** Inter-enterprise coordination; Business process integration; Information/knowledge management and analytics.
5. **Technical integration ICTs:** Integration technologies and infrastructures; Interoperability and standards.
6. **Trading / transactional management ICTs:** Regional energy management; District energy management; Facility energy management; Personal energy management.

Topics 1, 2 and 3 above focus on different life cycle stages while topics 4 and 5 underpin ICTs in all stages.

In each research area the roadmap suggests topics in short, medium and long term, bridging the gap between the state of the art and envisioned future.

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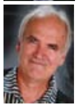

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Keywords: Buildings, Construction, Grids, Energy, FP7, ICT, Lighting, Manufacturing, Research, Roadmap

Acronyms and terms

Acronym	Description
2D	2 dimensional
3D	3 dimensional
4D	4 dimensional (3 dimensions + time)
6LoWPAN	Internet Protocol version 6 over Low power Wireless Personal Area Networks
AEC	Architecture, Engineering and Construction
AGC	Automated Generation Control
APS	Advanced Planning Systems
BAN	Building Area Network
BAS	Building Automation System
BE	Built Environment
BIM	Building Information Model
BMS	Building Management System
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CAPP	Computer Aided Process Planning
CAx	Computer Aided “Anything”
CEP	Complex Event Processing
CFD	Computational Flow Dynamics
CIM	Common Information Model [Grids]
CO2	Carbon Dioxide
CRM	Customer Relationship Management
DB (s)	Database(s)
DER	Distributed Energy Resources
DMU	Digital Mock-Ups
EDA	Energy Dependency Analysis
EE	Energy Efficient/Efficiency
EMS	Energy Management System
ERP	Enterprise Resource Planning
FEM	Finite Element Mode
FM	Facility Management
FMS	Facility Management System
HAN	Home Area Network
HEMs	Home Energy Management system
HFE	Human Factors Engineering
HPC	High Performance Computing
HVDC	High Voltage Digital Current
ICT	Information and Communication Technology

Acronym	Description
ICT4EE	ICT for Energy Efficiency
IPR	Intellectual Property Rights
ISP	Integration / Internet Service Platform
KM	Knowledge Management
LC	Life Cycle
LCA	Life Cycle Assessment
Mgmt	Management
nD	N Dimensional (model describing versatile aspects of a system (e.g. 4D + EE)
NFC	Near Field Communication
PC	Personal Computer
PDM	Product Data Management
PLC	Power Line Communication
PLM	Product Life cycle Management
QFD	Quality Function Deployment
QoE	Quality of Experience
QoS	Quality of Service
RFID	Radio Frequency IDentifier
RM	Rapid Manufacturing
RSS	Rich Site Summary / Really Simple Syndication
RTD	Research and Technology Development
SHP	Smart Hybrid Prototyping
SLA	Service Level Agreement
SOA	Service Oriented Architecture
SOTA	State Of The Art
SRA	Strategic Research Agenda
WSN	Wireless Senor Networks
VE	Virtual Enterprise
Volt-VAR	Management of VOLTage levels and reactive power (Volt-Ampere Reactive VAR) control (throughout power transmission and distribution systems to reduce waste and to increase grid capacity)
VR	Virtual Reality
ZigBee	a low data rate, low-power, wireless networking standard / protocol

Introduction

Purpose

The REVISITE project is a Coordination Action supported by the European Commission under the FP7 programme in the area of ICT for Energy Efficiency. The aim of REVISITE is to identify opportunities for research synergies between sectors:

- Many ICT tools & systems are generic and can serve different industry sectors with no or reasonable adaptation. This offers opportunities for larger markets to the ICT providers and better services to ICT users.
- Synchronised development of energy management systems for different sectors offers opportunities for energy trading via energy information exchange.
- The geographical frame of reference for the studies is the EU-27 and the time frame in terms of impact assessment and vision is 1990 to 2020.

This document suggests research priorities in the domain of ICT for Energy Efficiency across several industry sectors. The sectors especially considered are electricity grids, manufacturing, buildings and lighting. It is expected that the identified research topics will be relevant also to other sectors. It should be noted that different sectors will invariably represent different maturity levels with respect to the technologies outlined, however the aim is to produce a holistic cross-sectoral view.

Three complementary reports provide recommendations on specific actions to be taken by various stakeholders in line with this SRA:

- D3.3 Implementation Action Plan.
- D3.4 Recommendations for new standards to overcome interoperability barriers.
- D4.4 Recommendations to Education and Training Systems.

Contributions

LOU

- Pointing out visions based on D3.1 Vision.
- Reviews and suggestions to all sections from construction & manufacturing perspective.

VTT (supported by Aalto, subcontractor)

- Lead author of D3.2.
- Summary of existing roadmaps for Lighting (Appendix 1).
- Section on Specification and Design ICT's.
- Reviews and suggestions to all sections from buildings and lighting perspective.

CSTB

- Summary of existing roadmaps for Buildings (Appendix 1).
- Section on Technical Integration ICT's.
- Reviews and suggestions to all sections from buildings perspective.

KEMA

- Summary of existing roadmaps for Grids (Appendix 1).

- Section on Trading / transactional management ICT's.
- Reviews and suggestions to all sections from grid perspective.

INTEL

- Supporting use of the common methodology based on D2.1 + D2.3 (Appendix 3).
- Sections on Automation and operational decision support ICTs and Resource & process management ICTs.
- Reviews and suggestions to all sections from ICT perspective.

FhG

- Pointing out state-of-the-art and cross-sectoral RTD trends (from D2.2).
- Summary of existing roadmaps for Manufacturing (Appendix 3).
- Section on Materialisation ICT's.
- Reviews and suggestions to all sections from manufacturing perspective.

INN

- Collecting feedback from stakeholders to questionnaires on draft versions of the roadmap.

REViSITE Expert Group – REG
The members of the group were invited to participate in workshops with the consortium to develop this SRA. They also peer reviewed documents and provided advice during the course of the project. Their contributions, critiques and suggestions are highly acknowledged:

- Reiner Anderl / Thomas Rollman, TU Darmstadt, Germany
- Michel Böhms, TNO, The Netherlands
- Andrew Eastwell, BSRIA Limited, UK
- Alfio Galatà, Agsavings, Italy
- José Javier de las Heras Bueno, Advantic, Spain
- Andrew Haslett, Energy Technology Institute, UK
- Joao Martins, UNINOVA, Portugal
- Philippe Maréchal, CEA / LITE, France
- Shallandra Mugdal, Bio Intelligence Service, S.A.S, France
- Shahin Rahimifard, Loughborough University, UK
- Giorgo Recine, Labor, Srl. Italy
- Bruno Smets, Philips Lighting, The Netherlands
- Vernon Fox, Mainstream Renewable Power

The REViSITE Community, consisting of persons who expressed active interest to the project, participated in the validation of this SRA by providing feedback to questionnaires and suggestions at open workshops (see appendices 4-7). The feedback, representing their personal viewpoints, are acknowledged:

- Hamid Asgari, Thales Research and Technology (UK) Limited
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- Eilif Hjelseth, Norwegian University of Life Sciences (UMB)
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- Alvaro Sicilia, ARC
- Charis Stavrinou, Scientific & Technical Chamber of Cyprus/Cyprus technology Platform
- Mari Carmen Suarez-Figueroa, University Politechnica of Madrid
- Cesar Valmaseda, CARTIF
- Vladimir Vukovic, AIT
- Chris White, EPSRC

Methodology

The overall methodology to identify priority topics is described in Appendix 3.

The deliverables of Work package 2, together with the Vision of D3.1 combine to inform the proposed SRA as illustrated in figure 1 below.

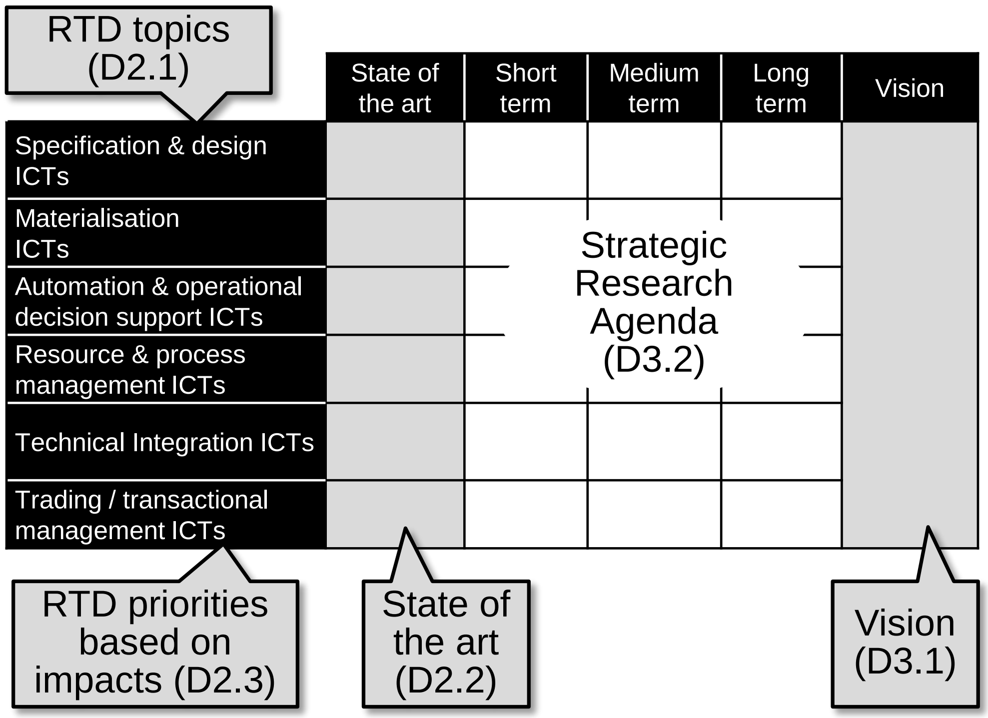

Figure 1. Combining deliverables in informing SRA development

The SRA is essentially built on the output of D2.3 'ICT4EE - Impact Assessment Model' and the subsequent qualitative discussion and assessment that output generated, both within the REViSITE consortium and the wider community.

D2.3 centred on identifying the potential relevance of key ICTs with respect to an ICT4EE focused SRA. D2.3 was based on the qualitative research of deliverable D2.2 'ICT4EE-Knowledge and current practices' and utilised the framework developed in deliverable D2.1 'ICT4EE- Data Taxonomy: A common methodology to assess the impact of ICT developments'.

Structure of the SRA

The report includes sections based on the 6 main categories and 21 sub-categories of the REViSITE SMARTT taxonomy (see Appendix 3. SRA Development Methodology). For each category there is a summarising table describing briefly:

- State of the art.
- Short-term research priorities (~3 years to industrial usage; adaptation, testing & take up of new technologies, demonstrations/pilots, dissemination etc.).
- Medium-term research priorities (~6 years to industrial usage; development of new applications and incremental technologies, etc.)
- Long-term research priorities (~9 years to industrial usage; radical technical developments, etc.).
- Vision (~desirable future situation based on currently foreseen developments).

The tables are preceded by succinct narratives that describe the scope of the sub-categories with give sector specific examples, and the baseline consisting of the SOTA (based on D2.2 ICT4EE - Knowledge and Current Practices) and vision (based on D3.1 Vision for multi-disciplinary ICT-enabled Energy Efficiency). This deliverable report incorporates into these tables feedback received within the consultation process with external stakeholders.

1. SPECIFICATION & DESIGN ICTS

Scope

Design is central given estimates that a major share *(indicatively ~80%)* of a products *(e.g. buildings)* life time environmental impact is determined in the design phase. This is especially the case when new products/systems are designed. However, design for retrofitting of existing systems is also crucial as many products/systems are renewed several times throughout their life time. The degree to which the designed energy efficiency potential will be actually materialised, depends on the downstream life cycle stages *(materialisation, operation)*. Therefore integration between different stakeholders and stages is of fundamental importance for design.

The main trend in this area is "integrated design" implying interoperability of various ICT applications and sharing of information at high semantic level between stakeholders over all life cycle stages.

Design conceptualisation: Methods and ICT tools for requirement engineering and management, concept modelling for design ideation, elements of PLM etc.

- *Grids:* e.g. requirement tools, mainly to collect & structure the great number of requirements in complex multivariable systems, such as grids.
- *Building/Lighting:* e.g. user/client requirement identification, concept solution development & initial cost estimate at building/urban planning levels.
- *Manufacturing:* e.g. digital factory & Green-PLM concepts etc. coupled with EDA in pre-design stage of products & production systems.

Detailed design: Design tools, CAD, multimedia, computer graphics, catalogues of materials, component and reference design solutions, etc.

- *Grids:* e.g. visualisation ICTs depicting the various elements constituting a smart grid at the energy & underpinning ICT infrastructure level.
- *Building/Lighting:* e.g. development of detailed solutions for the building architecture, structures, building services etc.
- *Manufacturing:* e.g. CAM & CAPP to plan / verify the manufacturing of parts & the optimisation of the production systems.

Modelling: Tools for representing physical artefacts with semantic information in machine-interpretable format enabling automated access & retrieval and offering potential for automation of some design tasks and integration with related activities.

- *Grids:* e.g. energy infrastructure behaviour modelling given static prosumer & market data. Data models at the ICT infrastructure level e.g. CIM
- *Building/Lighting:* BIM-based design, analysis and simulation tools
- *Manufacturing:* e.g. VR supported prototyping, DMU or SHP etc. in reducing physical mock-ups & optimising products & production systems.

Performance estimation: ICTs for system performance analysis e.g. LCA, FEM, financial analysis and a wide variety of domain specific engineering analysis tools.

- *Grids:* e.g. ICTs supporting technical & financial performance: operational resilience & reliability + cost/benefits & energy market effects.
- *Building/Lighting:* e.g. ICTs to assess the evolving design regarding functionality and requirements e.g. costs, energy, light distribution etc.
- *Manufacturing:* e.g. process / supply chain LCA type applications.

Simulation: ICTs supporting dynamic analysis as part of design e.g. CFD, power system, thermal & occupancy simulation, network simulators etc.

- *Grids:* e.g. power system prediction (generation & energy markets) including state estimators, grid simulation & consumption forecast logic etc.
- *Building/Lighting: e*.g. Dynamic analysis of the energy usage and thermal behaviour of the building, air flows, weather impacts etc.
- *Manufacturing:* Simulation of energy consumption on individual levels of the production sys. From machine to process chain.

Specification and product/component selection: ICTs for component specification and selection to meet design requirements e.g. material or product databases/catalogues and retrieval methods.

- *Grids:* e.g. ICTs supporting roll-up of requirement, technical & functional specifications + tender best practise as per EU rules & regulations.
- *Building/Lighting:* e.g. ICTs supporting selection by a contractor of the products/components/materials to be procured.
- *Manufacturing:* e.g. EDA coupled with embodied energy/carbon DBs for efficient manufacturing & component selection for eco-products.

Impact beyond current SOTA will stem mainly from the integration of standalone ICTs in terms of holistic EE design, see table 1.

Baseline

State of the art

Key decisions affecting the life time performance of a system are made in the **conceptual design** stage. However, only very limited tools are available for design conceptualisation like requirements capture and formalisation, holistic target setting regarding energy efficiency and other performance criteria, concept development and visualisation. Mostly ad hoc, domain and company specific tools are used. Some generic methods (e.g. QFD) are available.

Detailed design is a rather mature area with general purpose tools like CAD, PDM, PLM, visualisation tools, web based product catalogues etc. There are numerous proprietary and domain specific applications and add-ons to generic tools. Many tools are centred around graphics and shape representation with limited support for semantic data on properties. Intelligent tools, i.e. those with embedded design rules and knowledge, have limited applicability and market due to different national/regional regulations. Emerging technologies include e.g. scanning of existing facilities for retrofitting design and parametric product catalogues. Interoperability of various tools is improving but still remains as a key issue.

A long term trend in design has since several decades been towards increased semantics i.e. **modelling** (frequently referred to as “Building Information Modelling, BIM”, in the construction sector). Emerging model based tools exist today mostly for isolated design and analysis applications, file based data exchange etc. The great promise of the model-based approach is interoperability between various ICT applications. However, the existing standards and related certification procedures still fall short of providing the desired level of interoperability in practice. Therefore, model based information is generally not yet accepted as original source of contractual information, which leads to additional overhead costs in design. Also IPR concerns limit the willingness of stakeholders to distribute semantically rich information.

Energy efficiency is still a relatively new focus of design, and in most cases being only one out of many design criteria. Consequently, ICT tools for energy **performance estimation** are still in evolution. There is a lack of standardised or generally accepted performance indicators that could be assessed based on available data in various ICT systems. A key challenge is to assess holistic life cycle performance of products/systems with respect to versatile criteria, including but not limited to energy efficiency. In order to reduce design overheads, it is preferable to enhance existing design tools to cope with holistic criteria instead of introducing new specific tools for e.g. energy efficiency. In most cases, the existing estimation tools are not interoperable with design tools, which in practice limits possibilities for performance-driven design.

Energy **simulation** is an important kind of performance estimation. Several tools already exist for simulating manufacturing processes, buildings (e.g. CFD), energy grids etc. However, these are usually based on proprietary models and algorithms, and provide limited interfaces with design tools. The results of different simulation tools are often not comparable. Therefore simulation is not fully trusted and is often performed as an extra confirmation, rather than being relied on as the key validation of the proposed design solution.

In order to materialise the design, specific components that meet the design requirements are **selected and procured**. In many cases the available and selected products exceed the minimum requirements. However, the excess performance is seldom re-considered for optimising the total design solution. Furthermore, when replacing components later in the life time, the tendency is to meet or exceed the performance of the previous component, instead of just meeting the originally required performance. This leads to over-dimensioning and unnecessary extra costs. The challenges are in accessing and matching the original performance requirements with the performance of available components. Currently documented design information includes specification but not usually the original requirements. Currently available product catalogues provide no or very limited performance based search. For competitive reasons the suppliers prefer to emphasize differentiating rather than comparable performance data.

Vision

The vision of future design assumes semantically rich ICTs, open standards for interoperability and flexible integration (see also section 5 Technical integration ICTs):

- Integrated ICTs for holistic design, modelling and assessment covering energy interaction between the different subsystems, technical, commercial, sustainability and regulatory factors.
- Interoperability of design ICTs in model based information sharing.
- Catalogues of components and re-usable design solutions with rich search capabilities and embedded design rules (parametrics).
- Standardised data models covering energy and other performance aspects.
- Standardised energy performance indicators.
- Models of stakeholder profiles, requirements, energy consumption, market dynamics etc.
- Certified software for compliance assessment.
- Evidence-based knowledge about the impacts of ICTs on energy efficiency.

Radical innovations for the interoperability of complex ICTs such as design tools seem necessary but can not be currently foreseen. The short, medium and long term priorities are being seen as evolutionary steps with increasing levels of semantics and interoperability.

Short term

Methods for early stage **design conceptualisation** and decision support. Templates for requirements and user profiles.

Detailed design tools with design templates and interoperable component catalogues. Support (e.g. generic architectures) for designing service oriented systems.

Domain specific **modelling** tools based mostly on existing applications enhanced with energy related aspects. Tools for re-modelling existing products/systems for retrofitting (e.g. translation of laser scans).

Metrics and validation methods for holistic static **performance estimation**: technical, economic and environmental. Quality of Service and Service Level Agreements.

Simulation methods for design and validation. Dynamic/4D visualisations.

Templates for **specification and product/component selection**, catalogues of materials, products and suppliers. E-market tools.

Medium term

Improved **interoperability** between design tools, CAD, catalogues and various engineering applications for performance analysis, simulation, visualisation, etc. enabling holistic design of the interactions between different subsystems.

Tools for **design conceptualisation** and concept development. Reference models for LC requirements and usage scenarios. Simulation based systems for refining requirements for highly interdependent complex systems.

Detail design tools using parametric templates and product catalogues with embedded design rules.

Model based tools with increasing level of semantics for design, performance estimation, state prediction, optimization, simulation, object catalogues etc.

Metrics for dynamic **performance estimation**. Simulation based validation methods. Models and methods for attributing the contributions of components and subsystems to the overall energy efficiency.

What-if analysis using **simulation**, interfaced with design models. Integrated cross-domain simulation of interactions within complex systems such as major infrastructures.

Tools for **specification and product/component selection**: Specification models and templates. Model based product catalogues with semantic search capabilities for selection.

Long term

Generation of requirements from related system models for **design conceptualisation**. Context aware visualisation based on EE criteria, with context specific content suggestion, all rendered based on device capability and user preferences.

Configuration **design** based on reference solutions and intelligent component objects with embedded adaptation rules.

Functional (beyond data) **model-based** product/system objects enabling new object oriented applications.

Metrics and validation methods for real time **performance estimation**.

Live virtual models with built-in **simulation** capabilities by simulators and models. Live virtual models capturing each system parameter & user experience / perception.

Optimally automated component **selection** and procurement.

Table 1. Specification & design ICTs

<table>
<tr><th>RTD topic</th><th>State of the art</th><th>Short term ~3yrs</th><th colspan="2">Medium term ~6yrs</th><th>Long term ~9yrs</th><th>Vision</th></tr>
<tr><td>Design concept-ualisation</td><td>Limited tools for requirements capture and engineering, energy analysis and concept visualisation.</td><td>Methods for early stage decision support. Templates for requirements and user profiles.</td><td>Tools for concept development. Reference models for LC requirements and usage scenarios. Simulation based systems for refining requirements for highly interdependent complex systems.</td><td rowspan="6">Holistic design of the interactions between different subsystems. Interoperability between CAD tools, applications for design, performance analysis, simulation, visualisation, libraries etc.</td><td>Generation of requirements from related system models. Context aware visualisation based EE criteria, with context specific content suggestion, all rendered based on device capability & user preferences.</td><td rowspan="6">Integrated ICTs for holistic design, modelling and assessment covering energy interaction between the different subsystems, technical, commercial, sustainability and regulatory factors.

Interoperability of design ICTs in model based information sharing.

Libraries of re-usable design solutions with rich search capabilities.

Standardised data models covering energy related aspects.

Standardised energy performance indicators.

Models of stakeholder profiles, requirements, energy consumption, market dynamics etc.

Certified software for compliance assessment.

Evidence-based knowledge about the impacts of ICTs on energy efficiency.</td></tr>
<tr><td>Detailed design</td><td>Scanning of existing facilities for retrofitting design. General purpose tools like CAD, PDM, PLM and visualisation. Proprietary and domain specific applications. Web based product catalogues.</td><td>CAD tools with design templates and interoperable component libraries. Support for designing service oriented systems.</td><td>Parametric design using templates and design rules. Parametric product libraries.</td><td>Configuration design based on reference solutions, adaptation rules and intelligent component objects.</td></tr>
<tr><td>Modelling</td><td>Evolving model based tools for mostly isolated design & analysis applications, file based data exchange, reverse engineering, digital/hybrid prototyping, rapid manufacturing, visualisation etc.</td><td>Domain specific application tools enhanced with energy related attributes. Tools for modelling existing products/systems.</td><td>Model based tools (design, performance estimation, state prediction, optimization, simulation, etc.) and object libraries.</td><td>Functional (beyond data) product/system objects enabling new object oriented applications.</td></tr>
<tr><td>Performance estimation</td><td>Tools (LCA) for assessing costs, environmental impacts, comfort etc. (e.g. CFD).</td><td>Metrics and validation methods for holistic static performance: technical, economic and environmental. Quality of Service and Service Level Agreements.</td><td>Metrics for dynamic performance. Simulation based validation methods.</td><td>Metrics and validation methods for real time performance.</td></tr>
<tr><td>Simulation</td><td>Tools for simulating energy consumption, generation, markets. CFD. Some interfaces from CAD/design tools to simulation. 2D/3D/4D visualisations.</td><td>Simulation methods for design & validation. Dynamic/4D visualisation.</td><td>What-if analysis using simulation, interfaced with models. Integrated cross-domain simulation of interactions within complex systems such as major infrastructures.</td><td>Live virtual models enabled by simulators and models. Live virtual models capturing each system parameter & user experience / perception.</td></tr>
<tr><td>Specification & product/ component selection</td><td>Limited sector specific specification methods and tools, e-procurement.</td><td>Specification templates. Catalogues of materials, products & suppliers. E-market tools.</td><td>Specification models. Model based product libraries. Selection tools.</td><td>Optimally automated component selection & procurement.</td></tr>
</table>

2. MATERIALISATION ICTS

Scope

'Materialisation' follows the design phase & is a non-sector specific term understood within REViSITE to encompass construction, grid infrastructure & 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.

Decision support & visualisation: technologies supporting visual representation of work flows & production methods focused on efficient task completion. Cognitively compelling visualisation of: streamed / asynchronous data, simulations & models to support in-the-field decisions.

- *Grids:* e.g. grid roll out, is a civil & telecommunications engineering task. EE benefits stem from optimal design & in-the-field execution. A common requirement in this phase is to ensure electricity supply is not interrupted while installing new components.
- *Building/Lighting:* e.g. ICTs supporting access & the compelling contextual rendering / visualisation of information supporting decision making during construction e.g. production methods, logistical management & material selection data including embodied carbon/energy etc.
- *Manufacturing:* e.g. production-system development, is essentially a civil engineering & automation infrastructure implementation task, EE benefits stem from optimal design & in-the-field execution involving optimal equipment [factory line] & ICT system deployment.

Management & control: ICTs supporting dependable ubiquitous data access with respect to adherence to performance requirements, conformance validation, commissioning & phase specific task management in terms of efficient materialisation of the physical infrastructure, building or otherwise.

- *Grids:* e.g. [as above].
- *Building/Lighting:* e.g. ICTs supporting decisions regarding on-v-off-site production which have a major impact on logistical consumption, or compliance checking of actual progress with respect to design (BIM) and plan using e.g. image processing or laser scanning.
- *Manufacturing:* e.g. [as above].

Real/Near-time communication: ICTs that facilitate decision making, mobile/fixed tele-communications, visual & audial feedback mechanisms etc.

- *Grids:* e.g. [as above].
- *Building/Lighting:* e.g. sensor information regarding integrity of building materials during construction integrated into an alert mechanism such as a SMS text or on-screen display, or automatic monitoring of material consumption & progress on site using hand held tag readers or laser scanners & real time communication with the logistics management systems for JIT delivery.
- *Manufacturing:* e.g. [as above].

In short, benefits for EE stem from the optimisation of in-the-field work & coordination of different stakeholders, enabling abatements in terms of overruns & 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 & visualisation of materialisation processes, table 2 follows.

Baseline

The materialisation phase follows the design phase and describes in general the realization of the physical. In the building sector construction is a significant element of a buildings life cycle. Activities in this phase account for about 5% of total energy used, including construction related transports. Typically processes in the building sector largely involve a complex supply chain and even so transport is outside the scope of this project the impact of ICTs on EE cannot be ignored in this field.

In the Manufacturing sector Materialisation describes the formation of a production system. This encompasses the construction of a factory building (see building sector) but also setting up the production equipment within the factory and the implementation of control and automation ICTs.

Materialisation in the Grid sector is dominated by the installation of smart grid equipment, including communication infrastructure as well as monitoring and controlling systems. Energy related aspects are mainly a logistics issue in this domain, due to the number of installations, which are geographical spread. One rather common requirement in this phase is not to interrupt electricity supply while installing new components.

In the Lighting sector Materialisation can be considered as the production of lighting components as special use case of the manufacturing sector. But it also refers to infrastructure deployment (e.g. creation of street lighting systems) with a strong link to the grid sector.

In terms of ICT, the Materialisation phase is currently supported by conventional project management and Enterprise Resource Planning software, which could be assumed as common across the sectors. Additional regular systems provide logistic support, basic technical support and elementary test facilities. From an ICT4EE perspective initial research work is initiated in the building sector due to the energy intensive construction of the buildings and the transport and erection of building components. Despite that Energy Efficiency and sustainability in general, are emerging concerns, ICTs in the other sectors mainly focuses on the economic - optimisation (timing, costs and contracts). However even so financial aspects are still the main driver, energy savings are achieved as a second order effect from well planned and executed materialisation processes.

Within REViSITE we distinguish Materialisation ICTs in „Decision support and visualisation", „management and control" and „real-time communication" ICTs. The complexity of decisions in the Materialisation phase results in most cases in suboptimal performance. Therefore the consideration of energy data in decision support tools and real-time communications are evident for the efficient management and control.

The extension of existing real-time project management tools and practice is essential for the optimisation not only of financial result but also of environmental parameters. In our vision this leads to the development of tools allowing “flexible materialisation”, to standards for supply chain integration and then to the emergence of a fully integrated design and production processes.

To achieve this goal tools are needed to visualise the status of materialisation process of a system, including its subsystems, components and work in progress. In detail this visualisations should be 3D/4D/VR models derived from BIM or PLM, bar charts, flow-line schedules etc.

In terms of EE management and control of Materialisation, ICTs tools should be used to define strategies and support decisions for on-site/off-site production of components of the building but also of large production equipment as well as the optimization of its transportation and the selection of ideally local suppliers. Especially in manufacturing this technologies could be utilised in the manufacturing of „mega‟ structures/products (ships, plane construction etc.). But also tools and methods are needed for performance testing under different interactions with different stakeholders and for validation of conformance to requirements and design specifications.

In terms of real time communication, the benefits for EE stem from the optimisation of in-the-field work and from the improved coordination of different stakeholders, enabling abatements in terms of overruns, unnecessary logistical runs etc. Having an accurate digital representation to hand over to the operational phase would also help with EE operational decision support.

In summary the REViSITE vision for ICT in the Materialisation phase is:

- Usage of control mechanisms at various scales to optimise the financial results as well as environmental parameters and stability.
- ICTs to optimise / select production / materialisation / procurement methods based on optimum energy consumption.
- ICTs to rationalise materialisation processes (in terms of planning and control) for energy efficiency (e.g. logistics, sequence, etc.)
- enable real real-time communication in materialisation phase
- tracking and visualisation of materialisation processes in virtual planning models

This vision leads us to set up the following short, medium and long term actions:

Short term

Decision support and visualisation

For tracking the status of process in the Materialisation phase, the development of new tools are required to visualise the real time progress beside using traditional bar charts and flow-line schedules etc. In terms of decision support ICTs must include energy related aspects (for transport and production processes) to select different strategies and to support decisions especially for the selection of suppliers and for on-site/off-site production of components.

Management and Control

For securing the sustainability of the materialisation phase it is essential to not only focus on financial optimization but also to include energy related aspects into planning. This includes also logistics, scheduling & planning tools required for optimised material/asset tracking, and certification in terms of chain of custody. The benefits for EE stem from the optimisation of in-the-field work enabling abatements in terms of overruns, unnecessary logistical runs etc. Having an accurate digital representation over to the operational phase to hand would also help with EE operational decision support (see above).

In terms of project planning, the problem is more often accessibility and openness rather than a technical one. Especially SMEs do not have access to personal skills, practices & tools. This limitation must be overcome in order to realize the vision of a volatile network of (local) suppliers.

Real time Communication

RFID tags should be used to track transport and status of components, which allows to track work progress and consumption of asset and to fed this information into the back-office financial tracking systems etc.

Medium term

Decision support and visualisation

Tools for visualising the real time progress should be extended and use 3D/4D/VR models to represent the current state of the building/product (e.g. derived from BIM or PLM). Therefore the interaction of project management systems and different data management ICTs via standardized interfaces is essential. Furthermore this models should be used to visualize especially energy related data in materialisation phase.

Also the link between design & simulation and materialisation management ICTs is not there, augmentations of BIM /PLM are required in that regard to interconnect process changes across the life cycle based on a digital model.

Management and Control

Financial planning tools used in the Materialisation phase should regard the whole life costing the system and its components. Therefore material information are also required which links back to specification & design ICTs.

Furthermore tools are required for the automated testing of the energy performance and validation of energy related requirements and design specifications during the materialisation phase.

Real time Communication

One item to consider is to provide context related multimedia content to workers and back offices. Information platforms on portable devices will help to perform construction tasks efficiently and avoid errors. This also requires interfaces to project management systems and different data management ICTs.

Long term

Decision support and visualisation

In a longterm perspective the above described ICTs for decision support must change to proactive decision making instead of support only to optimise / select production / materialisation / procurement methods based on optimum energy consumption.

Also the visualisation for the tracking of the progress in the materialisation process needs to be represented in holistic virtual planning models.

Management and Control

Developed ICTs to rationalise materialisation processes (in terms of planning and control) for energy efficiency (e.g. logistics, sequence, etc.) need mechanisms for the continues comparison of real time targets and the actual performance.

Real time Communication

Real time Communication it is essential to feedback any changes in reality into simulations/ planning model in order for the digital /virtual model to match the reality for handing over into the operations phase of the life cycle. This checking of design realisation and conformance can be supported by RFID technologies.

Table 2. Materialisation ICTs

RTD topic	State of the art	Short term *~3yrs*	Medium term *~6yrs*	Long term *~9yrs*	Vision
Decision support & visualisation	Manufacturing / process simulation tools. 4D visualisation / animation of processes e.g. in construction. Life Cycle Assessment of different construction / manufacturing options.	Tools to visualise real time progress to plan for energy sourcing options regarding cost & CO_2 Impact (including CO_2 certificates). Energy related aspects included into decision support to select production strategies e.g. offsite / onsite production and materials. Tools and e-commerce platforms for waste re-use.	Tools & interfaces using data from multiple ICT systems (e.g. BIM/PLM/ERP) to analyse and visualize (e.g. in 3D/4D/VR) current state, energy related information, environmental impacts etc. Location based services to decide on optimum materials suppliers. Visualisation of trade-offs between environmental and economic concerns.	Automated alerts to persons in charge on deviations in the production process. ICT for proactive decision making (instead of support only). Decision recommendation to solve trade-offs between environmental and economic concerns.	ICTs to optimise / select production / materialisation / procurement methods based on optimum energy consumption. ICTs to rationalise materialisation processes (in terms of planning and control) for energy efficiency (e.g. logistics, sequence, etc.). Real-time communication in materialisation phase. Tracking and visualisation of materialisation process in virtual planning models.
Management & control	Generic project planning tools (Gant charts, cost estimation etc.). ERP, BIM & PLM systems.	Energy related aspects integrated into planning tools (finance, logistic, scheduling) to define energy targets for production.	Whole life cycle costing. Automated tools for testing energy performance & validation of compliance to energy related requirements. Automatic calculation of energy consumed during production.	Simulation based real-time production management. Real time target/actual performance comparison.	
Real-time communication	Syndication tools (e.g. RSS). Collaboration tools from video conferences to CAD collaboration used in project management.	Using RFID/ NFC tags or similar to track transport & status of components, enabling near real time manufacturing.	Pervasive Context related multimedia content provided to workers on portable devices & back office.	Direct feedback of changes into planning models / simulations.	

3. AUTOMATION & OPERATIONAL DECISION SUPPORT ICTS

Scope

This category, given its direct relationship to the operational phase of the respective sector life cycles, is probably the most obvious in considering impact on energy efficiency, especially in the context of existing buildings, production systems and grid infrastructure. The category scope and how sub-categories relate to target sectors is briefly outlined, followed by Table 3 describing potential research topics and timeframes in extending SOTA.

Automated monitoring & control ICTs: supporting intelligent sensing / control with respect to energy efficient building, industrial and grid resource automation including sensing/control software and hardware, control & optimization algorithms, embedded microcontrollers etc.

- *Grids:* e.g. distribution: grid wide supervisory control & monitoring of infrastructure.
- *Building/lighting:* e.g. Intelligent HVAC, Lighting & device control. BAS, control logic & energy optimisation algorithms.
- *Manufacturing:* e.g. efficient intelligent control of motor drives, CNC operation, compressed air etc.

Operational decision support & visualisation ICTs: to include SCADA, Business Activity Modelling, Management dashboards, methodologies for analysing situation awareness in complex systems, integrative visualisation of diverse systems [safety, security, weather, energy etc.] at different levels of abstraction e.g. plant, building, district or energy ecosystem.

- *Grids:* e.g. decision support in terms of negotiation, production, consumption & distribution control.
- *Building/lighting:* e.g. Facilities Management software. Energy consumption reports / bills / displays / dashboards.
- *Manufacturing:* e.g. visualisation with regard to MES, ERP & PLC systems. Provisioning & development of Energy Performance Indicators.

Secure Wired / Wireless control & sensor networks & Quality of Service ICTs: to include wired and mobile network infrastructure, network specific hardware e.g. routers, convertors. Manageability and optimization software/algorithms, network architectures, protocols & modulation strategies, cyber security, etc.

- *Grids:* e.g. ICT network infrastructure & protocols underpin the energy network infrastructure.
- *Building/lighting:* e.g. HAN & BAN monitoring & control communications, PLC, Zigbee, BACnet, KNX, DALI etc.
- *Manufacturing:* e.g. networks for remote monitoring & control of production systems. Sensor network based intra logistics etc.

Baseline

State of the art

Automation [sensing and actuation] and operational decision support is a paramount theme in the ICT impact on energy efficiency discussion. REViSITE research supports this, for example all 'automation and operational decision support' ICTs ranked in the top median of ICTs surveyed in deliverable D2.3 in terms of impact on energy efficiency. The theme was seen as less important within the Built Environment sector in terms of relevance to a Research Agenda development a trend supported by survey iterations at the CIB2011 event (Appendix 5). But taking all sectors into account the theme dominated the top five rankings with positions 1, 2, 3 and 5 within D2.3. A possible reason for this might be that the impact of such

ICTs is perhaps the easiest to comprehend as they typically directly enable energy efficiency as opposed to being an enabler to an enabler.

Automated monitoring and control is an ICT theme that is well developed in terms of current sophistication. There are exemplars of high levels of automation in existence today across all the sectors. For example, there are levels of automation within manufacturing facilities consistent with level 8 of Sheridan's[1] levels of automation while embedded devices i.e. microcontrollers often operate at level 10. However, automation tends to be at a sub-system level of say a building or manufacturing facility. Operational decision support, sensing and actuation at the system level, for example building level or super system level i.e. district, leads us to the REViSITE vision with regard 'Automation and operational decision support' ICT's.

Vision

While already relatively sophisticated extension to current SOTA with regard to this category will of course relate to the development of energy monitoring, control and optimisation logic at the individual infrastructure component level e.g. substation, machine, HVAC, etc.

However significant augmentation/impact will come from the integration of such components in terms of holistic energy management, and therefore the REViSITE vision sees strong connections to categories 5 Technical/semantic Integration and 6 Transaction /Trading management.

The role of ICT in the context of automation, as identified in the REViSITE Vision (D3.1) is outlined below:

- Embedded ICTs that permeate sectors providing the "intelligence" to monitor and control energy resources in enabling resource/energy optimisation.
- ICT systems that facilitate informed intuitive user control through integrative data visualisations.
- ICT which act as learning systems, providing reliable, secure and affective decision support to energy producers and consumers alike.
- Building operating systems and district energy management systems with automation to install software in buildings or districts similar to installation on PCs and broker to serve energy trading similarly to software on computers now with varied level of interoperability.
- Predictive controls algorithms resolve optimisation problems in near/real time.
- Systems learn and adapt to user preference via combined anticipatory context aware logic.

Short term

Much of the hardware and software needed to realize the long term vision with regard 'automation and operational decision support' ICTs exists today. The issue however is that devices and state of the art innovations are often created in isolation whereas interoperability is central to vision realization. Integration of heterogeneous sensors is required i.e. sensor fusion. The difference between short to long term advancement is primarily a matter of scale and complexity. Real-time communications regarding usage will be required. Energy dashboards based on HFE, Data Visualization and cognitive work analysis principles should be achieved in the short term. Secure backend wired / wireless communications with defined

[1] T.B. Sheridan, and W.L. Verplank, *Human and Computer Control of Undersea Teleoperators*, MIT Man-Machine Systems Laboratory, Cambridge, MA 1978.

quality of service and privacy is also a reasonable expectation at least from a technical perspective. In REViSITE research would indicate that integration/interoperability aside the need is for incremental research and development but that the time to impact is short and level of impact is high. It is envisaged that development in the medium term will include -

- Integration of heterogeneous sensors i.e. 'sensor fusion'.
- Interconnected systems through internet of things / IPV6. Advancement primarily aligns to the Technical Integration space. Combined local v Cloud based control services for automated control & monitoring.
- Energy dashboards and near/ real-time communications regarding usage. Such visualisation should be based on HFE, Data Visualization and cognitive work analysis type principles.
- Ability to cope with Big Data volumes and diverse data source via semantic ontologies, cloud based data services, and streamed data processing.
- Streamlining of the design process by simplifying data acquisition, manipulation and assignment to graphical components.
- Secure communications with defined QoS, QoE and privacy in terms of grid infrastructure and at the edge devices.
- Self-configuring, scalable secure and adaptable wireless sensor networks.
- Near Field Communication for identity management in wireless sensor networks.

Medium term

Advancement primarily sits within Technical Integration space so central to handling the collection, correlation and transformation of heterogeneous data from a myriad of devices into valuable and accessible knowledge. It is envisaged that development in the medium term will include –

- Increased levels of autonomous diagnostics and machine-learning such augment current and short term advancements leveraging virtual sensors, inference technology and no-intrusive load monitoring etc.
- Dynamic dependable combination of local v Cloud based control services for automated control and monitoring.
- Intuitive, easily deployable, easily-usable, dynamically adaptable visualisations incorporating streamed and asynchronous data.
- Contextual rendering of data visualisations based on end-user device capabilities & information consumption preferences.
- Wide scale deployment of secure, fault / delay tolerant communication networks allowing for service provisioning & manageability including authentication & use of Cyber Security best known ICTs & methods.

Long term

If the long term vision is realized data levels will be unprecedented, high performance compute power may well be required, this is where cloud computing services and HPC will most likely play a role. It is envisaged other augmentations will include –

- Autonomous machine level diagnostics, prediction and optimization, with near / real time monitoring of streamed data, Full integration and interoperability of sensor and actuation devices with optimized use of ambient resources e.g. natural light, free cooling etc. Increased integration and optimized data visualization of diverse systems e.g. weather, security, energy, price information etc. incorporating anticipatory logic, context aware user preferences including privacy and visual programming of performance indicators. Additionally, in the compute domain one would expect seamless edge to cloud processing of near /realtime data together with increased levels of user based participatory sensing.

- In general advancement would seem to align with the move from a building / plant level focus to considering neighbourhood / district level sensing, automation and control. From a research perspective development in terms of optimisation and control algorithms and the visualisation of district level decision support seem to be two areas of interest that buck the overall trend for incremental improvement.

Table 3. Automation & operational decision support ICTs

RTD topic	State of the art	Short term *~3yrs*	Medium term *~6yrs*	Long term *~9yrs*	Vision
Automated monitoring & control	Existing software, algorithms embedded micro-controllers, sensor / actuation hardware, variable speed drives, remote lighting, heating & appliance control etc. Standalone component technology relatively sophisticated, issue is integration & interoperability of same.	Integration of heterogeneous sensors i.e. sensor fusion. Interconnected systems through internet of things / IPV6. Advancement primarily aligns to the Technical Integration space. Combined local v Cloud based control services for automated control & monitoring.	Virtual sensors, inference technology & non-intrusive load monitoring. Increased levels of autonomous diagnostics & machine-learning. Advancement again aligns to Technical Integration space. Dynamic dependable combination of local v Cloud based control services for automated control & monitoring.	Autonomous machine level diagnostics, prediction & optimization, real time monitoring of streamed data, full integration & interoperability of sensor & actuation devices with optimised use of ambient resources [ambient light, passive cooling] + increased use of renewable energy & water thru integration with Smart Grid/Water networks.	Embedded ICTs permeate sectors providing the “intelligence” to monitor & control energy resources in sustainable ways. ICT systems facilitate user control through integrative data visualizations that sustain user interest. ICT act as learning systems providing reliable, secure & affective decision support to prosumers. Building operating systems & district energy Mgmt. systems automatically install software & services in buildings / districts similarly to PCs now. Predictive control algorithms perform real time optimization. Systems learn & adapt to user preference via incorporated anticipatory logic. Secure wired/wireless & optical sensor networks act as a comms backbone to the Energy grid.
Operational decision support & visualisation	Existing Information Systems, HEMs type devices, decision support dashboards. Visualisation technologies / methodologies.	Energy dashboards & real-time communications regarding usage. Based on HFE, Data Visualization & cognitive work analysis principles. Ability to cope with Big Data volumes & diverse data source via semantic ontologies, cloud based data services, & real time streaming data processing. Streamlining the design process by simplifying data acquisition, manipulation & assignment to graphical components.	Intuitive, easily deployable, easily-usable, dynamically adaptable visualisations incorporating streamed & asynchronous data & platforms e.g. What if - simulations to support operational EE optimisation in manufacturing lines, micro-power generation, heat systems or spatial representations integrating real time data to a BIM platform. Contextual rendering of data visualisations based on end-user device capabilities & information consumption preferences.	Visual programming of performance indicators. Full integration and optimized data visualization of diverse systems e.g. weather, security, energy, price information etc. Moving towards autonomous & automated ‘context aware’ decision support.	
Secure Wired / Wireless sensor networks & Quality of service	High speed wired / wireless networks, sensor hardware /software essential for sub-metering strategies & linking to HAN type technologies such as 6LoWPAN, ZigBee, PLC etc.	Secure communications with defined QoS, QoE & privacy in terms of grid infrastructure & at the edge devices Self-configuring, scalable secure & adaptable WSN. NFC for identity management in WSN.	Wide scale deployment of secure, fault / delay tolerant communication networks allowing for service provisioning & manageability including authentication & use of Cyber Security best known ICTs & methods.	Incorporated anticipatory logic, context aware user preferences including privacy & security. Seamless edge to cloud data processing, through real time & user based participatory sensing.	

4. RESOURCE & PROCESS MANAGEMENT ICTS

Scope

This category focuses on supporting holistic EE management & decision making regarding processes/resources that span LC phases, organisational functions & indeed organisations.

Inter-enterprise coordination: contract & supply network management, process planning & scheduling, procurement, Intra-logistics, elements of Enterprise Resource Planning systems etc.

- *Grid:* e.g. ICTs supporting coordination & planning of generation & maintenance tasks, based on short & long term consumption forecasts.
- *Building/lighting:* e.g. ICTs supporting innovation & holistic EE building life cycle optimisation, aiming at win-win between various stakeholders in moving beyond traditional division of role between disciplines & focus on lowest first investment cost per participant.
- *Manufacturing:* e.g. ICTs supporting optimized scheduling & APS with respect to logistics/intra-logistics & ERP.

Business Process integration: collaboration support, groupware tools, electronic conferencing, distributed systems, social-media, business work flows, ERP (front end) systems.

- *Grid:* e.g. collaboration/communication ICTs as described above, supporting collaboration/understanding between the large number of domain actors incorporating market structure & processes.
- *Building/lighting:* e.g. communication ICTs supporting companies in collaborating & in integrating their internal processes with their inter-enterprise collaborative projects, in ensuring technologies are not applied on a project-specific basis bypassing internal management systems.
- *Manufacturing:* e.g. ICTs supporting Collaborative Engineering & ad-hoc collaboration in product development within distributed teams & between supply chain partners via messaging services, mobile devices, mobile applications & web based communications.

Knowledge sharing/mgmt. & analytics: access to knowledge, knowledge management, knowledge repositories, knowledge mining and semantic search, long-term data archival and recovery. Technologies here are involved in moving data up the DIKW (Data, Information, Knowledge, Wisdom) chain in order to add value.

- *Grid:* e.g. ICT's, vocabulary, ontology's supporting knowledge creation via the effective processing of heterogeneous data/information central to energy optimised smart grids i.e. any ICTs/practices that extract & inform understanding from lower level data.
- *Building/lighting:* e.g. ICT's, vocabulary, ontologies & regulations that support knowledge creation, distribution and use through effective processing of data/information into knowledge i.e. that which assists in making tacit construction/building knowledge explicit.
- *Manufacturing:* e.g. similar to other sectors ICTs supporting knowledge creation by effectively processing often voluminous data & information, so central to eco design & EE production.

Baseline

State of the art

What follows describes augmentations to current SOTA and focuses unsurprisingly on integration, collaboration, effective knowledge management and analytics that span organisations and sectoral LC phases.

'Modelling and simulation' at the enterprise or super system level together with 'data mining and analytics' although not having any direct impact on energy efficiency were in the context of the four sectors seen as been key enablers to enablers of energy / resource efficiency.

The importance of these sub-themes was supported by the results of the CIB2011 survey with the category "knowledge sharing/management" having the second highest priority overall.

Vision

The REViSITE vision with regard 'Resource & process management' ICTs focuses on the following:

- Enhanced knowledge creation, sharing and management including: Infrastructure, data mining and analytics, semantic mapping, filtering, knowledge consolidation algorithms, distributed data bases, catalogues of re-usable EE solutions etc.
- Wide availability of ICT based services and infrastructure.
- Enhanced value-driven business processes and ICT enabled business models.
- ICTs to facilitate virtual enterprise business relationships.
- ICT integrated processes are adopted for EE (including: models developed within RTD initiatives, human, legal, contractors, economics, business models, liability).
- Video conferencing, groupware, social media and collaboration ICTs support process integration and new services while reducing needs for transport and commuting.
- Intellectual property rights are protected (legally and technically e.g. via encrypting methods).

Short term

In the short-term augmentation relates more to technical and semantic interoperability. Contract and supply network management, process planning, ERP, logistics, procurement, production etc. need to embed EE criterion in technology, technology practices and policies.

There should be augmentation in terms of business integration of operational processes: design production, on/off-site production and make-v-buy etc. and increased functionality in terms of social media and crowd sourcing type research /validation with respect to energy data sharing / integration.

We can also expect developments in semantic and ontology engineering with respect to agreed data modelling best practise in describing energy flow at the district and intra-enterprise level, this will have strong links/implications for technical integration. Additionally, we can expect agreed methods for knowledge consolidation and distribution utilising for example cross-organisational repositories and digital catalogues of products /sensors/services containing parametric information. Research is also required in terms of links to technical and semantic integration of relevant information touch points to improve analytics / modelling capability and accuracy. Increased levels of open initiatives and community discussion forums should be encouraged /supported.

Medium term

In the medium-term one would expect established methods for virtual enterprise (VE), network setup and evolution. An agreed legal framework for implementation of VE's is required. Short to medium-term development in terms of dependable, scalable and extensible networks platforms is needed to support new devices and services in terms of knowledge and value creation.

We can expect increased levels of integration with respect to heterogeneous data/ information sources in order to build inference type applications that add valued extensions aligning to Knowledge Management sub-category.

There should be agreed strategies, technologies and standards to link and process heterogeneous energy data and semantic information relating to entire life cycles and districts in producing holistic scalable /extensible analytics for energy optimisation, pattern identification, predictive diagnostics etc.

Easy access to knowledge about energy efficiency which is modelled according to standards and easily accessible should be achieved. User awareness tools (syndication).

Long term

Following the scalable platform / network theme, one can expect fully validated machine readable service level agreement technologies with semantic based contract management and enactment.

In the long-term improvement over medium-term is expected to be incremental with respect to increased accessibility, extensibility and scalability of semantic information, energy data, analytics and compute, all of which will underpin innovative energy services so central to wider resource efficiency targets. Template solutions based on good practices and ubiquitous context-based access to inter-organisational knowledge platforms should be a reality.

Table 4. Resource & process management ICTs

RTD topic	State of the art	Short term *~3yrs*	Medium term *~6yrs*	Long term *~9yrs*	Vision
Inter-enterprise coordi-nation	Diverse, often proprietary based systems in terms of ERP, CRM type systems exist. Standalone ICT technology is relatively sophisticated interconnectedness is the prime issue.	Augmentation relates more to technical & semantic interopera-bility. Contract & supply network mgmt., process planning, ERP, logistics, procurement, production etc. need to embed EE criterion in technology, practices & policy.	Methods for virtual enterprise (VE) & network setup & evolu-tion. Short to medium-term development in terms of dependable, scalable & extensible networks platforms to support new devices & services in terms of knowledge & value creation.	Following the scalable platform / network theme, fully validated machine readable service level agreement technologies with Se-mantic based contract manage-ment & enactment.	Enhanced knowledge creation, sharing & mana-gement including: Infra-structure, data mining & analytics, semantic map-ping, filtering, consolidation algorithms, distributed data bases, catalogues of re-usable EE solutions etc. Wide availability of ICT based services & infra-structure. Enhanced value-driven business processes & ICT enabled business models. ICTs to facilitate virtual enterprise business rela-tionships. ICT integrated processes are adopted for EE (inclu-ding: models developed within RTD initiatives, human, legal, contractors, economics, business models, liability). Video conferencing, group-ware, social media & collaboration ICTs support process integration & new services reducing needs for transport & commuting while allowing for knowledge / value creation.
Business process integration	Business process modelling & re-engineering methods. Fairly sophisticated ICTs in terms of business process integration from a - purchase / deliver interface, collaboration support, groupware tools, ERP (front end) systems, electronic conferencing, distributed systems, social-media, business work flows - perspective.	Augmentation in terms of busi-ness integration with respect to operational processes: design production, on/off-site production and make-v-buy etc. Increased functionality in terms of social media & crowd sourcing type research /validation with respect to energy data sharing / integration.	Integration of heterogeneous data/ info sources in order to build inference type applications that add valued extensions aligning to KM sub-cat.	Standards & interfaces for model / semantics based inter-enterprise collaboration.	
Information /knowledge manage-ment & analytics	Technologies in the Knowledge management space exist how-ever augmentation relates to the interconnectedness of info relating to elements within smart district, inter-enterprise & production systems domains. With additional improvement required in terms of data mining, analytics, modelling & visualisation given the anticipated increase in sensor data that will result from realizing smart 'X' vision's & in improving information reliability.	Semantic & ontology engineering in terms of agreed data modelling best practise in describing energy flow at the district & intra-enter-prise level. Strong links to techni-cal integration. Methods for knowledge consolidation & distribution. Cross-organisational repositories. Research also required in terms of links to technical & semantic integration of relevant information touch points to improve analytics / modelling capability & accuracy Community forums for discussion. Digital catalogues of products /sensors/services containing parametric information.	Strategies / technologies to link & process heterogeneous energy data & semantic information relating to entire life cycles & districts in producing holistic scalable /extensible analytics for energy optimisation. Easy access to knowledge about energy efficiency which is modelled according to standards & easily accessible. User awareness tools (syndication). Open accessible analytics in terms of energy consumption & optimisation, pattern identification, predictive diagnostics etc.	Incremental improvement over medium term with respect to Increased accessibility, extensibility & scalability of semantic information, energy data, analytics & compute which will underpin innovative energy services Template solutions based on good practices; ubiquitous & context-based access to inter-organisational knowledge platforms	

5. TECHNICAL INTEGRATION ICTS

Scope

Semantic interoperability & technical integration are central to a holistic energy management strategy & arguable links to all categories & subcategories of ICTs. Semantic interoperability is equally as important as technical integration, but the main focus from a technical perspective is integration technologies / ICTs.

Integration technologies & infrastructures: Including technical protocols & formats for data exchange, middleware, gateways, interfaces, APIs, service orientated & event driven architectures / platforms. BMS/FMS backend infrastructure. Elements of BIM & ERP systems.

- *Grid:* e.g. ICTs supporting the technical acquisition, aggregation, storage & exchange of heterogeneous data which needs to be processed [i.e. understood] by a multitude of systems; Supervisory control, billing & settlement, market administration, customer management etc.
- *Building/lighting* e.g. ICTs supporting the technical acquisition, aggregation, storage & exchange of heterogeneous data required for collaborative distributed engineering, integration of various automation, monitoring & controls systems (towards a "Building Operation System"). Gateways for remote access, monitoring & control, & integration with various external services (e.g. fire brigade, energy efficiency consultancy etc.).
- *Manufacturing* e.g. ICTs supporting the technical acquisition, aggregation, storage & exchange of varied often voluminous data which supports what is best defined as the 'Digital Factory…a comprehensive network of digital models, methods and tools – including simulation and 3D-visualisation – integrated by a continuous data management system.'

Interoperability & standards: As stated, semantic interoperability is as important as technical integration. Semantic & interoperable frameworks, practices, standards & initiatives are paramount to linking/collaborating across heterogeneous domains in realising synergies & EE targets.

Table 5 that follows breaks slightly from our ICT focus to also describe some more abstract/semantic points for consideration, given the level of importance 'interoperability' has for the domain of ICT4EE & for leveraging cross-sectoral synergies.

Baseline

State of the art

Smart systems need sensors and control instruments in order to produce detailed reports related to Energy or Energy Efficiency or to trigger actions towards the same objective which is using the energy is the most efficient way. This leads to a first and mandatory need, the technical interoperability among these various sensors, equipments and systems. But the integration has to be performed also at a higher level as we are talking about an integrated flow of information that permeates through all sectors and feed inference and prediction algorithms, complex event processing (CEP). These enabling ICTs must be context independent and therefore must rely on standards. Solutions like BMS, BIM or PLM are now integrating EE related data and therefore would allow a holistic management of the EE. The ultimate step will be probably met with the convergence of these 3 main domain related approaches.

Vision

Considering a system in a holistic perspective leads to manage with a huge amount of information (the system could be one/several building(s) or one/several Districts encompassing energy grid with distributed micro generators, CHP, etc…), there will be a stronger need for ICT tools. The integrating role of ICT is especially expected for the following topics identified in the REViSITE Vision (D3.1):

- ICTs support compliance to Regulations and standards.
- Integrated infrastructures are implemented to support all ICT tools and systems for EE: design, collaboration, sensing/monitoring, automation, control, operation, services, energy trading etc.
- Universal control and communication protocol standards for system integration and interoperability are agreed and adopted.
- Interoperability is achieved for all stake holders over all life cycle stages.
- True System integration is achieved.
- Middleware to facilitate interoperability amongst different devices and systems.
- Infrastructure for collaborative distributed engineering.
- Ability to share information in model based collaboration.

Short term

The concept of virtual organisation requires high integration at several levels.

On the technical side, this integration is facilitated by the general and systematic adoption of Service Oriented Architectures (SOA). The next step towards better integration is the definition of Integration Service Platform (ISP).

A better integration requires also the definition of common models and languages allowing in the particular scope of REViSITE the integration of information regarding energy efficiency allowing the different sector to share information on the same subject.

To facilitate the take off / the adoption of these new solutions, there will be also the need to elaborate community forums for discussion, digital catalogues of products/sensors/services containing parametric information.

Medium term

It will be still needed to continue the process towards the adoption of SOA and enrich smart aggregation of Services on ISP, allowing the management of complex systems in a more efficient ways. This will allow sharing even more complex information and performing accurate forecast and adjustments.

This will also be accompanied by the definition / enrichment / unification of a standard for managing complex systems from an EE perspective.

These previous points should be accompanied along with an easy access to knowledge about energy efficiency which is modelled according to standards and easily accessible.

Long term

Then, there will be a need for the specification of an international (European?) framework defining the way services could be developed to be integrated/added to such ISP in order to facilitate the integration of new organisation and processes. In the same spirit, integration of gateways from this Open Communication Standards towards other domains (like

Transportation) will open the door to a more holistic approach about the question of Energy Efficiency.

Template solutions based on good practices; ubiquitous and context-based access to inter-organisational knowledge platforms

Table 5. Technical integration ICTs

RTD topic	State of the art	Short term *~3yrs*	Medium term *~6yrs*	Long term *~9yrs*	Vision
Integration technologies & infrastructures	Wide variety of systems/com-ponents/interfaces/te chno-logies. They are limited (no holistic management). Level of knowledge sharing is very low (because of incompatibility among media, file format, language, etc…)	Systematic adoption of Service Oriented Architectures (SOA). Definition of Integration Service Platforms (ISPs). Definition / extension of common open models and languages from the semantic to the physical level allowing integration of information regarding energy efficiency.	Continued adoption of SOA & event driven architectures. Enriched smart aggregation of Services on ISP, allowing the management of complex systems in a more efficient secure way. Development & mgmt. of dependable/trust-worthy, open, scalable & extensible platforms. Development of a holistic ontology / data model & methodology for understanding energy flows / energy data in districts / cities. Definition of unified open com-munication standards for managing complex systems (e.g. in the built environment at building or district level) from an EE perspective.	Specification of an international framework defining the way services could be developed to be integrated / added to such ISPs. Integration of gateways from this Open Communication Standard towards other domains (like Transportation). Cross infrastructure and systems data exchange leading to shared managed infrastructure (Energy, Water etc...)	ICTs support compliance to regulations and standards. Integrated infrastructures are implemented to support all ICT tools and systems for EE: collaborative distributed design & engineering, sensing/moni-toring, automation, control, operation, services, energy trading etc. Universal control and communication protocol standards for system integration and interopera-bility are agreed and adopted.
Interoperability & standards	Because of the variety of solutions, there are today too many non-interoperable solutions. Interoperability among standards is partially implemented.	Definition / extension of common open models and languages from the semantic to the physical level allowing integration of information regarding energy efficiency. Harmonisation of ontologies behind different building infor-mation models (BIM, BACS, FM, etc. & non building sector models e.g. the grid CIM. Open data, Linked data initiatives Governments & users combine data sources provided enhanced information sharing & decision making.	Definition of unified open com-munication standards for managing complex systems (e.g. in the built environment at building or district level) from an EE perspective. Development of building side information models related to Smart Grids to enable load and production controls and the communication with smart grid.	Integration of gateways from this Open Communication Standard towards other domains (like Transportation).	Interoperability is achieved for all stakeholders over all life cycle stages. True system integration is achieved. Middleware to facilitate interoperability amongst different devices and systems. Ability to share information in model based collaboration ensuring data security and appropriate accessibility / authentication.

6. TRADING / TRANSACTIONAL MANAGEMENT ICTS

Scope

This category relates to technologies & practices required to support an economic negotiation driven relationship between energy grids (both regulated operators & competitive market parties) & prosumers in both the manufacturing & building/lighting domains. The topic has been divided & described in terms of four energy management levels.

Regional energy management: Traditional energy management of large regional and nationals levels using support tools such as Energy Management Systems (EMS), distribution management, auxiliary services, automated generation control (AGC), etc.

District / neighbourhood energy management: Managing energy exchanges between local generators, (prosumer) building loads & excess energy, local storages & the energy grids. Main drivers are a common (interruptible) energy supply contract.

Facility energy management: Building (Energy) management that focuses on load shedding & economic options. Includes the management of local (own) energy sources of various kinds (mainly solar, heat pumps etc.) & specific loads (e.g. electric vehicle charger).

Personal energy management: Future personal energy management tools are largely based on home automation systems & use multifunctional equipment (smart phone) to opt for new energy flexibility products & price incentives.

Table 6 below shows potential trajectories towards achieving the REViSITE vision and also includes a short description of the current state-of-the-art for the four energy management levels. The references to energy management in the listed levels refer mainly to two specific areas: **1)** Facilitation of distributed energy resources, interruptible loads & local storages while maintaining a secure & reliable network operation, warranting network stability & power quality (the responsibility for transport/distribution network operators) and **2)** facilitation of a level playing field for a competitive energy market for energy & flexibility products (suppliers, aggregators, etc.)

Baseline

Most of the components of a "smart" infrastructure are there. Regional and district energy management systems are readily available, facility energy management systems are readily available, and for the high-end of the market personal energy management systems are technically available.

These systems are not interconnected, and mostly not standardised. Connectivity of these systems is not easily achieved, and co-operation between these systems is currently out of the question.

The Regional and District Energy Management Systems usually follow a series of internationally accepted standards for communication protocols and data modelling. The energy sector was a driving force behind several of these standards.

Facility Energy Management Systems most often follow a sector specific series of de-facto standards. Optimisation of energy consumption, if implemented, is most often based on the most economical choice of available energy sources, within the facility. Supply surplus electricity to the grid is in some cases included as a factor in the optimisation.

Personal Energy Management Systems are rare. Some electricity traders have started the roll out of remote meter reading infrastructure, and feedback of consumption data through the Internet. This however is not common, and hardly ever follows any reasonable standard.

Short term

Primarily the several variations of Energy Management System should be fitted for interoperability. Data exchange, at the first stage data acquisition, should allow Regional Energy Management Systems to get data on energy consumption.

This short term activity should typically include the roll out of large scale remote meter reading infrastructures with the ability to easily expand local logic and local interfaces. Several European countries are currently preparing national standards for a remote meter reading infrastructure. These standards unfortunately are not always compatible, and are hardly ever designed in cooperation with other stakeholders than meter management companies. It would be preferable to consult trading companies and user groups in the design.

These short term activities should result in a data acquisition infrastructure, capable of acquiring, storing and processing energy consumption data, and where appropriate energy generation data, of "all" consumers in the region. This data should be available to end-users for t5he purpose of invoicing and settlement.

Medium term

The medium term activities should result in an infrastructure that can not only acquire measured data, but that can also optimise the local generation (by DER) against energy market conditions and grid constraints. This would then typically include local optimisation systems, e.g. to optimise the production of a manufacturing facility against product order, storage, market conditions, and also energy market conditions and energy production or generation constraints. Optimisation algorithms should result in advices to the prosumers.

Long term

In the long term the optimisation should be fully automated. Based on special, presumably low, tariffs the prosumers would allow the automated infrastructures to control their energy consuming or generating equipment.

Local optimising systems could then –autonomously- negotiate with their peer systems on optimal consumption and generation patterns. Configurable boundaries and user preferences are required for that negotiation.

Main challenges here are to ensure that the functionality on all levels is indeed conforming to the requirements of all stakeholders including trading organisations and consumers (or prosumers rather), and to ensure that the resulting transport and distribution networks are indeed stable, secure and reliable.

Table 6. Trading / transactional management ICTs

RTD topic	State of the art	Short term *~3yrs*	Medium term *~6yrs*	Long term *~9yrs*	Vision
Regional energy management	Regional energy mgmt. has a long tradition. New developments mainly related to market integration & sector liberalisation. Most energy mgmt. systems (EMS) conform to international standards.	Generic ontology's, use cases and standards that support plug-&-play functionality for control centres, resources and interoperability.	Integrated infrastructures, market models and applicable legislation that take environmental aspects, market responsibilities and ethical concerns into account.	Stable energy supply on a continental scale using distributed resources, full network integration, long distance supply and distributed control.	Regulatory frameworks take environmental, economical and ethical aspects into account and common metrics enable univocal transparent assessments of energy efficiency measures. Distributed energy management functions enable the integration of DER, Storage, HVDC, Demand Response, micro-grids and Smart appliances in large inter-connected grids. Integrated information networks warrant secure and reliable distribution grids while managing energy exchanges from the continental scale to the building & individual prosumer level. Advanced (cloud-based) balancing functions use (near) real-time measurement data and advanced control algorithms for the optimization of resources, loads and grid capacities.
District energy management	Energy management on a regional / district neighbour-hood scale is largely non-existent except for large ind-ustrial sites, university cam-puses and commercial areas.	District energy management systems for DER, intermittent loads & local generation. Optimisation of these resources for market conditions and the local energy balance.	Optimisation of wide area DER and bidirectional power flow control mechanisms (Volt-VAR control, Load flow, state estimation etc.) to ensure grid stability.	Seamless integration of tot-down and bottom-up energy management control strategies. Self-healing (micro) grid components.	
Facility energy management	Facility energy management systems exist for considerable time, both as manufacturing (plant-wide) systems and in building systems. Here, with a wide range of user organi-sations and user sectors, stan-dardisation is not widely accepted. Facility energy management systems are usually vendor-specific.	Enhance existing legislation with regard to the building EE & the audit / verification process. Building optimisation includes energy consumption, local pro-duction & energy market interactions (buy/sell). Integration of Facility Energy Management systems in regional information systems, enabling regional energy balance optimisation.	Integrated building / grid ontology's & interoperability standards. Smart appliances & generic infrastructures that allow direct device coordination, market & users. Market & grid balance optimisation via distributed decision support functions. Data quality mgmt. via automated validation tools based on fast & flexible data exchange facilities (cloud).	Facility energy management systems would "negotiate" with Regional or District energy management systems on their energy consumption, taking energy markets, product markets, economical, technical and human factors into account.	
Personal energy management	Personal energy management systems e.g. for households will be common. Some of the higher end premises use home-control systems. Such systems however hardly ever include specific energy management functions.	Raise awareness regarding new roles (e.g. prosumer) in the energy arena & support the transition towards energy mgmt. Basic personal energy informa-tion systems, based on remote meter reading architectures, to include energy consumption monitoring functions, invoicing, settlement & report on individual devices consumption	Regulatory frameworks that ensure privacy & transparency for participants in general & the end-user (prosumer) in particular. Personal energy mgmt. systems enhanced with advisory functions that allow individual consumers to monitor & influence consumption & generation patterns & automatic context aware control actions	Personal energy management systems control household energy exchanges according to profiles, rules and preferences. User friendly interfaces and specific functionalities that allow for distributed automated decisions, user preferences and constraints.	

CONCLUSIONS

The SRA presented in this report is essentially based on the RTD topics (taxonomy) defined in the early stage of the project (D2.1 ICT4EE - Data Taxonomy). The evolving SRA was exposed to comments by external experts in several iterations. The analysis of the received feedback indicates that:

- the SRA covers the target domain with sufficient width and depth,
- all listed topics are regarded as relevant and important,
- there is no basis for pointing out specific topics with exceptionally high or low priority.

Altogether, the conclusion is that the target research domain consists of complementary areas that need to proceed in a balanced way in order to achieve sustainable long term impacts. The overall expectation is that ICTs will contribute to applications with higher level of semantics, knowledge sharing, system integration and interoperability.

The impacts of ICT on energy efficiency are subject to complex causal interdependencies of many different systems over several life cycle stages. This fact in itself calls for research to model and quantify ICT impacts for decision making about investments in ICT research and use.

APPENDICES

1. **ICT4EE view of existing sectoral SRAs / roadmaps**
2. **Manufuture Trans-sectoral roadmaps**
3. **SRA development methodology**
4. **Feedback to prioritization questionnaire at the ECTP-E2BA Conference, Warsaw, Poland on 4-5 October 2011**
5. **Feedback to prioritization questionnaire at the CIB W78-W102 Conference, 26-28 October 2011, Sophia Antipolis, France**
6. **Feedback to the questionnaire embedded in the draft short version of D3.2, 29 February 2012**
7. **Feedback to Survey Monkey web questionnaire, April 2012**

ICT4EE view of existing sectoral SRAs and roadmaps

Appendix 1 to: D3.2 Multi-disciplinary Strategic Research Agenda for ICT-enabled Energy Efficiency

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1. Grids

1.1 Summary of existing SRAs / roadmaps

The traditional electricity networks are relatively simple, unidirectional conducting infrastructures, with large scale generators that connect to the high voltage grid and are controlled by a centralised, often national, organisations and optimised by the electricity market (ref *Figure 1*).

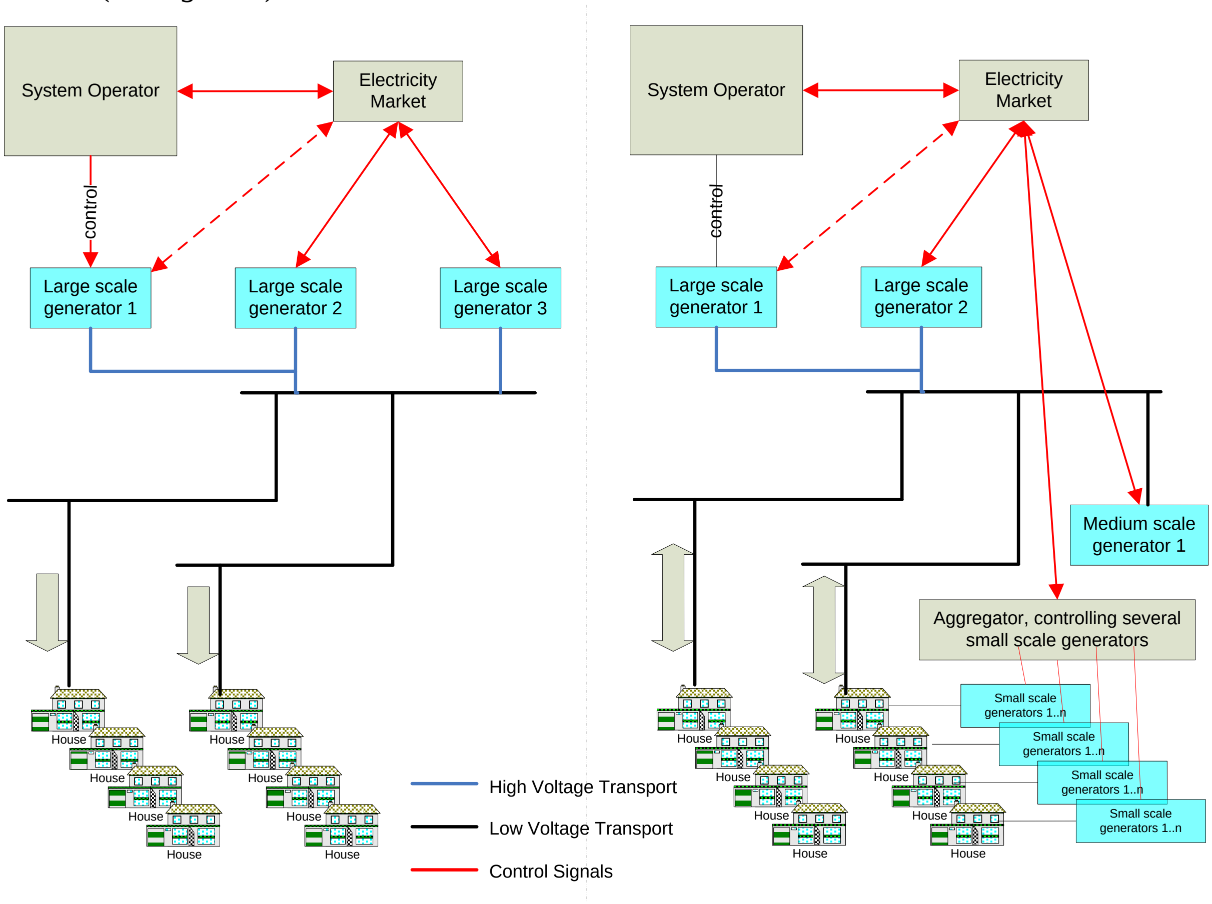

Figure 1. Traditional (left) vs. Smart transport & distribution grids

Smart grids facilitate distributed energy resources and rely on the coordination between the large generator units and a large number of geographically wide spread small generators and feature bidirectional flows (parities). In both cases the same physical and electro technical laws hold. In the smart grids however, the number of interacting control loops is large.

There are three main topics for a Strategic Research Agenda as prepared by the European Technology Platform Smart Grids:

- Strengthening the grid, and enabling two-way electricity transport rather than one-way transport, including monitoring and control facilities on all levels of the grid
- Developing control mechanisms that allow control of all levels generators, including large, medium and relatively small scale generators in a way that guarantees stability of the electricity grid, and optimises all generation capacity
- Developing communication mechanisms that can support the monitoring and control of the grid, and the monitoring and control of the control mechanisms.

Topics for further development

The following topics require specific ICT related developments.

Monitoring and control of transmission and distribution networks

The high voltage transport grids, throughout Europe, are mostly completely monitored and controlled. Medium voltage grids, with voltages between 110 and 50 kV, are not always entirely monitored, and rarely remotely controlled. Low voltage (below 10kV) distribution grids are hardly ever monitored and controlled.

Monitoring and controlling the entire transport and distribution grid is based on existing technology, however the size of the entire grid, and the amount of data to be processed, complicates this issue.

Research and development is needed to:

1. Complete the existing data models (Common Information Model) and data definitions for transport grids, include definitions for distribution grids (this activity is now 90% complete), and introduce DG, RES as well as DSM functionalities into the data models.
2. Design and build systems to process the monitoring data generated by relatively large distribution grids.

Control Mechanisms

The centralised control scheme, key generators and the high voltage transport grid are controlled from a central control centre, must be replaced by a distributed control architectures which will be coordinated and integrated into existing control methodologies in order to take advantage of the intelligence that will enhance the networks of the future.
Such control mechanisms should be fully automated, and should optimise the following:

1. Generation of electricity for large central generators as well as for relatively small scale DG, RES. Aggregation into VPP should be supported. Optimisation can be one of the following:
   a. Optimise financial result of all generators, based on a market model
   b. Optimise environmental parameters, e.g. set preference to renewable energy sources
   c. Optimise the stability of the grids, and security of energy supply to consumers.
2. Transport and distribution; primarily to minimise (technical) transport losses.

Research and development is required to define control functionalities and test them.

Energy Markets

The energy markets that are operational at this time are based on financial parameters. This could possibly lead to a preference for large scale, high efficiency, generators. If environmental aspects are to be taken into account in the choice for energy generators, then the market model should be changed.

Extensive research and development is required to achieve this. Market structures should allow for intermittent generators (wind and solar energy), and should not penalise intermittent schedule deviations.

Prosumer User Interface

For optimal results DG, or RES, may be controlled by a combination of the following groups:

- Energy traders, with direct access to the electricity market;
- Local installation owners, controlling their own electricity consumption profile;
- Transport or distribution companies, mainly focused on stability of supply.

Each one of the control interfaces must allow for complex decision-support functions. These decision-support functions may also vary in time, or depending on market or grid status.

Decision support functions for the local installation owner should e.g. take into consideration the financial implications of control actions that can be forecasted based on market structure, but should also take into consideration the possibility of instability in the distribution or transmission grids.

Besides ICT developments, the development of User Interfaces also requires other, non-technical effort. Prosumers do need incentives to play their role in the Smart Grid infrastructure. New tariff structures, or at least strong financial incentives besides social pressure to conform to optimise energy exchange, are considered.

Prosumer Installation Interface

Besides the basic control of (local) generators, prosumers may also let electricity consumption patterns (profiles) be controlled. This would mean in case of a small scale industry, the control of a production line, with the ability (e.g.) consuming the bulk of the energy for a production cycle in off-peak hours. In case of households (or groups of households), this could mean (e.g.) delaying (smart) washing machine cycles until after midnight.

In addition, infrastructural modifications (i.e. installation of metering equipment within production processes or in washing machines), it would also mean an advanced data communication mechanism to acquire measured data and to control instruments.

1.2 Main ICT4EE issues

1. Specification & design ICT's

a. Design conceptualisation: none
b. Detailed Design: none
c. Modelling: Modelling of grids, and of the effects of DER. Modelling of the control loops for large generators, markets, and DER. Most complex task here is to develop a model for the interaction between all levels of generators.
d. Performance estimation: Based on the simulation of grids, and based on state estimation and forecasts of generation and consumption.
e. Simulation: Simulation of grids, based on state estimation and forecasts of generation and consumption.
f. Specification & Product / component Selection: none

2. Materialisation ICT's

a. Decision support & Visualisation: none
b. Management & control: none.
c. Real-time communication: none .

3. Automation & operational decision support ICT's

a. Automated monitoring & control: Major development activities are required for the control functions that are to be installed in the hierarchy of supply/consumption control loops. Although the basic technology is well understood, shown and proven in numerous pilot projects, and there are no unknown issues there, the large scale roll out would require the coordination of extremely large numbers of control loops, each with potentially different characteristics and properties. The complexity of large scale roll out is not considered yet and stability can not be ensured. We consider this to be one of the most important issues in the entire grid upgrade process.
b. Operational decision support & visualisation: Owners of DER, and also households, small industries, may consider entering the energy market. The implications of decisions (buy or sell, generate or consume) are too complex for intuitive decisions, also because the

decisions of a large number of DER owners could theoretically destabilise either the electricity grid, the electricity market, or both. Decision support systems need to be developed. We consider this to be a key issue in the grid upgrade process.

c. Quality of service: There are two issues here: the availability of electricity at all times, and the quality and stability of the electricity supply. Both can be measured in electricity meters, and the measurements can be transferred to back offices. There is no new technology required for this. Some research would need to be done to process the amounts of data that may become available when measurements are made and transferred on a large scale, e.g. when QoS measurements are performed and transferred from "every" energy meter in the grid. The extend of consumption data will require data quality management measures.

d. Wired/Wireless sensor networks: Main topic here is cyber security. Confidentiality of measured energy consumption, and fraud prevention, are two of the most important issues. A secure communication, including data encryption, mutual authentication, is minimally required. These are known technologies and need no huge effort, however at this time it is uncertain if these technologies can be implemented in low cost electricity metering devices. This needs investigating.

4. Resource & Process management ICT's

a. Inter-enterprise coordination: There are no new or unknown technologies here. The only important issue is the amount of data that needs to be transported and processed. There is up to now, little or no experience with the processing of the amounts of data that can be expected from large scale roll out of smart grid technology

b. Process integration: Same issue as above.

c. Knowledge sharing: Same issue as above.

5. Technical Integration ICT's

a. Technical integration & interoperability: The basic technology is well known. New developments on data definitions regarding smart grids are required. CEN, CENELEC and ETSI initiated a series of activities that resulted in a conceptual model for the smart grid and its components, in a general description and requirements of a communication infrastructure for smart grid related data, in security requirements, and in an information architecture. Such information architecture includes expansion of the current versions of the Common Information Model (CIM: IEC 61970), of decentralised data definitions and communication mechanisms (IEC 61850) and of metering data definitions and communication mechanisms (DLMS, COSEM). Activities are listed and detailed in the CEN, CENELEC and ETSI publication "Report of JWG on standards for smart grids; v1.0; 2010-12-17". One area that is still not considered in standardisation committees is the control and data acquisition interface with e.g. household equipment (smart appliances).

6. Trading / transactional management ICT's

a. District energy management: Little of no new developments are required, however the amount of data to be processed, the complexity of mutual influencing processes are possibly a topic for investigation.

b. Facility energy management: There are several non-standard facility management systems available, and few standardised. Integrating facility management systems with other smart grid related information systems may be a considerable effort. Presumably this effort need not be complex, it can be costly however.

c. <u>Citizen (personnel) energy management:</u> A personal energy management system is a topic that would be relatively new in the market. Functionality and most importantly ergonomics must be well specified and tested. This type of system is practically an extension to a home automation system, with energy management functions added. This topic relates to small companies, and private households. In order to make the large number of personnel energy management systems manageable, they need to be aggregated and controlled as a group. The control theory behind this method is as yet not fully tested and proven.

2. Manufacturing

2.1 Summary of existing SRAs / roadmaps

Manufuture Strategic Research Agenda:

The Manufuture European Technology platform published a SRA [REF1] in 2006 based on the document "Manufuture - a Vison for 2020" [REF 2] but also considering other European studies (as MANVIS [REF5] or FuTMaN [REF6]). On a very high level Manufuture defines the following five priority "pillars" to react on future competitive and sustainable challenges (see *Figure 2*) [REF1]:

1. *new, high- added-value products and services (present)*
   describes the need for a change from cost based competition to a paradigm of producing high added value of products and services, which requires continuous innovation in manufacturing processes as well as an integrated development of products and services taking into account the hole life cycle.
2. *new business models (short term)*
   describes how European companies should generate revenue in future by building open collaboration networks, which also requires new hard and soft "business-process" technologies.
3. *new manufacturing engineering / Advanced Manufacturing (medium term)*
   describes the design of a production system. Therefore the factor itself has to be approached as a new and complex type of product.
4. *emerging manufacturing science and technologies (long term)*
   The main objective of this pillar is the acceleration of technological innovation in manufacturing by the development of high-end machines and systems. Within the SRA Manufuture points out that "the reduction of energy consumption of manufacturing processes and products over the hole life cycle is highly relevant."
5. *transformation of existing RTD and educational infrastructures to support world-class manufacturing, fostering researcher mobility, multidisciplinary and lifelong learning (long term)*

In order to create to successful and competitive research infrastructure Manufuture recommendations focus on strong links between academia and industry.

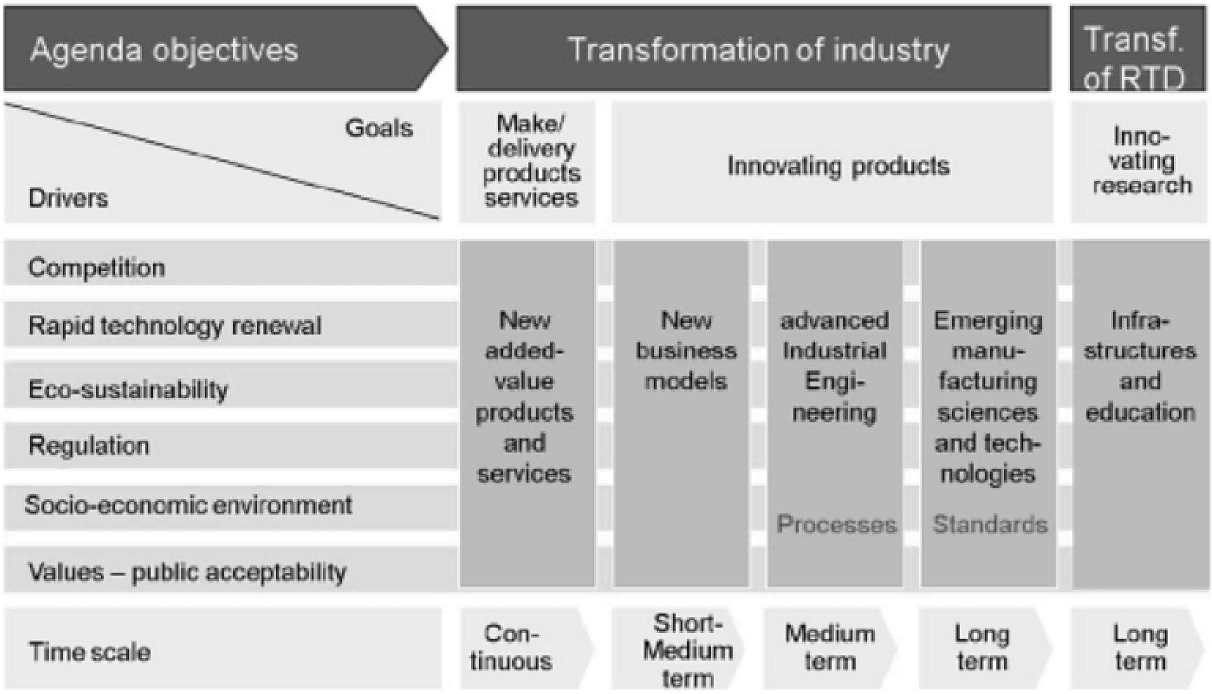

Figure 2. Manufuture SRA - Industrial transformation reference model [REF1]

Based on the SRA Manufuture developed 6 individual trans-sectorial roadmaps by identifying and prioritising the future research topics.

Manufuture trans-sectorial roadmaps

The trans-sectorial roadmaps have been developed in 2006 and 2007 corresponding with the SRA. The "European Road of Manufacturing" is published in [REF 3]. *Figure 3* provides a short overview listing the 6 sectors and their main enabling technologies. The individual Roadmaps for each sector are presented in Appendix 2:

		Competition →	**Leadership →**	**Globalisation →**	**Emering**
	New Business Models	Beyond Lean…; Life Cycle Services; Survival Strategies	European Product-ion System Know-ledge & Services	European Product-ion System Know-ledge & Services	Invest in R&D Enterpreneur-ship
Adv. Industrial Engineering	**Adaptive Manufacturing**	Adaptive Automation Modular Products Configurable Sys.	Adaptive Factories Real-Time Adapt-ation Adaptive Systems	Real-Time Factories Disruptive Factories	Knowledge-based Factories
Adv. Industrial Engineering	**Networking in Manufacturing**	Network Engineering Interoperable Networks Customisation	Manufacturing on Demand Net-working Standards	Supply Chain Mgt.: -Real-Time -Global	Knowledge-based Order Management
Adv. Industrial Engineering	**Digital Engineering**	3D PLM and Tools Fast Engineering Digital Prototyping	Multi-Scale Simulation Digital Factory Material Engineering	Process standards Smart Factory Cognitive Simulation	Knowledge-based Engineering
	Emergent Technologies	Intelligent Products High Performance Energy Saving	Gen. Technologies Adaptive Materials Micro & Nanotechn.	Reliability Process Models and Simulation	In-Situ Process Control beyond Borders
	ICT for Manufacturing	Configuration Systems Embedded Systems	Multimodal Interfacting Soft-ware Engineering	Grid Manufacturing Ubiq. Computing	ICT Environment Manufacturing

Figure 3. ManuFuture Enabling Technologies for the Next-generation Manufacturing and European Production Systems [REF3]

2.2 Main ICT4EE issues

Even though "ICT for Manufacturing" is one dedicated Roadmap within the six Manufuture Roadmaps, it becomes an enabler technology for all sectors. What follows is a selection of important RTDs from all six roadmaps taking into account the potential impact on ICT4EE mostly in an indirect way. The RTDs are grouped in short, medium and long term activities and prioritised by large (L), medium (M) and small (S) importance. The full list of actions is published in [REF 3].

Short term activities (1-3 years):

- Developing methods of cost-efficient condition monitoring systems (S) for production systems combining information of multiple available sensors and controller signals (i.e. sensor fusion) is able to avoid increased energy consumption of worn out production equipment.
- The advanced monitoring of complex manufacturing systems (S) requires complex measurement and analysis functions. Since today's learning capabilities and the use of environmental data are limited the improvement of functionalities of these systems trough software adaptation and new configuration is required.
- Interoperable and standardised production networks (M) refers to the holistic development of processes and methods for the collaborative planning, management and optimisation of production and logistic resources. Therefore the supporting ICT systems require a common understanding of the exchanged information also for energy related data.

Medium term activities (3-5 years)

- High precision manufacturing by plug and play, components based on adaptive smart materials (M). By creating a new generation of active plug- and-play components, the adaptiveness of production systems for changing conditions can be increased. Intelligent plug and play systems allow a high accuracy and efficiency of production systems under different conditions.
- Intelligence-based process capability enhancement (M) refers to the implementation of cognitive systems enabling the push of the manufacturing quality towards zero defects in processes and process chains and realise intelligent self-optimising manufacturing systems also with impact on it's energy efficiency.
- Real-time enterprise management (L) by using real time data, information and knowledge, distributed throughout the supply chain and customer environment enables the development of suitable tools for Enterprise and Supply-Chain Management and allows the holistic optimization of value creation networks.
- Digital manufacturing for rapid design and virtual prototyping of factories on demand (S/M) refers to the development of new methodologies and innovative tools, which enable and support the rapid design and prototyping of the entire production systems. The aim is a complete detailed framework for the Virtual Factory and tools for the design/analysis and effectively and efficiently optimisation of processes and manufacturing systems.
- Interdisciplinary design of high performance, reliable and adaptive manufacturing equipment (M) aims at supporting the mechatronics design approach towards rapid and cost efficient and effective design and implementation and operation of next generation production systems
- The development of new classes of models for the simulation of complex manufacturing and assembly systems (M) supports the aggregated representation of processes in complex manufacturing and assembly systems and will be the basis for developing new possibilities in order to map and analyze processes.
- Virtual Reality-based simulations for machine operations and Life Cycle impacts (S) focus on the development and integration of VR applications in the entire life cycle. VR based

tools, methods and prototype applications may support the efficient design of machines, production systems and production logistics networks
- Self-optimising electric-fluidic energy sources for optimal energy consumption (S) are innovative technologies for temperature control, power generation and storage in production processes and open up a big energy saving potential.
- Condition prognostic capabilities for improved reliability and performance (S) focus on extending the condition monitoring system with prognostic capabilities. Different learning approaches for individual machines or classes of machines could be a valuable contribution in order to optimized for productivity, maintenance costs, energy consumption
- Planning tools for open reconfigurable and adaptive manufacturing systems (S) refers the implementation of a knowledge system in planning process by a platform for process planning, which is integrated in the information and execution system of factories.
- Optimal energy consumption by flexible self-optimising drive concepts (S) addresses directly a flexible adaptation of electric-fluidic energy resources for high performance drives both to production system and to process needs
- Sustainable Life Cycle Management of factories and products (M) needs to expand the focus from the product life cycle to the factory life cycle. The main goal of Factory and Product Life Cycle thinking is to reduce the resource use and to improve the technical and social performance, in various stages of a factory and a product's life.

Long term activities (3-5 years)

- Pervasive and ubiquitous computing for disruptive manufacturing (S/M) supports the manufacturing enterprises with solutions to collect and use production information from globally distributed factories by real time.
- Global and real-time network management (M) provides integrated solutions for the management of global production and logistics networks, which requires further integration of sensors into the production and logistic equipment, collecting data about environment conditions and storing this information for the further decision processes on the local level.
- Adaptive and responsive factories describes a fully integrated approach to develop reliable and flexible factory automation systems which can be developed or reconfigured with reduced times and costs.
- Capturing and synchronising heterogeneous production data with the Digital Factory has a clear focus on the coupling of the digital and the virtual factory with the real-time factory through the development of the so-called sensitive digital and virtual factory, capable of managing real-time data, captured from several heterogeneous and autonomous data sources and applications. Therefore the real-time factory integrates the real factory with the digital and virtual factory by continuously communicating, connecting and evaluating the factory's operational data.

ICT and Energy Efficiency - The case for Manufacturing

Even though the research topic ICT4EE is not directly addressed in the Manufuture Roadmap many of the proposed ICT related RTDs tackle this topic. However in order to promote the high potential of ICT as an enabler of energy efficiency not only in the manufacturing sector, the European Commission started a consultation and partnership process with industrial and societal stakeholders. In the year 2009 the recommendations of the Consulting Group "Smart Manufacturing" are published in the document " ICT and Energy Efficiency - The case for Manufacturing" [REF4]. For developing the next generation of ICTs for smart manufacturing the authors published the following R&D Needs:

- Improvement of control systems as an enabler for improved energy and material efficiency through better process stability

- Enhancemend of ICT tools and techniques (sensors, diagnostic and energy monitoring systems etc.) for Plant Asset management
- Promotion of intelligent drives in production equipment in order to reduce base load and avoide peak loads through intelligent controls.
- Development of cheap and robust sensors as an enabler technolgy for gathering not only energy related data
- coordinated optimisation of supply chain management, logistics and intra-logistics to support the evolution of "Energy-Optimised Supply Chains"
- Cost efficient "track & trace" approaches to control goods flows by using RFID and sensor networks
- Promote Total Energy Management (TEM) methods in production
- ICT-enabled methods for the development of products which are energy efficient:
- Design for logistics, for recycling and reuse, for optimal energy use
- Assistant systems with functionality to evaluate energy efficiency
- LCA (Life Cycle Assessment) including energy efficiency of manufacturing
- Include Energy cost as an aspect of Life Cycle Management/Total Cost of Ownership
- Knowledge support systems and selfevaluation systems based on clear KPIs
- Extantion of PLM (Product Lifecycle Management) supporting energy monitoring and saving by storing and retrieving energy related data also from production and usage phase.
- Tuneing ERP systems to energy efficiency needs including better shop-floor scheduling and production planning
- PDM Systems tuned to energy efficiency needs. (Digital) Factory management uses Production Data Management (PDM) systems and simulation tools to optimise manufacturing at the planning phase
- holistic simulation of production system involving technical building services and building climate, production machines / material flow and production management
- Improve sensing and computational methods for the management of large-scale monitoring data
- Interoperable ICT infrastructures that allow real time monitoring of energy consumption
- Adequate models for energy consumption prediction and simulation
- Intelligent drives and digital metering and components for real time information
- Integration of energy audits in business software central collection of real time energy data and interfaces with monitoring agencies

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3. Buildings

3.1 Summary of existing SRAs / roadmaps

Regarding the Building sector, we can consider mainly the three relevant initiatives below:

1. The first one has been done by the ECTP that produced a Strategic Research Agenda (SRA) and an Implementation Action Plan (IAP). These documents were released in 2005 & 2007.
2. The second one is the work achieved by the Reeb project (European Strategic Research Roadmap to ICT enabled Energy-Efficiency in Building and Construction). Reeb issued its Roadmap end of 2010.
3. The third initiative to be taken into account is the E2BA Roadmap, issued in April 2010

3.1.1 ECTP SRA & IAP

ECTP has developed a Strategic Research Agenda (SRA) that was published at the end of 2005 (http://www.ectp.org/documentation/ECTP-SRA-2005_12_23.pdf)
ECTP SRA defines strategic research priorities, around three axes, in 13 chapters:

1. Meeting client and user requirements
2. Becoming sustainable
3. Transformation of the construction sector

In June 2007, ECTP published an associated roadmap (http://www.ectp.org/documentation/SRA_IAPv1.pdf) proposing an Implementation Action Plan of the SRA.

This SRA/IAP explains how exactly the research themes defined in the SRA should be implemented in the coming years and describes how ECTP and its stakeholders would facilitate this process, and which parties to involve. The Implementation Action Plan of the Strategic Research Agenda of ECTP explains how the research themes defined in the SRA should be implemented in the period 2007-2013 and describes how ECTP and its stakeholders would facilitate this process, and which parties to involve.

Nine ECTP priorities for the period 2007 to 2013

The selection of the most important and urgent research areas of the SRA, which should be strategically dealt with in the period 2007-2013, was carried out through a prioritization process organised from November 2005 to September 2006) in the framework of the ECTP and its comprehensive Network of National Technology Platforms.

From the 13 main areas of the SRA, a set of 9 major Priorities, with a limited number of well agreed research items (around 60, instead of 160 in the SRA), was selected for implementation in the period 2007-2013.

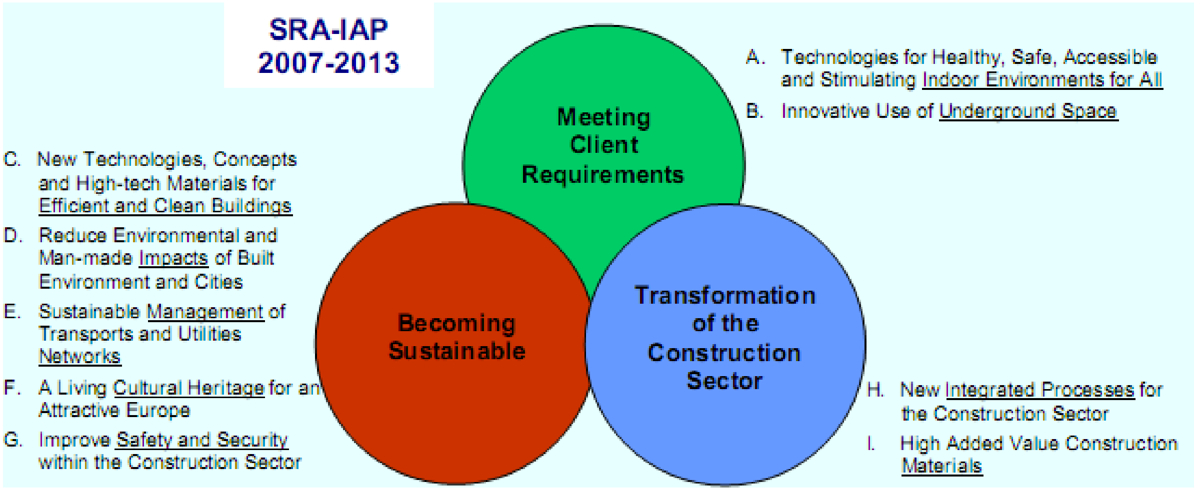

Figure 4. The 3 pillars of the ECTP SRA and the 9 IAP priorities

In the scope of REViSITE, the priority H is particularly of importance as the ICTs have been identified as the main innovation driver in most industries and core enabler of economic growth in the 21st century (NESSI 2006). Process renewal, supported by ICT, is one of the main vehicles towards the vision of the ECTP.

The Vision in that field is that Construction is a highly information intensive industry which uses state-of-the- art technologies in all processes and products in order to satisfy client's expectations in a sustainable way. As a knowledge-based industry it offers attractive workplaces for skilled and well educated personnel. European construction industry works competitively on the open global market supported by flexible SME-based supply networks.

Aiming at this vision, the objectives of the proposed R&D are to develop the 8 following RTD topics:

1. Value-driven business processes
2. Industrialised production
3. Digital models
4. Intelligent constructions
5. Interoperability
6. Collaboration support
7. Knowledge sharing
8. ICT enabled business models

3.1.2 REEB Roadmap

The REEB project (http://www.ict-reeb.eu/) has established a Roadmap regarding ICT4EE in Building.

The scope is ICT supported energy efficiency of buildings (ICT4EEB). This topic is in the intersection of 3 disciplines: building/construction, ICT and energy.

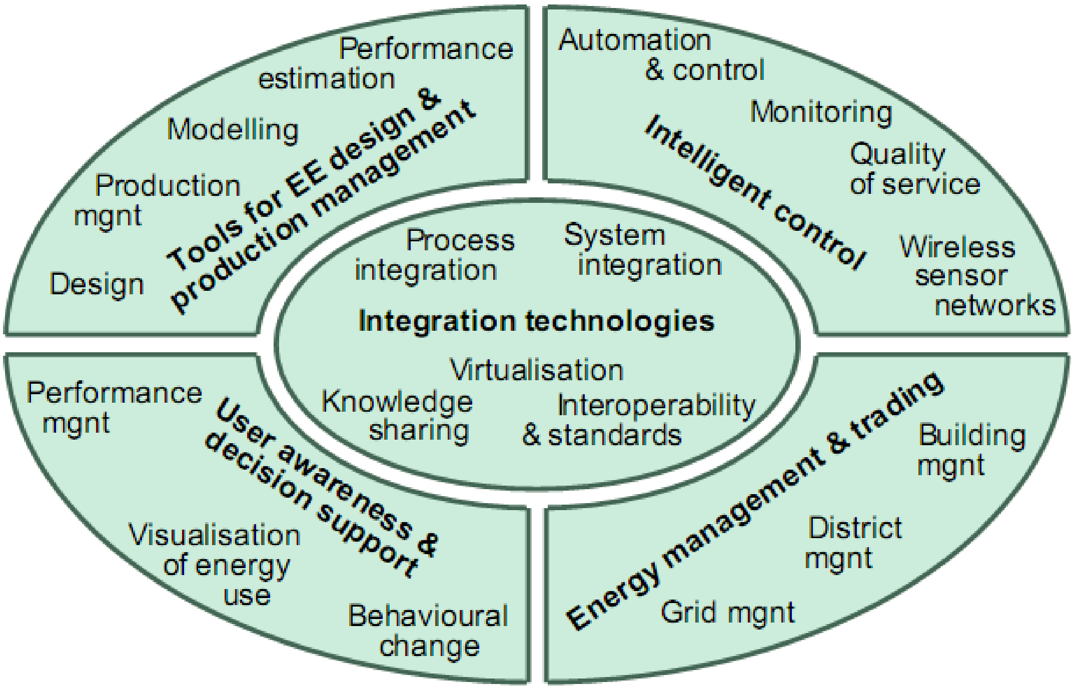

Figure 5. RTD priorities in the "ICT for energy efficient buildings" domain (REEB)

3.1.3 E2BA Roadmap

Within a ten year time perspective, E2BA expect to achieve an impact following a stepped approach, namely:

- Step 1: Reducing the energy use of buildings and its negative impacts on environment;
- Step 2: Buildings cover their own energy needs;
- Step 3: Transformation of buildings into energy providers, preferably at district level.

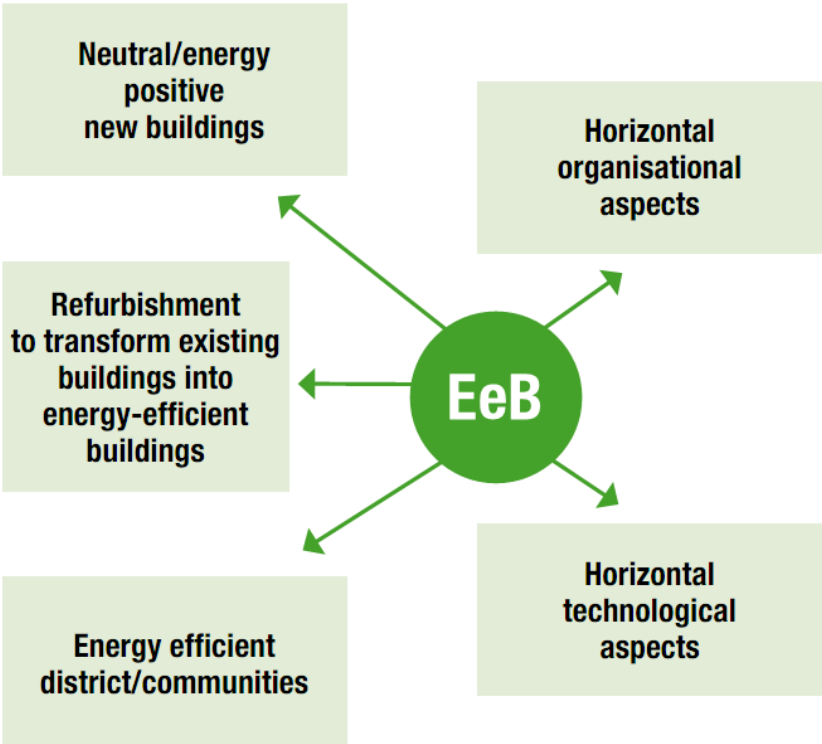

Figure 6. Key research areas targeting the challenges at the basis of the long term strategy

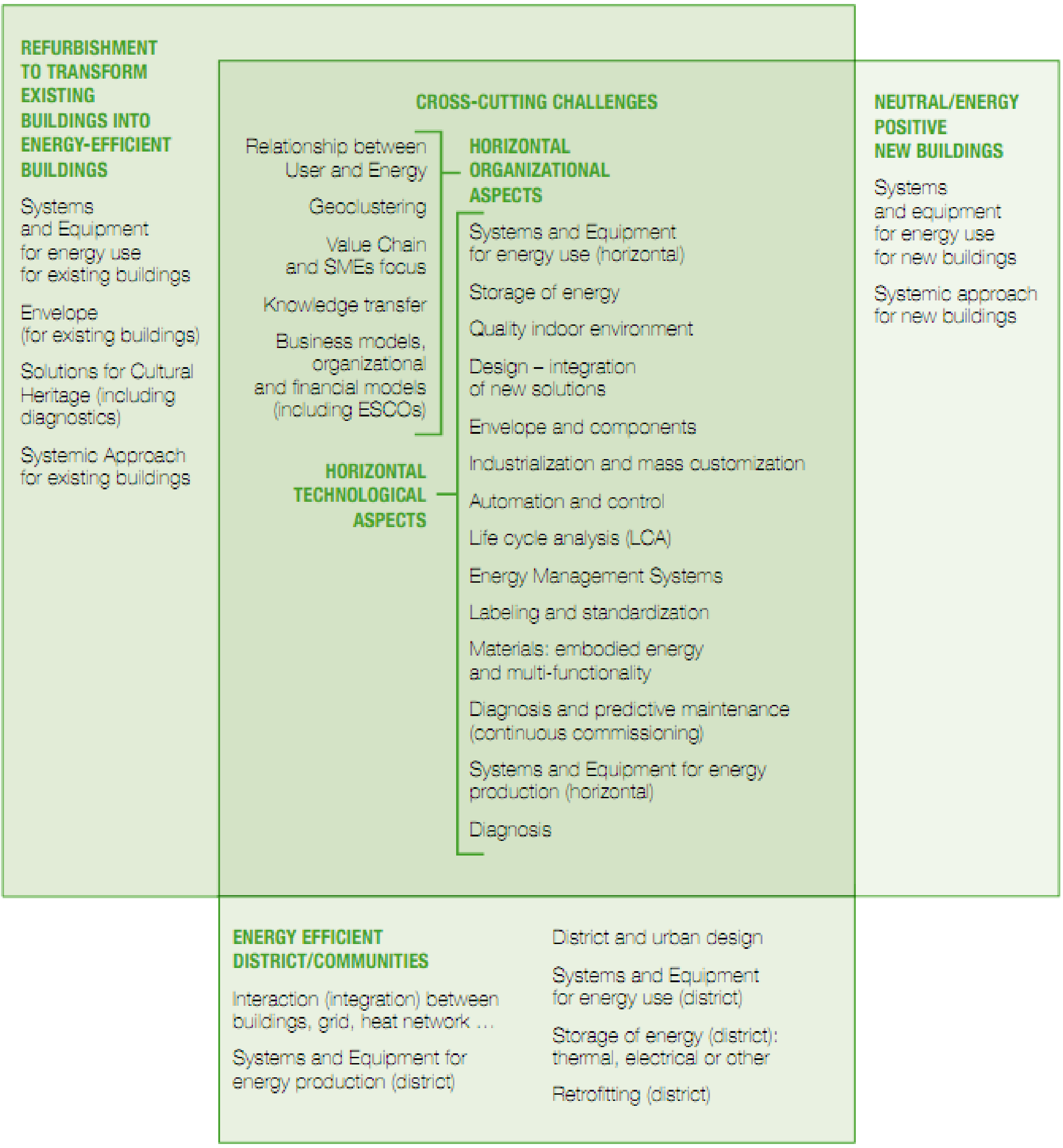

Figure 7. VENN diagram showing inter-relationship among research challenges

These research priorities are distributed along a time scale covering 3 years that will be repeated within longer term “wave action” strategy. Regarding Revisite objectives it is worth noticing that the following research topics are proposed in the first “wave” (2011-2013):

- Design – Integration of new solutions, fostering ICT technologies / integration of new solutions, focus on assessment, simulation and visualization techniques to support decision making, removing gaps between prediction and reality.
- Interaction (integration) between buildings, grid, heat network;
- Relationship between User and Energy, leveraging on ICT tools;
- Labelling and standardization.

3.2 Main ICT4EE issues

Of course, the topics and priorities listed above and coming from heterogeneous initiatives are not strictly aligned with the REViSITE approach and its taxonomy. Even more, the notion of ICT for energy efficiency is not explicitly mentioned in the key topics of some of these roadmaps but below are listed ordered according to our taxonomy some key topics extracted from these roadmaps

Specification & design ICTs

Digital models / Complex models / nD models are foreseen as the right way to provide access to life time information for all stakeholders anywhere anytime. They represent also the pathway to achieve interoperability at the semantic level. Beyond this notion of complex digital models, one can detailed the need to have a new and holistic approach of the design towards new kinds of buildings. These will allow to perform realistic simulations. Theoretical engineering models should be compared with rules and norms to achieve benchmarking of pilots so as to validate the models.

Materialisation ICTs

New methods and tools are required to have good communication through information-sharing among different actors on projects, using tools such as the Building Information Model (BIM).

Development of methodologies and support tools allowing a simplified building monitoring and building performance analysis would allow a drastic reduction of required data input and a simplified assessment. A standardised methodology for European countries would mean a more comprehensive approach to building assessment.

Automation & operational decision support ICTs

Service oriented architectures are needed to introduce building and district automation and control systems. Service platforms should be developed to host various software sub-systems for monitoring, control, automation.

Monitoring should be connected with data-mining modules to support tracking and performance evaluation in interactive environments. Interoperability standards, protocols and interfaces for wired and wireless communication need to be addressed and developed.

Resource & process management ICTs

New methods and procedures are needed to integrate ICT tools into construction processes while maintenance operations are essential for energy efficiency, productivity and security.

Technical Integration ICTs

There is a need for integration and definition of standard protocols to make it possible to analyse energy behaviour on the same terms in all EU countries, better understanding energy aspects from building experts to end-users.

Trading / transactional management ICTs

Innovative methodologies for the bi-directional connection between storage systems, smart grids and buildings are needed. New methods for real-time energy demand-supply management are required jointly with innovative approaches for building-to-grid integration without power quality pollution. In this framework, new technologies and approaches are needed to enable effective Building-to-Building interaction as in an energy market.

At the Citizen level, reliable knowledge of the relationship of energy efficiency versus wellbeing needs to be created, taking into account the behaviour of the users.

4. LIGHTING

4.1 Summary of existing SRAs / roadmaps

The 21st century will be the century of the photon – much as the 20th century was the century of the electron. Photonics will enable the transition in lighting from the current technology to low energy consumption, digital technology, built around LEDs, OLEDs, sensors and microprocessor intelligence. Lighting energy savings are due to low-energy light sources and intelligent lighting controls.

Organic and large area electronics will enable the full integration of organic photovoltaic generation devices and digital lighting control systems within buildings and windows. resulting in energy-positive buildings and communities.

In the future solid –state lighting (SSL) will be much more energy-efficient than the existing lighting installations offering 50 % energy savings. In addition 20 % energy savings are anticipated, when SSL lighting is combined with ICT.

[Source: Photinics21 2011. Photonics - Our vision for a key enabling technology of Europe]

In the SRA of Photonoics21 it is pointed out that the market today wants higher quality and more adaptable lighting, while regulations demand more efficient output. This will shift emphasis to the lighting system as a whole. It is not just the light source that determines efficiency of a lighting installation. Lighting control systems will in future be interconnected with building management systems to operate blinds, heating and ventilation as well as the lighting itself in the interest of improving efficiency and reducing carbon dioxide emissions.

The overall target for SSL lighting systems is high-quality white light for general illumination. Other challenges are low-cost manufacturing and luminaires with high functionality. For OLEDs the technological challenge is flexibility and transparency.

The research goals for LEDs are luminous efficacy over 180 lm/W and high light quality and high lumen package (from one unit). In addition of the LED component also thermal management, electronics and optics have to be improved in order to create a highly efficient light source.

The overall efficiency of lighting, especially in buildings, can be further increased by combining efficient SSL solutions with intelligent light management systems in which lighting is controlled according to the presence of people in the room or the ambient daylight. Some 20 to 50% of the energy used in buildings could be saved in this way. While individual systems and some sensors already exist, standardised communication protocols are lacking as are intelligent light control algorithms, integrated controllers and intuitive interfaces. LEDs offer new opportunities, through controlled colour changing, to imitate the natural rhythms of night and day. Acceptance studies are needed to explore the biological impact and opportunities offered by these effects.

[Source: Photonics21 2010. Lighting the way ahead. Second strategic research agenda in photonics.]

Smets and Wessler give some estimation of energy savings by lighting control. Combining presence detection and daylight harvesting up to 70 % are feasible in real life situations. Even if intelligence can be combined with existing technology, the benefits are larger when combined with LEDs.

Smets and Wessler suggest following ICT-related actions to be done

- Member states and local authorities should provide incentives for intelligent energy efficient lighting technologies.

- The Commission and member states should support large pilot actions to demonstrate the benefits of intelligent SSL lighting technology, to study its acceptance and to determine its economical cost.
- Industry must work towards open standards supported by the Commission.
- The Commission should extend its present research focus beyond photonic components, i.e. LEDs and sensors, to the integration of these components into solutions, system integration at present being hardly addressed in European projects.

[Source: Smets and Wessler. Lighting & photonic technologies for energy efficiency]

Smart Lighting Systems have some extra features over conventional light sources namely, adaptability and awareness. Smart lighting enables efficient lighting systems and they can be interfaced to external grid and building systems. Smart lighting opportunities are:

- Comfort: the right light where you want.
- Productivity: adaptive lighting systems.
- Health: therapeutic lighting.
- Information: lighting and data at the same time.

[Source: Bob Karlicek. Smart Lighting: The Next Wave in Solid State Lighting, Smart Lighting Engineering Research Center]

In vision 2020 has been given strategies for market transformation, technology development of light sources, ballasts and luminaires and also technology development for lighting controls. The lighting controls development strategy includes high levels of intelligence, interface capabilities, multiple levels of control, and ease of configuration. The suggested actions are:

- Enable easy installation (e.g. self-configuring and friendly to non-experts).
- Develop controls that are self-teaching, intuitive, easy to use.
- Develop universal control and communication protocols for component interconnection (such as BACnet or Echelon).
- Create a dialogue with energy management companies and lighting control industry in an effort to develop simple, easy-to-use controls.
- Incorporate anticipatory logic so systems learn and adapt to user preference.
- Sense multiple inputs to configure and define lighting environments to user (colour, room temperature, user temperature, user mood, eyesight of user, occupancy of room, motion, activity type, time of day, daylight levels).
- Allow ease of programming by time of day and date.
- Improve robustness (e.g. non-volatile memory).
- Establish interactive linkage between the lighting, HVAC, and other system controls.
- Provide some control at building level (range of levels, override).
- Develop a universal building interface (remote control and monitoring) for load shedding, optimization of lighting/heat, preventive maintenance.
- For public spaces, develop control systems that accommodate multiple uses of the space.
- Develop control systems that serve emergency-response needs.
- Develop control systems that monitor status of settings.

[Source: Vision 2020. 2000. The lighting technology roadmap. A 20-year industry plan for lighting technology. U.S. Department of Energy.]

IEA ECBCS Annex 45 recommends following measures to improve energy efficiency of lighting:

- Upgrade lighting standards and recommendations
- Integrate values of lighting energy density (kWh/m2, a) into building energy codes
- Monitor and regulate the quality of innovative light sources and products
- Pursue research into fundamental human requirements for lighting (visual and non-visual effects of light)
- Stimulate the renovation of inefficient old lighting installations by targeted measures
- The introduction of more energy efficient lighting products and procedures can, at the same time, provide better living and working environments, and also contribute in a cost-effective manner to the global reduction of energy consumption and greenhouse gas emissions.

[Source: IEA ECBCS Annex 45. 2010. Guidebook on Energy Efficient Electric Lighting for Buildings. www.ecbcs.org]

4.2 Main ICT4EE issues

The main ICT development needs regarding lighting are:

- Control: self-teaching, intuitive, easy to use & program, anticipatory logic, sensing of multiple inputs, etc.
- System integration: open standards, universal control and communication protocols, linkage with HVAC and other systems.

Manufuture Trans-sectorial roadmaps

Appendix 2 to: D3.2 Multi-disciplinary Strategic Research Agenda for ICT-enabled Energy Efficiency

Author: Daniel Kuhn, FhG

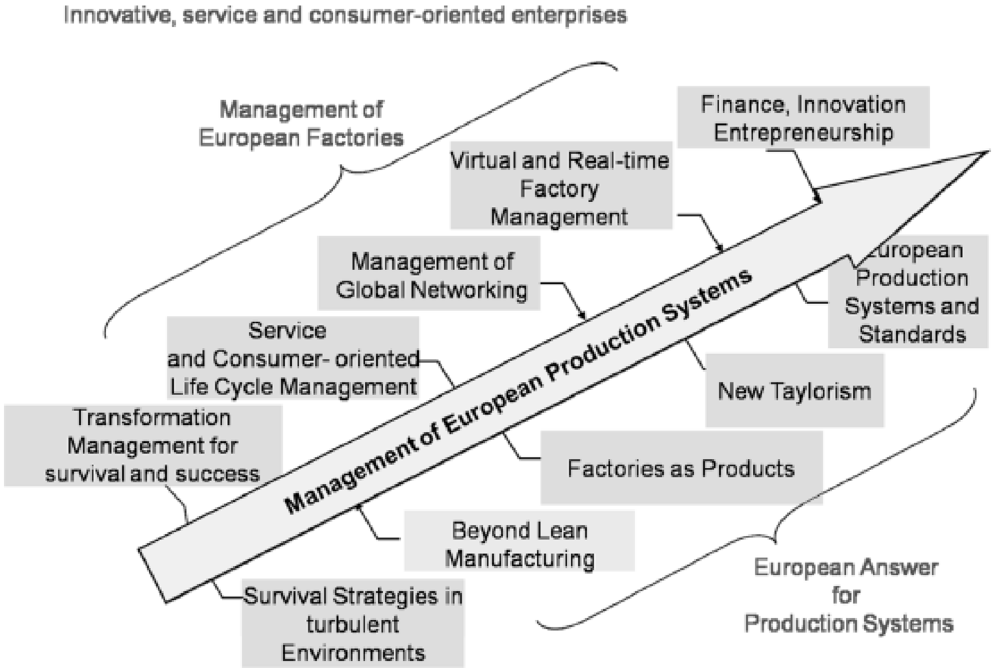

Fig. 5.6. ManuFuture Trans-sectorial Roadmap: New Business Models [5.7]

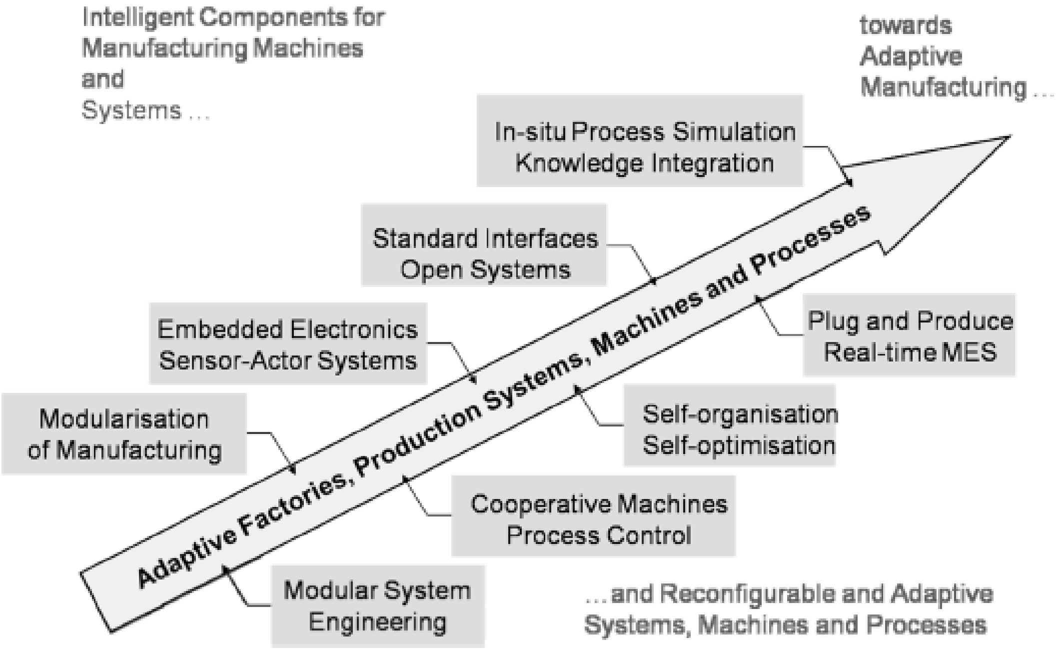

Fig. 5.7. ManuFuture Trans-sectorial Roadmap: Adaptive Manufacturing [5.8]

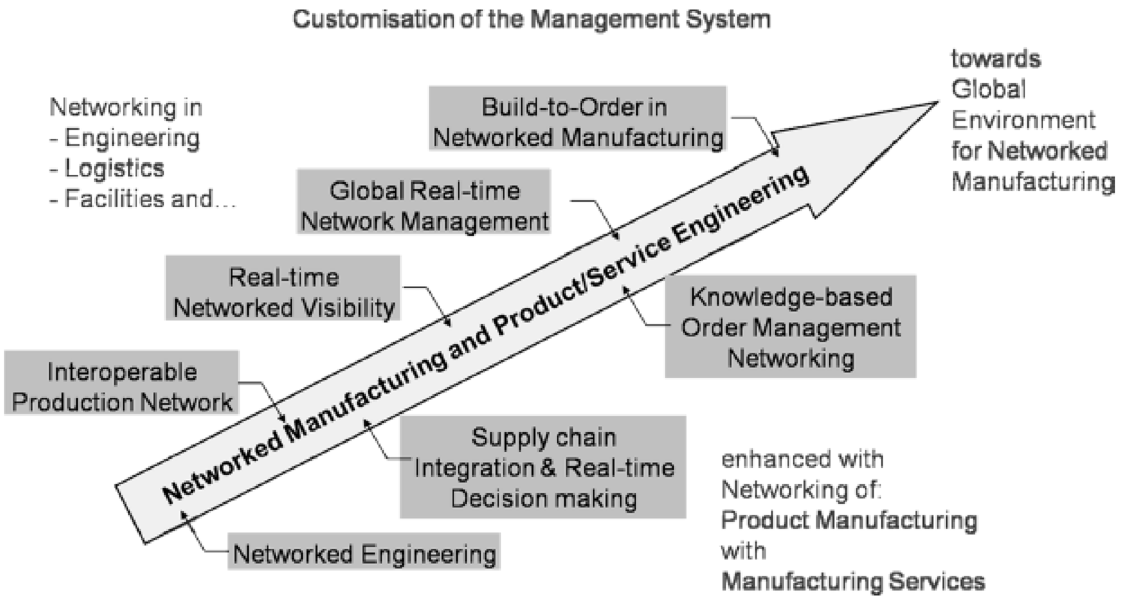

Fig. 5.8. ManuFuture Trans-sectorial Roadmap: Networking in Manufacturing [5.9]

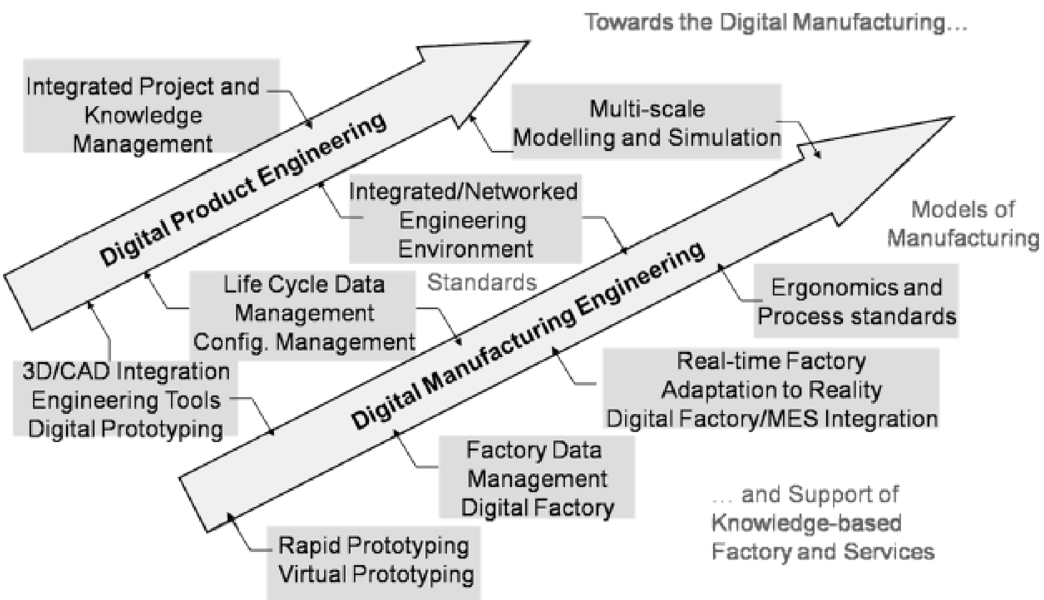

Fig. 5.9. ManuFuture Trans-sectorial Roadmap: Digital, Knowledge-based Engineering [5.10]

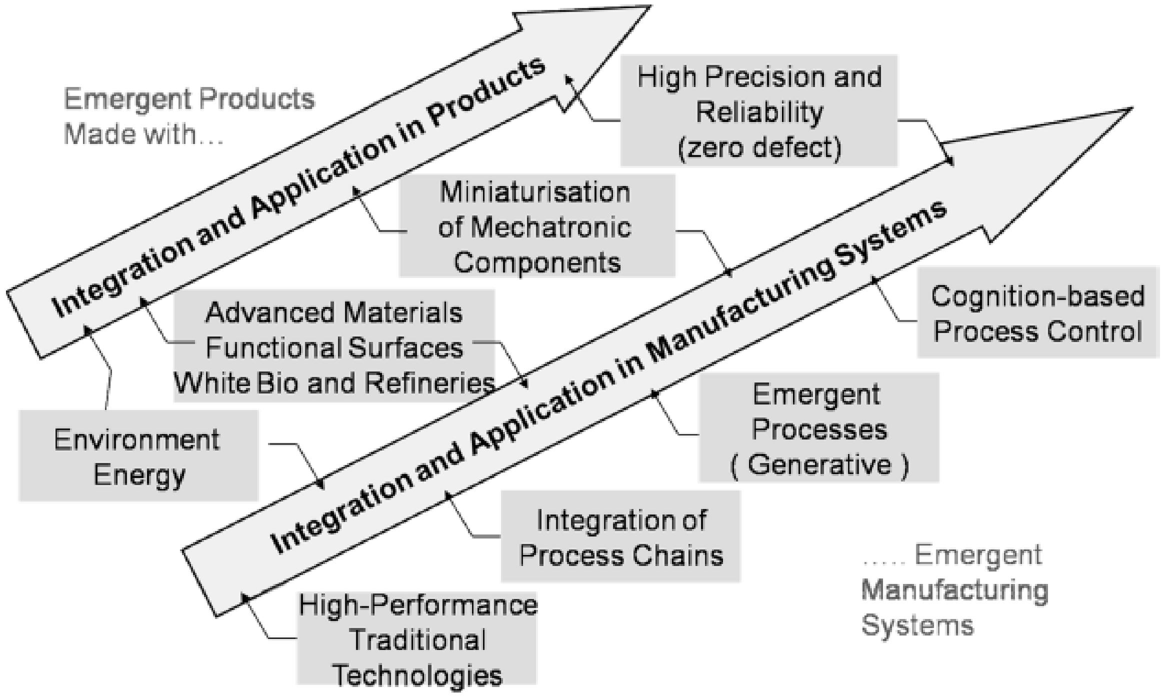

Fig. 5.10. ManuFuture Trans-sectorial Roadmap: Emerging Technologies [5.11]

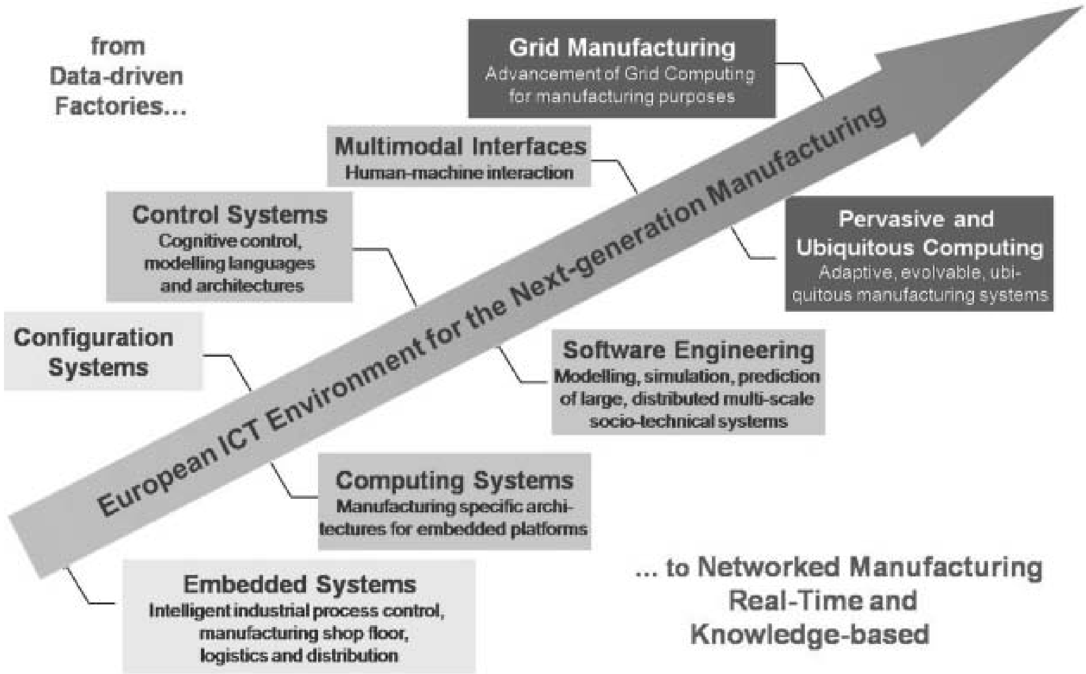

Fig. 5.11. Trans-sectorial ManuFuture Roadmap: ICT for Manufacturing [5.12]

SRA development methodology

Appendix 3 to: D3.2 Multi-disciplinary Strategic Research Agenda for ICT-enabled Energy Efficiency

Authors: Keith Ellis INTEL
Matti Hannus VTT

SUMMARY OF SRA DEVELOPMENT METHODOLOGY

The deliverables of Work package 2, together with the Vision of D3.1 combine to inform the proposed SRA as illustrated in *Figure 1* below

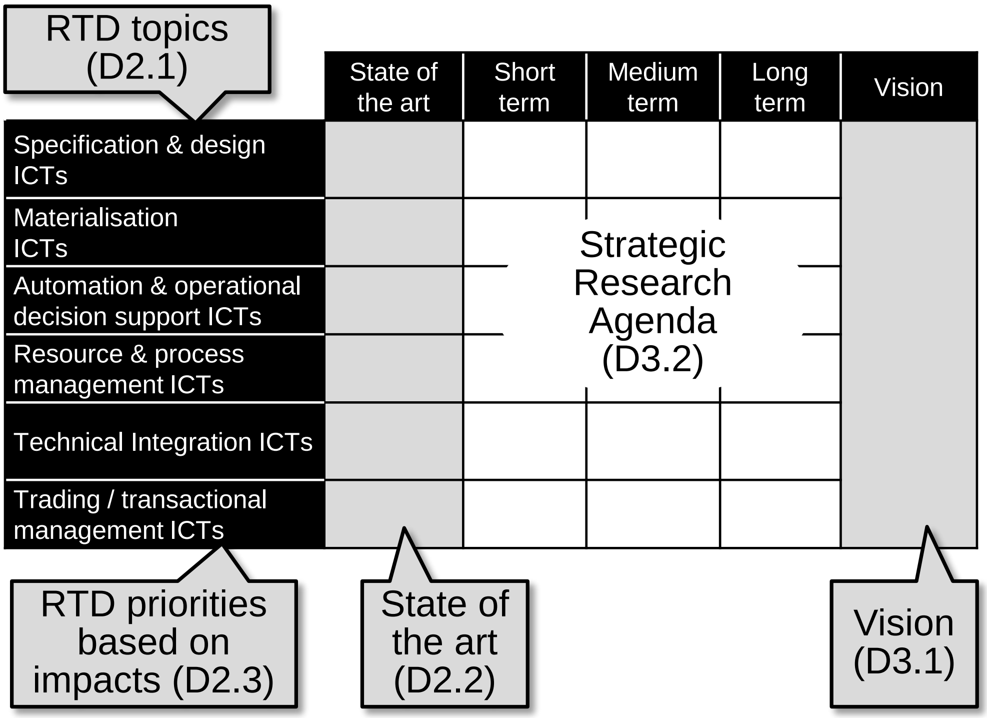

Figure 1. Combining deliverables in informing SRA development

The SRA is essentially built on the output of D2.3 'ICT4EE - Impact Assessment Model' and the subsequent qualitative discussion and assessment that output generated, both within the REViSITE consortium and the wider community.

D2.3 centred on identifying the potential relevance of key ICTs with respect to an ICT4EE focused SRA. D2.3 was based on the qualitative research of deliverable D2.2 'ICT4EE-Knowledge and current practices' and utilised the framework developed in deliverable D2.1 'ICT4EE- Data Taxonomy: A common methodology to assess the impact of ICT developments'.

In identifying 'a common methodology' D2.1 research was clear, emerging best practice in assessing ICT impact on energy efficiency utilised some form of 'Life Cycle Assessment' (LCA) or 'life cycle thinking' [*Figure 2*]

Body	Method	Direct effects	Enabling effects
ITU (International Telecoms Union)	Hybrid LCA	Yes	Yes
ETSI (European Telecoms Standard institute)	Hybrid LCA (National level)	Yes	Yes
iNEMI (International Electronics Manufacturing Institute)	Process-LCA	Yes	No
IEC (International Electrotechnical Commission)	Process-LCA	Yes	No
Ericsson	Process-LCA	Yes	Yes
ATIS (Alliance for Telecom Industry Solutions)	Process-LCA	Yes	Yes
GeSI (Global e-Sustainability Initiative)	Hybrid	Yes	Yes
ISO LCA **standards** 14040 /44 & British standards Institute PAS-2050			

Figure 2. ICT impact assessment utilises some form of life cycle approach

D2.1 assessment of best practice also suggested that the capacity to quantitatively assess ICT impact, while desirable, was in practice an arduous task. Situations where an existing system and a replacement ICT enabled system can be directly measured are not overly common. Where feasible, the task is often complicated by the fact that the replacement system rarely differs from the old with respect to just the ICT element. As such it can be difficult to apportion energy savings as being ICT enabled or otherwise, while abstraction to the sector level becomes an even more onerous process. In other words, determining if an energy impact (effect) is solely attributable to an ICT (cause?) can be difficult

Typically, in scenarios where opportunity for direct quantitative comparison is limited, one must make some form of estimate based on heuristics whereby part-measurement, secondary data, specialist knowledge etcetera all play a part. In that vein REViSITE developed a qualitative based framework for identifying those RTDs/ICTs most likely to positively impact on energy efficiency. The framework [*Figure 3*] was based on 'Life cycle thinking' and an adapted 'Capability Maturity Model/Framework' (CMM or CMF), and utilised a triangulation of approach[i] in leveraging the heuristics of domain experts, together with available quantitative and qualitative sources.

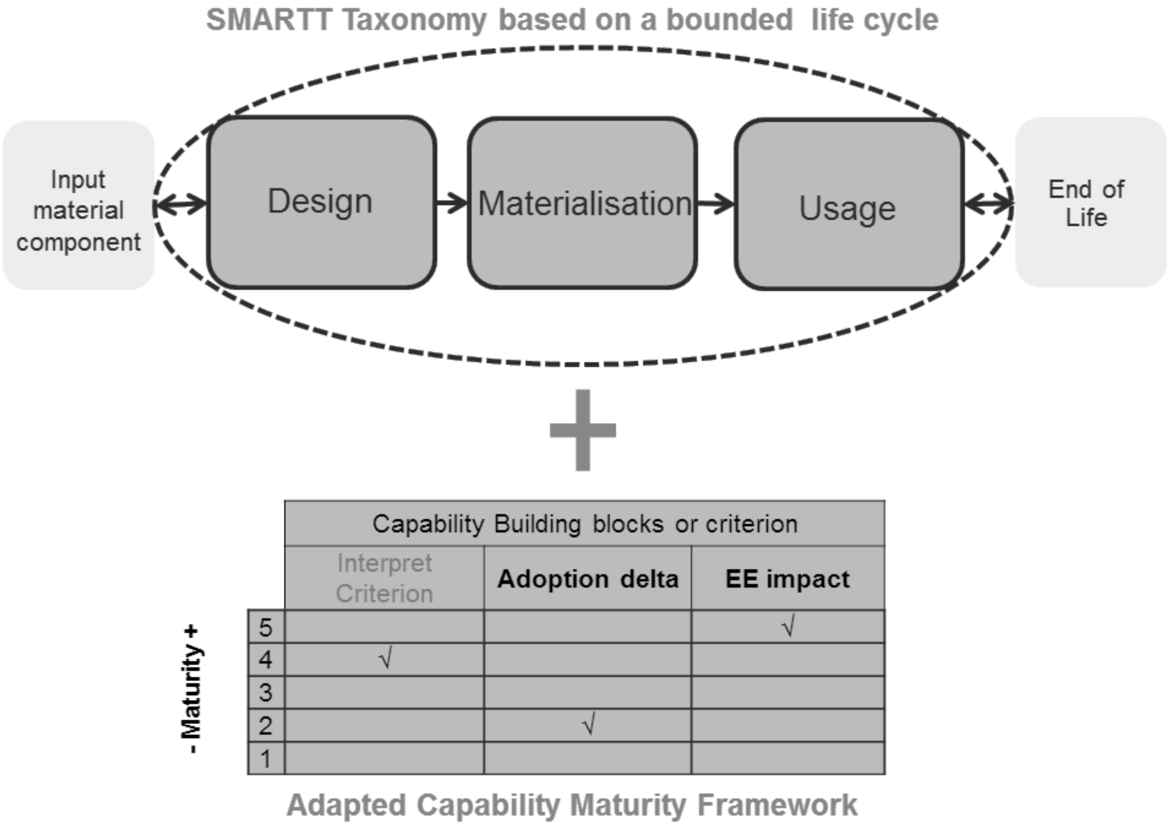

Figure 3. The REViSITE Framework

But before the four target sectors could begin to compare across their respective domains it was essential to first speak a common technical language and therefore the first stage of framework development focused on developing a common taxonomy. The output was the SMARTT taxonomy comprising of six high level categories with 23 sub-categories nested within these. The high level categories [see *Figure 4*] were aligned to a generic bounded life cycle as identified in figure 3

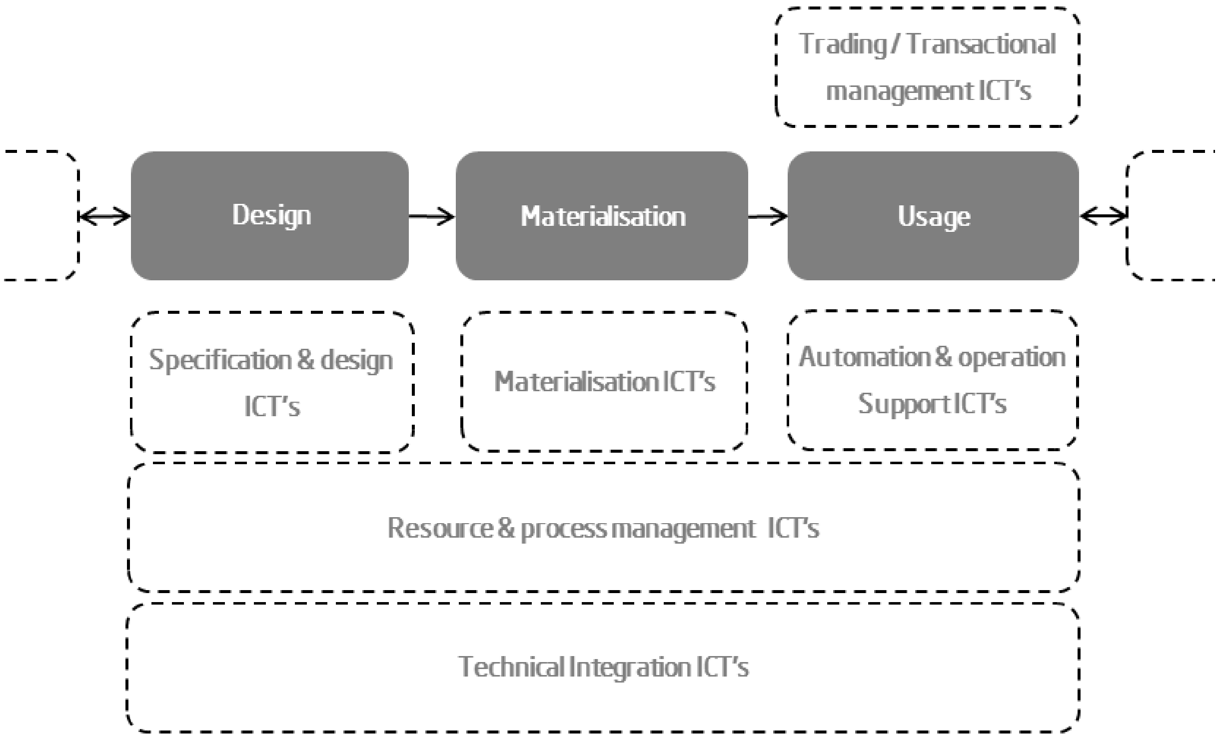

Figure 4. The SMARTT Taxonomy high level categories mapped to Life Cycle phases

Both categories and the 23 sub-categories were fixed and deemed to cover the scope of the ICT4EE domain allowing for common categorisation of ICTs and RTDs across sectors. Sector RTD/ICT topics were nested within the sub-categories and were partner defined. This life cycle aligned SMARTT taxonomy was utilised throughout as an integrative classification system and as an aid to cross sector ICT4EE assessment

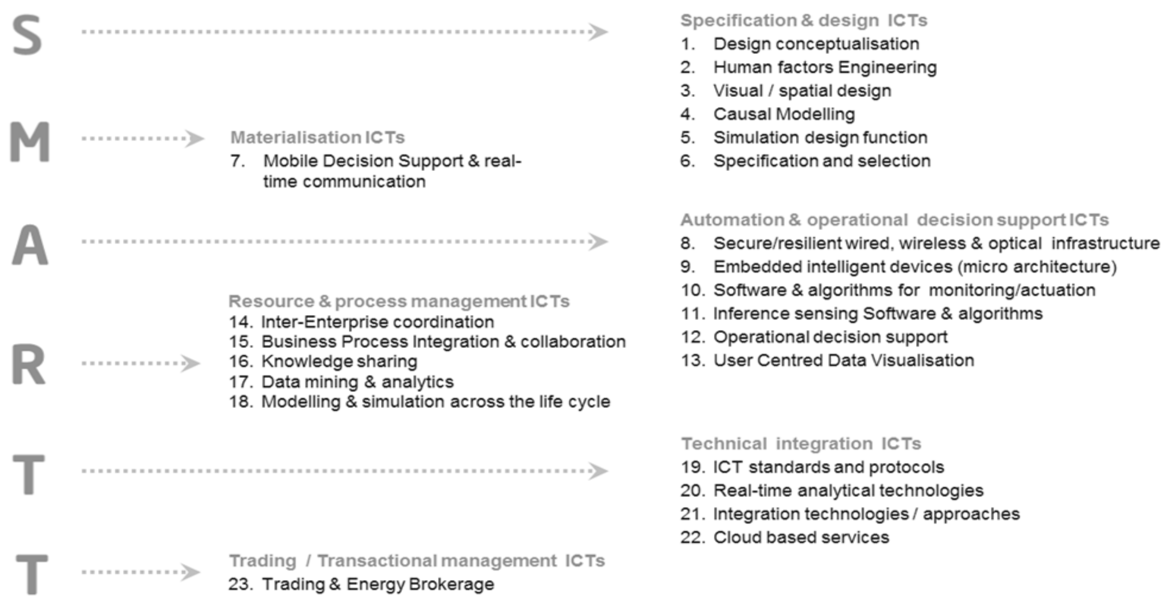

Figure 5. Taxonomy sub-categories mapped to the high level SMARTT categories

The adapted capability maturity framework was used to assess in more detail those themes outlined in D2.2 which were aligned to the 23 sub-categories.

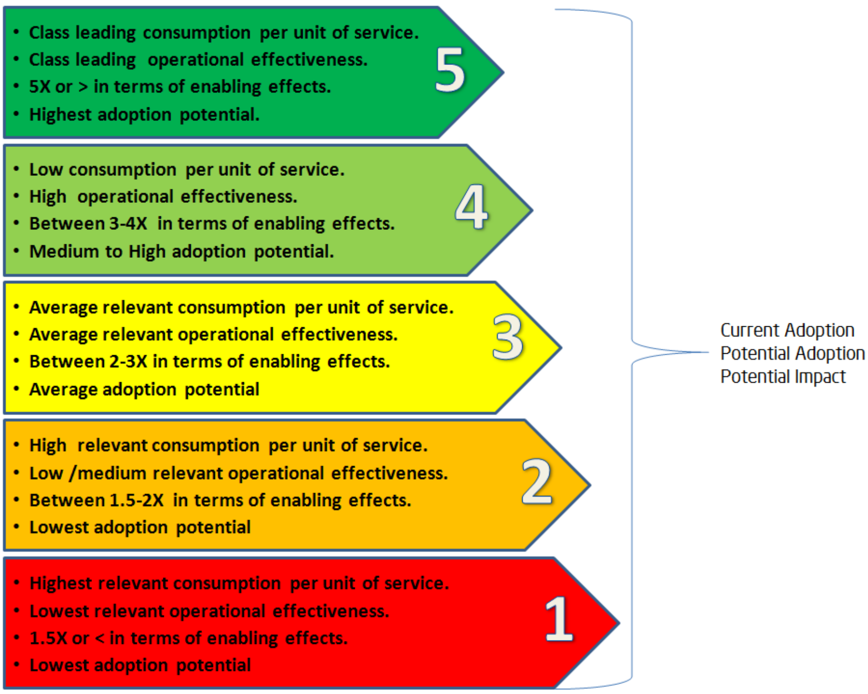

Figure 6. Scale scoring maturity levels in terms of 3 criterion

The assessment was conducted via an online questionnaire process. Essentially, individual respondents made an assessment of the 23 ICT themes based on heuristics and expertise within their defined sectors, scoring them based on the scale of *Figure 6*. By doing so we were able to build sector specific views regarding SRA relevance, where SRA relevance equalled Potential Impact score * [Potential adoption score – current adoption score]

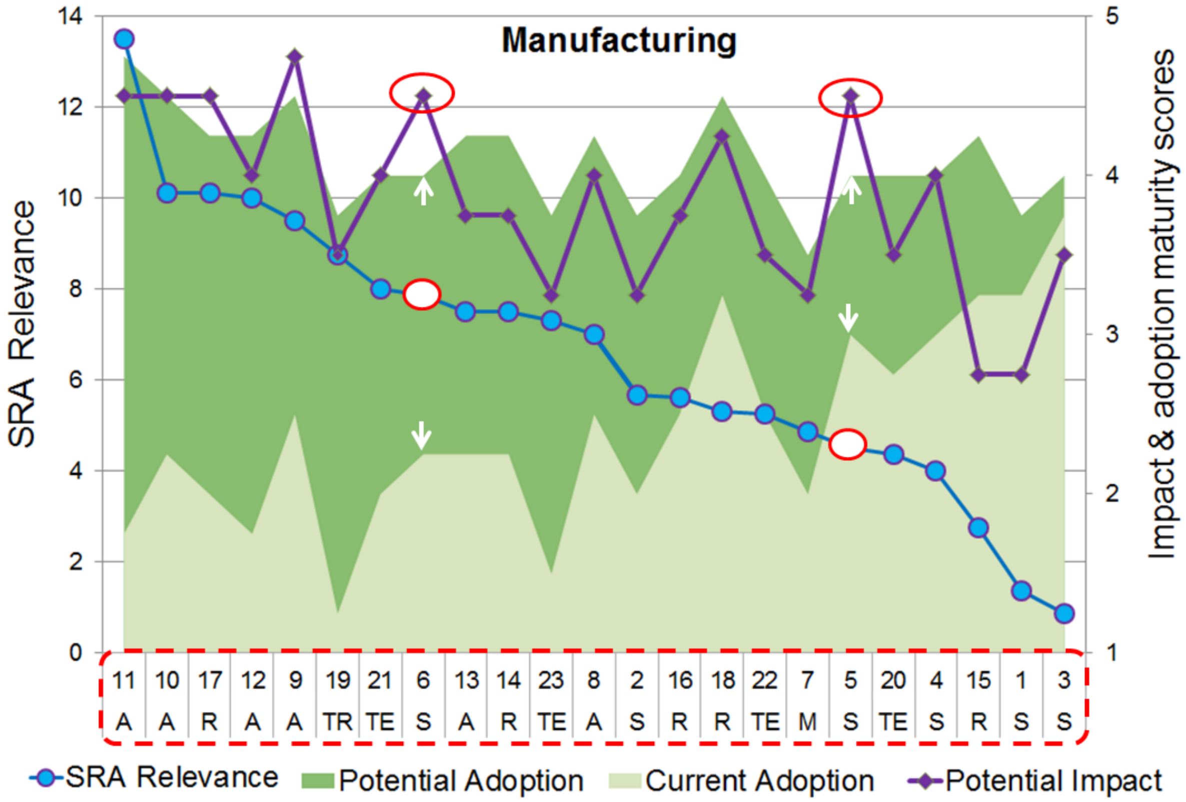

Figure 7. Manufacturing SRA-relevance example

Figure 7 above is an example of the sector specific output produced for each target sector. It can be seen that one might have two ICT themes that score as equally important in terms of 'potential impact' but that due to their respective adoption delta scores [potential adoption – current adoption] they might prove to be different in terms of SRA relevance. Subsequently utilising a reorderable matrix technique we examined cross-sectorial trends [see D2.3 for more details] this analysis coupled with the sector specific outputs offered the basis for workshop and consortium discussion in developing the SRA.

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i Mangan, J., Lalwani, C., Gardner, B. (2004). 'Combining quantitative and qualitative methodologies in logistics research' International Journal of Physical Distribution & Logistics Management, 2004 Volume: 34 Issue 7

Feedback to prioritization questionnaire at the ECTP-E2BA Conference, Warsaw, Poland on 4-5 October 2011

Appendix 4 to: D3.2 Multi-disciplinary Strategic Research Agenda for ICT-enabled Energy Efficiency

Author: Matti Hannus, VTT

Contributions from the following experts are acknowledged:

- Robert Gerylo, ITB
- Jana Kloudova, Tzus Prague
- Agnieszka Kowalska, ASM Ltd.
- Sylvain Kubicki, CRP Henri Tudor
- G.J. Maas, BAM
- Leandro Madrazo, Escola Tècnica i Superior d'Arquitectura La Salle, Universitat Ramon Llull
- Karoly Matolcsy, EMI Nonprofit Kft
- Aleksandra Oleksik, ASM-Marliet Research
- Juan Perez, Tecnalia
- Luc Pockelé, Red Srl
- Joaquim Rigola, CTTC-UPC
- Charis Stavrinou, Scientific & Technical Chamber of Cyprus/Cyprus technology Platform
- José Vicente Fuente, Aidico
- Vladimir Vukovic, AIT

SUMMARY OF FEEDBACK

The main conclusions from the feedback are:

- Replies were received from 14 experts mainly from the construction domain. Most of them have a research background and expertise on all areas of the questionnaire except one. To some degree the replies reflect the background of the respondents.
- There is a strong correlation between high priority and expected long time to industrial usage. Therefore both are highlighted in the following tables.
- The respondents added only a few topics that were not mentioned in the questionnaire. It appears that the questionnaire has a good coverage of relevant topics.

The feedback is summarised in the tables below at the level of main and sub-categories. Note that each sub-category consists of 2-6 detailed RTD topics some of which may have a high priority. See the detailed tables in this document.

RTD categories		Prior[&]	Time[#]
1.	**Specification & design**		
1.1	Design	**H**	M
1.2	Modelling	M	M
1.3	Performance specification & estimation	M	M
2.	**Construction**		
2.1	Contracting	M	M
2.2	Production management	M	M
3.	**Automation & operational decision support**		
3.1	Automation & control	M	M
3.2	Infrastructure for operations communications	L	M
3.3	Monitoring	**H**	M
3.4	User awareness	**H**	**L**
4.	**Resource & process management**		
4.1	Process integration	**H**	**L**
4.2	Knowledge sharing	**H**	**L**
4.3	Whole life cycle management	**H**	**L**
5.	**Energy trade & transactional management**		
5.1	District energy management beyond buildings	M	M
5.2	Smart grids and the built environment	**H**	**L**
6.	**Technical integration**		
6.1	System integration	M	M
6.2.	Data models, interoperability & standards	M	M

High priority RTD topics related to standardisation (Category 6)		**Prior[&]**	**Time[#]**
6.1.4	Integration of BIM to real time operational systems.	**H**	**L**
6.2.1	Interoperability between BIM-based design, analysis and planning.	**H**	M
6.2.2	Interoperability between BIM-tools and simulation.	**H**	M

[&]Priority: Low, Medium, **High** [#]Time: Short, Medium, 3=**Long** term

METHODOLOGY

The respondents were asked to assess research topics from two aspects:

- Priority in the scale: blank = NA, 1 = Low, 2 = Medium, 3 = High.
- Expected time to industrial usage in the scale: Blank = NA, Short, Medium, Long.

Persons filled to questionnaires in very different ways. Some persons used high scores, assigned them to different time spans of each question, and answered to most questions. Others used moderate scores, only one time span per question and answered only to selected questions.

In order to give a similar weight to the feedback of each person the scores were calibrated as follows:

1. First the scores given by a person to any single question were calibrated to max 3.
2. These numbers were then divided by the total sum of numbers from the same person to all questions.
3. Finally all numbers from all persons were calibrated to give the average 2.

Due to this procedure the modified numbers in some cases have a higher value than 3.

This is illustrated by the following example:

	Person A			**Person B**		
RTD priorities for different time spans	S	M	L	S	M	L
Original scores given by persons			2	3	3	3
Calibrated numbers; step 1 above			2	1	1	1

PROFILES OF RESPONDENTS

Which stakeholders' class do you represent?		Persons
1	Building client / owner / developer / housing organisation	
2	Designer (AEC)	0,5
3	Project manager (consultant)	1
4	Construction company / subcontractor (buildings, building services systems,)	1
5	Supplier (material / product)	
6	Manufacturer (material, component, system)	
7	Building automation company (manufacturer / constructor / systems integrator)	0,5
8	Building operator / facility manager	
9	Building occupant	
10	Public authority (for buildings)	0,33
11	ICT provider / developer	
12	Energy Utility	
13	Research Institute / University / Research funding organisation	**9,33**
14	Financial organisation / business developer	
15	*Other: (Not clear from answers)*	1,33
	Total	**14**

Most of the 14 respondents expressed belonging to one stakeholder class. A few indicated several classes. These were weighted so that each person is calculated totally as one. 67% of persons had research background. All other classes were represented by less than 2 persons.

Your main area of expertise?		Persons
1	Building design	1,92
2	Construction / renovation	0,87
3	Building materials / components	1,20
4	Building use / operation / monitoring / maintenance	1,62
5	Building automation / Electrical building services	
6	Energy management at building / district level	**3,12**
7	ICT software / services	1,75
8	R&D	**2,95**
9	*Other:* Socio-economic analysis, business models, project management, user assessment, Marliet analysis. Socio-economic impact analysis, user requirements, user acceptance of the new technology, market studies, social studies on construction energy efficiency.	0,58
	Total	14

Different respondents expressed expertise in 1 – 6 areas. These were weighted so that each person is calculated totally as one. Areas represented by more than 2 persons were: Energy management at building / district level and R&D. Nobody claimed expertise in Building automation / Electrical building services, which is also reflected in the feedback.

PRIORITISATION OF RESEACH TOPICS

1.	Specification & design	Prior[&]	Time[#]
1.1	**Design**	**H** 2,74	M 2,47
1	Requirement engineering.	**H** 3,29	**L** 3,00
2	Concept design.	**H** 4,46	**L** 2,59
3	Detailed design, CAD, component/solution libraries.	M 2,12	M 2,09
4	Configuration management, mass-customisation.	L 1,42	M 1,95
5	Visualisation of design solutions.	M 2,42	**L** 2,70
6	*Other:* User requirements *(=1.12)*	M 2,32	S 0,91
1.2	**Modelling**	M 2,21	M 2,19
1	Modelling components, systems, buildings, districts.	M 2,05	M 2,30
2	Modelling & understanding ICT impacts on energy efficiency.	**H** 2,58	M 1,91
3	Model/BIM-based design tools	**H** 2,51	M 2,28
4	Semantic mapping, co-use of different semantics.	M 1,69	M 2,26
5	*Other:* User requirements & preferences; evaluation with users *(=1.12)*	L 0,54	S 0,36
1.3	**Performance specification & estimation**	M 2,44	M 2,47
1	Performance metrics & criteria.	**H** 2,98	M 2,28
2	Performance specification.	M 1,84	M 1,70
	Performance estimation methods and tools:		
3	• Simulation.	**H** 2,52	M 2,37
4	• Life cycle cost analysis.	M 2,24	**L** 2,73
5	• Life cycle impact assessment.	**H** 2,60	**L** 3,28
6	Other: *(No data was given)*	M 1,79	S 0,55

[&]Priority: Low, Medium, **High** [#]Time: Short, Medium, 3=**Long** term

2.	Construction	Prior[&]	Time[#]
2.1	**Contracting**	M 1,83	M 2,00
1	Contract & supply network management.	M 2,00	M 2,18
2	Management of performance based contracts.	M 1,66	M 1,82
2.2	**Production management**	M 1,73	M 2,35
1	Material/product/component/system specification, selection & procurement.	M 1,81	M 2,28
2	Product tagging & tracking (e.g. RFID)	M 1,58	M 2,09
3	Site-bound logistics.	L 1,42	M 2,28
4	On/off-site production strategy and management.	M 1,60	M 2,28
5	Mobile data access, guidance, decision support etc. "in the field".	M 2,23	**L** 2,82

[&]Priority: Low, Medium, **High** [#]Time: Short, Medium, 3=**Long** term

3	Automation & operational decision support	Prior[&]	Time[#]
3.1	**Automation & control**	M 2,05	M 2,28
1	System concepts.	**H** 4,02	M 2,28
2	Building energy management systems.	M 1,88	M 2,10
3	Software & algorithms.	M 1,83	M 2,12
4	Instrumentation, sensors, actuators, smart meters, smart appliances.	L 1,37	M 2,00
5	Intelligent HVAC, lighting, microgeneration & storage.	M 1,78	M 2,46
6	Predictive / learning control. Pattern recognition.	M 2,14	**L** 2,64
7	Operational decision support.	L 1,35	M 2,37
3.2	**Infrastructure for operations communications**	L 1,19	M 1,86
1	Hardware, embedded intelligent devices, smart appliances.	L 1,15	M 1,57
2	Secure wired / wireless / optical networks.	L 1,15	M 2,11
3	Integration & service platforms, middleware, gateways.	L 1,28	M 1,91
3.3	**Monitoring**	**H** 2,69	M 2,38
1	Diagnostics, performance analysis, evaluation & conformance validation.	**H** 3,98	**L** 2,56
2	Commissioning, energy audits, labelling.	M 2,30	M 2,28
3	Operational decision support.	M 1,78	M 2,29
4	*Other:* Smart materials for automatic monitoring *(not an ICT topic)*	L 0,24	S 0,27
3.4	**User awareness**	**H** 4,02	**L** 3,73
1	Human factors Engineering Modelling user behaviour.	**H** 4,21	**L** 3,91
2	User centered, situation based data visualisation.	**H** 3,09	**L** 3,19
3	Support for behavioural change, social pressure.	**H** 4,75	**L** 4,10

[&]Priority: Low, Medium, **High** [#]Time: Short, Medium, 3=**Long** term

4	Resource & process management	Prior[&]	Time[#]
4.1	**Process integration**	**H** 3,44	**L** 3,22
1	Business and process models.	**H** 4,70	**L** 3,82
2	Inter-enterprise coordination, collaboration & communication.	**H** 3,24	**L** 2,64
3	Distributed systems.	M 2,37	**L** 3,19
4.2	**Knowledge sharing**	**H** 3,33	**L** 3,55
1	Knowledge capture, formalisation and consolidation.	**H** 2,60	**L** 2,64
2	Knowledge repositories, data mining, semantic search, long-term archival & recovery.	**H** 3,35	**L** 3,82
3	Knowledge analytics of energy consumption & optimisation, pattern identification etc.	**H** 4,04	**L** 4,19
4	*Other:* Mentoring models development; dissemination of knowledge.	M 1,79	S 0,55
4.3	**Whole life cycle management**	**H** 3,83	**L** 4,46
1	Modelling & simulation e.g. "what-if" scenario planning & continuous improvement.	**H** 3,83	**L** 4,46
2	Other: *(No data was given)*	L 0,29	S 0,55

[&]Priority: Low, Medium, **High** [#]Time: Short, Medium, 3=**Long** term

5	Energy trade & trans-actional management	Prior[&]	Time[#]
5.1	**District energy management beyond buildings**	M 2,22	M 2,33
1	District energy management systems.	**H** 3,00	**L** 3,09
2	ICT architectures and infrastructures for districts.	M 2,08	M 2,28
3	Management of local generation, distribution and storage.	**H** 3,00	M 2,46
4	Energy trading & brokerage, prosumer forecasting, resource tracking, consumption/price negotiation.	L 0,82	S 1,49
5	*Other:* Smartgrids development based on novel ICT	L 0,24	S 0,27
5.2	**Smart grids and the built environment**	**H** 4,17	**L** 2,64
1	Smart metering.	M 2,08	M 2,18
2	Balancing between users' need (e.g. comfort) and supply side constraints (demand control).	**H** 6,26	**L** 3,09

[&]Priority: **L**ow, **M**edium, **High** [#]Time: **S**hort, **M**edium, 3=**Long** term

6	Technical integration	Prior[&]	Time[#]
6.1	**System integration**	M 1,72	M 1,97
1	Plug & play connections/interfaces.	L 1,22	M 1,52
2	Integration platforms, gateways, middleware.	L 1,41	M 1,89
3	Service oriented architectures, web services, cloud based services, event driven architectures.	M 1,62	S 1,46
4	Integration of BIM to real time operational systems.	**H** 2,51	**L** 2,82
5	Integration of external monitoring and services with building operation & management.	M 1,83	M 2,18
6.2	**Data models, interoperability & standards**	M 1,94	M 2,07
1	Interoperability between BIM-based design, analysis and planning.	**H** 2,91	M 2,37
2	Interoperability between BIM-tools and simulation.	**H** 2,91	M 2,37
3	Interoperability of real time operational systems across heterogeneous control, sensor and actuation devices.	L 1,03	M 1,55
4	Energy trading protocols between buildings, districts and energy grids.	L 0,90	M 1,98

[&]Priority: **L**ow, **M**edium, **High** [#]Time: **S**hort, **M**edium, 3=**Long** term

Feedback to prioritization questionnaire at the CIB W78-W102 Conference, 26-28 October 2011, Sophia Antipolis, France

Appendix 5 to: D3.2 Multi-disciplinary Strategic Research Agenda for ICT-enabled Energy Efficiency

Authors: Matti Hannus VTT
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Contributions from the following experts are acknowledged:

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- Jonas Flub, FIR of RWTH
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- Xavier Brunotte, Vesta System
- Jean Christophe Clemente, Industry and Commerce Chambre
- Klaus Kabistzsch, TU Dresden
- Franck Bernier, Schneider Electric
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- Cesar Valmaseda, CARTIF
- Alvaro Sicilia, ARC
- Christian Mastrodonato, D'Appolonia SpA
- Raimar Scherer, Tu-Dresden

SUMMARY OF FEEDBACK

18 experts filled the REViSITE prioritization questionnaire at the CIB conference. The main conclusion from the feedback is that all topics were assessed to have a similar order of priority and similar time to expected availability of results. The differences are indicative but do not point at any clear "winners or loosers". The respondents added only a few topics that were not mentioned in the questionnaire. It appears that the questionnaire covers the domain well with relevant topics.

The feedback is summarised in the two tables below at the level of subcategory, each one of which consists of 2-10 more detailed RTD topics.

Highest priority[&]		Longest time[#] to results	
2.2 Modelling	**2,38**	6.1 District energy management beyond buildings	2,20
5.2 Knowledge sharing	**2,28**	1.3 NEMS – Neighbourhood Energy Management Systems (usage stage)	2,08
2.3 Performance specification & estimation	**2,22**	5.2 Knowledge sharing	2,03
…	…	…	…
Lowest priority[&]		**Shortest time[#] to results**	
4.1 Automation & control	1,91	4.1 Automation & control	1,70
3.2 Production management	1,80	2.1 Design	1,64
6.2 Smart grids and the built environment	1,75	4.3 Monitoring	1,53
…	…	…	…

RTD categories		Prior[&]	Time[#]
1.	**Data models, interoperability & standards**	**2,12**	**1,91**
1.1	BIM – Building Information models *(design stage)*	2,10	1,97
1.2	BEMS – Building Energy Management Systems *(usage stage)*	2,19	1,75
1.3	NEMS – Neighbourhood Energy Management Systems *(usage stage)*	2,07	2,08
1.4	Grids *(usage stage)*	2,11	1,85
2.	**Specification & design**	**2,20**	**1,76**
2.1	Design	2,00	1,64
2.2	Modelling	**2,38**	1,84
2.3	Performance specification & estimation	**2,22**	1,80
3.	**Construction**	**1,86**	**1,81**
3.1	Contracting	1,92	1,86
3.2	Production management	1,80	1,76
4.	**Automation & operational decision support**	**1,98**	**1,77**
4.1	Automation & control	1,91	1,70
4.2	Infrastructure for operations communications	1,97	1,90
4.3	Monitoring	2,03	1,53
4.4	User awareness	2,00	1,94
5.	**Resource & process management**	**2,20**	**1,95**
5.1	Process integration	2,15	1,83
5.2	Knowledge sharing	**2,28**	2,03
5.3	Whole life cycle management	2,17	2,00
6.	**Energy trade & transactional management**	**1,94**	**2,10**
6.1	District energy management beyond buildings	2,13	2,20
6.2	Smart grids and the built environment	1,75	2,00
7.	**System integration**	**2,18**	**1,81**
7.1	System integration	2,18	1,81

[&]Priority: 1=Low, 2=Medium, 3=High [#]Time: 1=Short, 2=Medium, 3=Long term

PROFILES OF RESPONDENTS

Which stakeholders' class do you represent?		Persons
1	Building client / owner / developer / housing organisation	
2	Designer (AEC)	0,25
3	Project manager (consultant)	0,25
4	Construction company / subcontractor (buildings, building services systems)	
5	Supplier (material / product)	
6	Manufacturer (material, component, system)	0,5
7	Building automation company (manufacturer / constructor / systems integrator)	1
8	Building operator / facility manager	
9	Building occupant	
10	Public authority (for buildings)	1
11	ICT provider / developer	1,75
12	Energy Utility	
13	Research Institute / University / Research funding organisation	**12**
14	Financial organisation / business developer	1
15	*Other:* Industry and Commerce Chambre, Engineering Service Provider	0,25
	Total	**18**

Most of the 18 respondents expressed belonging to one stakeholder class. A few indicated several classes. These were weighted so that each person is calculated totally as one. 67% of persons had research background. All other classes were represented by less than 2 persons.

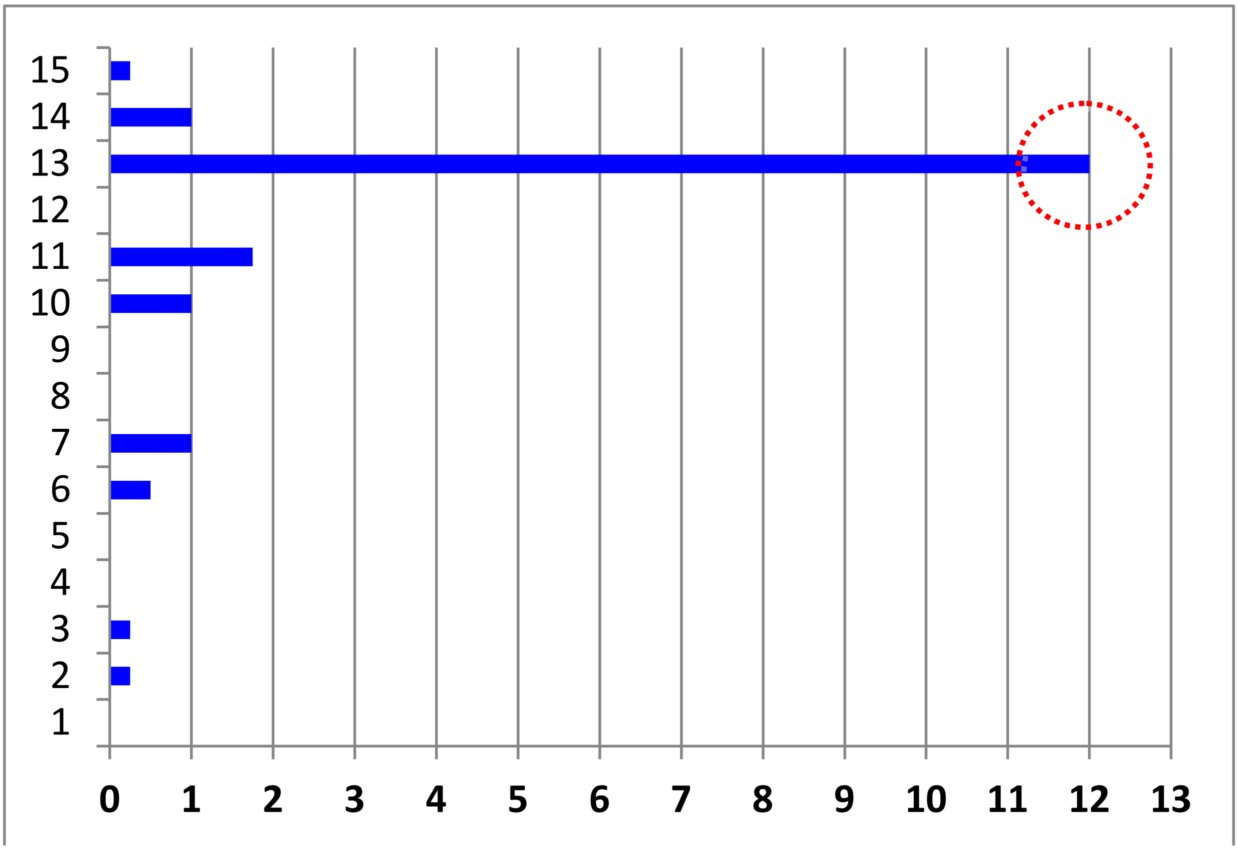

Figure: Stakeholder classes of respondents

Your main area of expertise?		Persons
1	Building design	
2	Construction / renovation	
3	Building materials / components	
4	Building use / operation / monitoring / maintenance	0,67
5	Building automation / Electrical building services	1,92
6	Energy management at building / district level	2,58
7	ICT software / services	**4,75**
8	R&D	**5,58**
9	*Other:* Develop Smart Grid Cluster, Ontologies	1,5
	Total	**17**

Most of the 18 respondents expressed expertise in several (2-4) areas. These were weighted so that each person is calculated totally as one. One person did not fill this information whereby the total is 17. Areas represented by more than 2 persons were: R&D, ICT, Energy management.

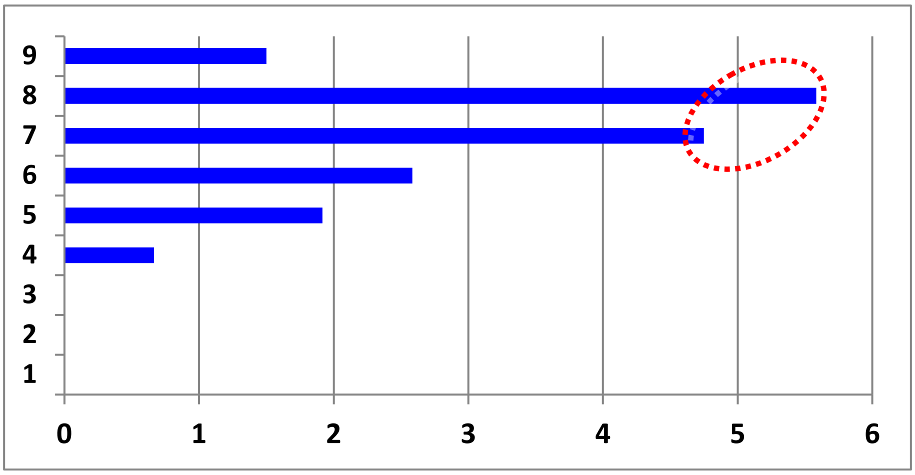

Figure: Expertise areas of respondents

1. DATA MODELS, INTEROPERABILITY & STANDARDS

1.1 BIM – Building Information models (design stage)		**Prior[&]**	**Time[#]**
1	Enhancement of BIM with energy-related data (coverage of energy related information needed & provided by various disciplines).	**2,15**	**1,38**
2	Interoperability between BIM-based design, analysis, and planning tools (availability of necessary data from BIM for various application tools).	**2,29**	**1,62**
3	Interoperability between BIM and assessment & simulation tools (availability of necessary data from BIM for static & dynamic energy performance estimation).	2,07	1,92
4	Interoperability of reference data (e.g. catalogues of materials, products, best practices) with BIM.	2,20	1,86
5	Harmonisation of building regulations with BIM (availability of necessary data from BIM for assessing compliance).	2,00	2,15
6	Harmonisation of design and construction standards with BIM and related process definitions.	2,08	2,00
7	Interoperability of BIM with collaborative working environments (metadata, semantic mapping).	2,07	2,15
8	Interoperability between BIM and visualisation & decision support (availability of necessary data from BIM).	2,00	2,31
9	Interoperability of BIM and GIS (urban plans, infrastructure networks, local energy-related services etc.)	2,00	2,30
10	*Other:* None		
	Average	**2.10**	**1,97**
Relevant standardisation bodies	BuildingSmart (IAI), several national, OMG, Virtual Enterprise groups, IAI + GIS groups.		

[&]Priority: 1=Low, 2=Medium, 3=High [#]Time: 1=Short, 2=Medium, 3=Long term

The priorities and time to availability of results in all topics were assessed close to 2 / medium term. The main deviation from the average assessment is that shorter time to results was expected in topics “eeBIM” and “interoperability of BIM based tools”.

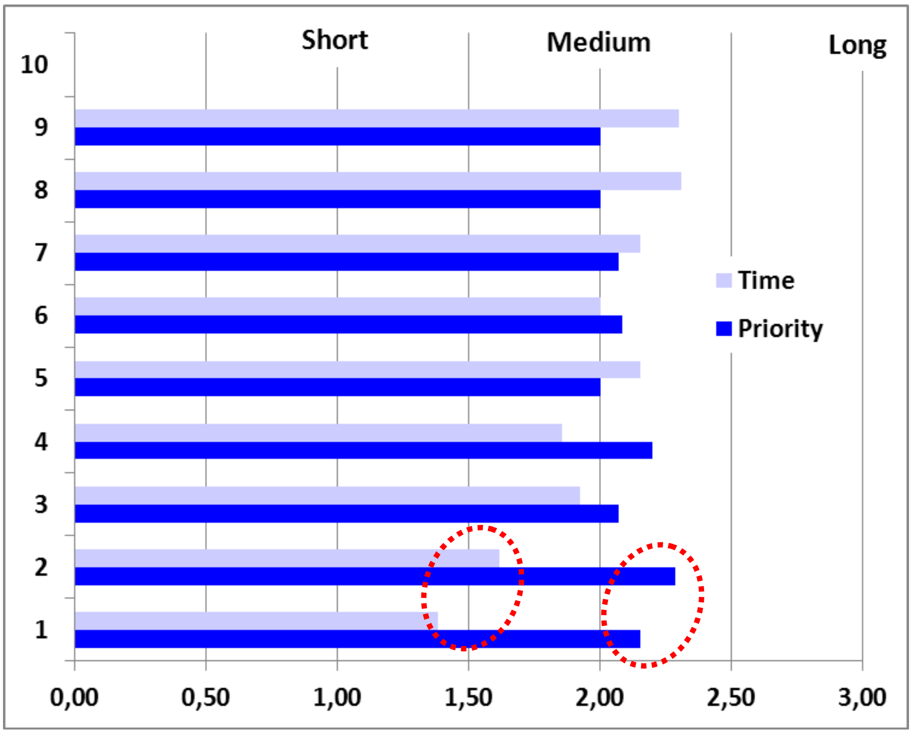

Figure: BIM – Building Information models

1.2 BEMS – Building Energy Management Systems (usage stage)		**Prior[&]**	**Time[#]**
1	Energy performance metrics supported by ICT (definition of indicators based on available data from BIM & BEMS).	**2,31**	**1,62**
2	Interoperability between BEMS and BIM (availability of necessary data from BIM to support operation). Harmonisation of BIM and BEMS data models regarding common objects (e.g. spaces).	2,07	1,92
3	Interoperability of real time operational systems with energy producing and energy consuming equipment.	2,20	1,71
4	*Other:* None		
	Average	**2,19**	**1,75**
Relevant standardisation bodies	IAI, IEC OPC UA		

[&]Priority: 1=Low, 2=Medium, 3=High [#]Time: 1=Short, 2=Medium, 3=Long term

In all topics the priorities were assessed to be slightly above 2 while time to results is expected to be slightly below medium term. Compared to generally small deviations, it is notable that relatively higher priority and shorter time to results is expected in all topics, especially performance metrics. This may reflect urgency and/or the fact that these topics are already on the research agenda.

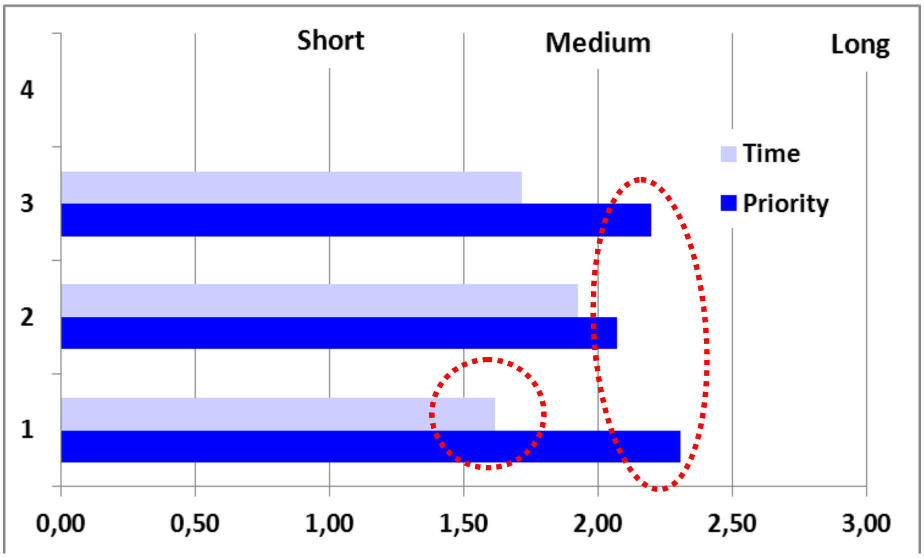

Figure: BEMS – Building Energy Management Systems

1.3 NEMS – Neighbourhood Energy Management Systems (usage stage)		**Prior[&]**	**Time[#]**
1	Interoperability of NEMS with BEMS and with local generation and storage systems.	2,14	2,08
2	Energy trading & brokerage protocols between buildings and local energy sources at neighbourhood/district level.	2,00	2,08
3	*Other:* None		
	Average	**2,07**	**2,08**
Relevant standardisation bodies	IEC OPC UA		

[&]Priority: 1=Low, 2=Medium, 3=High [#]Time: 1=Short, 2=Medium, 3=Long term

Average scoring does not support any specific conclusions.

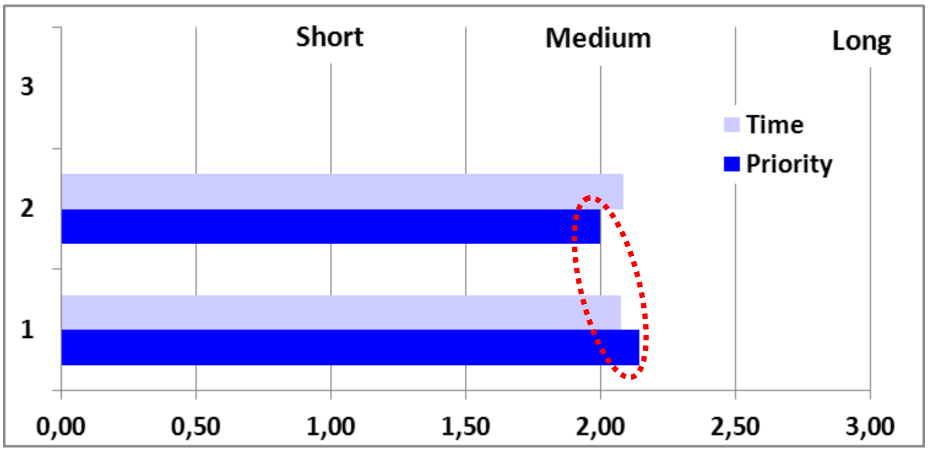

Figure: NEMS – Neighbourhood Energy Management Systems

1.4 Grids (usage stage)		**Prior**&	**Time**#
1	Interoperability of BEMS & NEMS with smart metering infrastructures and energy grids (availability of necessary data for holistic optimisation at building & neighbourhood & grid levels).	2,21	1,69
2	Energy trading & brokerage protocols between buildings/ neighbourhoods/ districts and energy grids.	2,00	2,00
3	*Other:* None		
	Average	**2,11**	**1,85**
Relevant standardisation bodies	IEC OPC UA		

&Priority: 1=Low, 2=Medium, 3=High #Time: 1=Short, 2=Medium, 3=Long term

Average scoring does not support any specific conclusions.

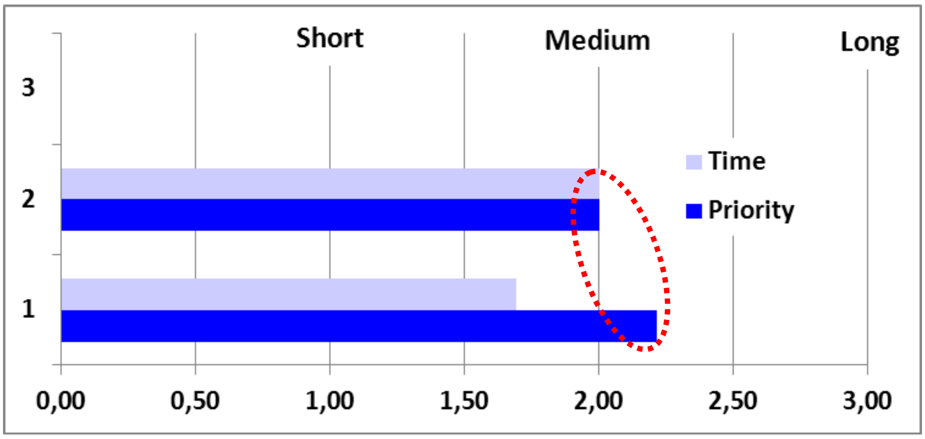

Figure: Grids

2. SPECIFICATION & DESIGN

2.1	**Design**	**Prior[&]**	**Time[#]**
1	Requirement engineering.	**2,33**	**1,30**
2	Concept design.	1,90	1,67
3	Detailed design, CAD, component/solution libraries.	2,10	1,44
4	Configuration management, mass-customisation.	1,89	2,11
5	Visualisation of design solutions.	1,78	1,67
6	*Other:* None		
	Average	**2,00**	**1,64**
Relevant standardisation bodies			

[&]Priority: 1=Low, 2=Medium, 3=High [#]Time: 1=Short, 2=Medium, 3=Long term

This subcategory as a whole has the second shortest expected time to results. The topic ”requirement engineering” has the highest priority and also the shortest expected time to results. This may indicate urgency of the topic.

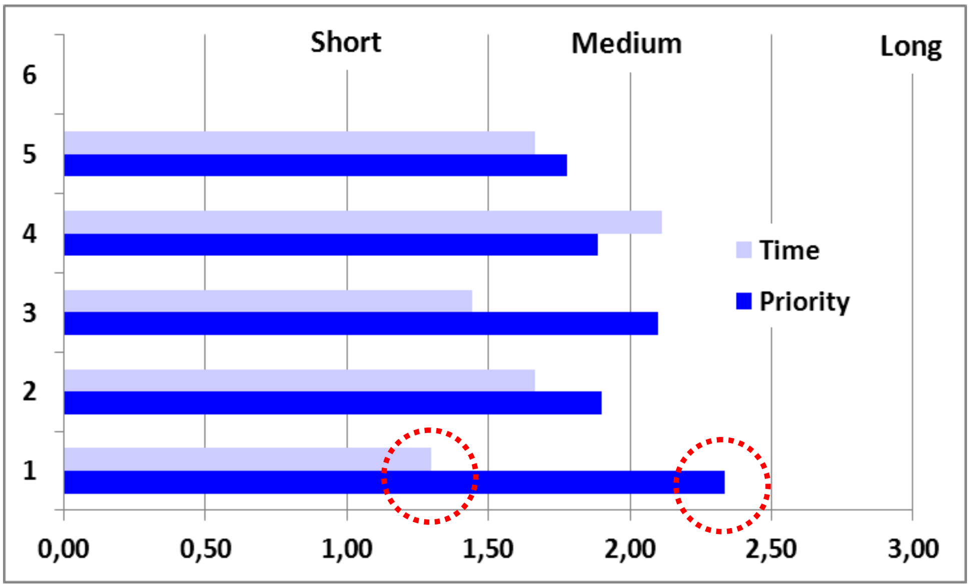

Figure: Design

2.2	**Modelling**	**Prior[&]**	**Time[#]**
1	Modelling components, systems, buildings, districts.	2,42	1,60
2	Modelling & understanding ICT impacts on energy efficiency.	2,20	**1,56**
3	Model/BIM-based design tools	2,30	2,11
4	Semantic mapping, co-use of different semantics.	**2,58**	2,09
5	*Other:* None		
	Average	**2,38**	**1,84**
Relevant standardisation bodies			

[&]Priority: 1=Low, 2=Medium, 3=High [#]Time: 1=Short, 2=Medium, 3=Long term

Modelling has the highest priority of all subcategories in this survey. Topic “semantic mapping” has the highest priority of all topics. Another interesting item in this area is that topic “ICT impacts” has relatively high priority and short time to expected results. This probably reflects the urgency of the topic because very little has been done so far.

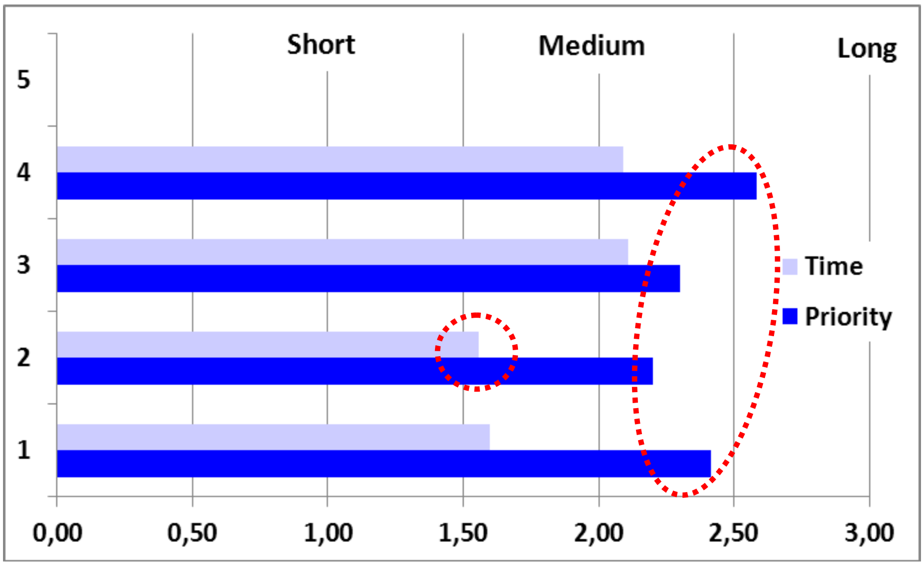

Figure: Modelling

2.3	Performance specification & estimation		Prior[&]	Time[#]
1	Performance metrics & criteria.		2,09	1,91
2	Performance specification tools.		1,91	1,91
3	Performance estimation methods and tools:	- Simulation.	**2,20**	1,60
4		- Life cycle cost analysis.	**2,40**	1,90
5		- Life cycle impact assessment.	**2,50**	1,70
6	*Other:* None			
		Average	**2,22**	**1,80**
Relevant standardisation bodies				

[&]Priority: 1=Low, 2=Medium, 3=High [#]Time: 1=Short, 2=Medium, 3=Long term

This subcategory has the third highest priority of all in this survey. The topic "life cycle impact assessment" has the second highest priority of all. Results from all topics are expected earlier than medium term. This may reflect urgency and/or the fact that these topics are already on the research agenda.

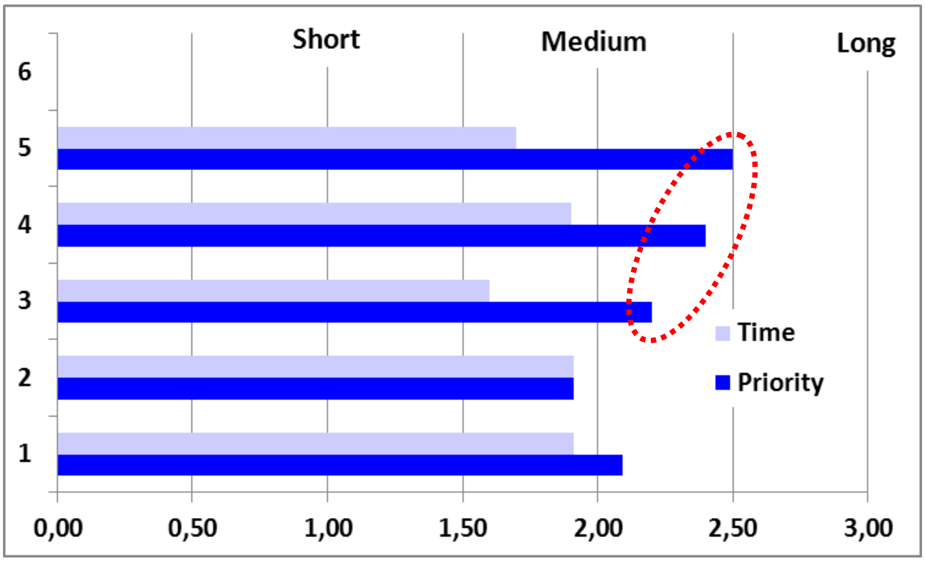

Figure: Performance specification & estimation

3. CONSTRUCTION

3.1	Contracting	Prior[&]	Time[#]
1	Contract & supply network management.	2,00	1,71
2	Management of performance based contracts.	1,83	2,00
3	*Other:* None		
	Average	**1,92**	**1,86**
Relevant standardisation bodies			

[&]Priority: 1=Low, 2=Medium, 3=High [#]Time: 1=Short, 2=Medium, 3=Long term

The feedback indicates need for incremental development.

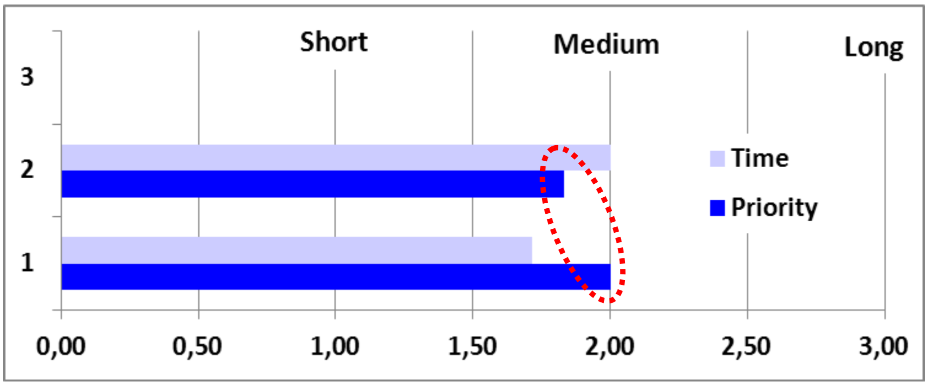

Figure: Contracting

3.2	Production management	Prior[&]	Time[#]
1	Material/product/component/system specification, selection & procurement.	1,71	1,50
2	Product tagging & tracking (e.g. RFID)	1,71	1,43
3	Site-bound logistics.	1,71	1,71
4	On/off-site production strategy and management.	2,00	1,86
5	Mobile data access, guidance, decision support etc. "in the field".	1,86	2,29
6	*Other:* None		
	Average	**1,80**	**1,76**
Relevant standardisation bodies			

[&]Priority: 1=Low, 2=Medium, 3=High [#]Time: 1=Short, 2=Medium, 3=Long term

This subcategory is generally seen to have less than medium priority and shorter than medium time to results. This indicates need for incremental development.

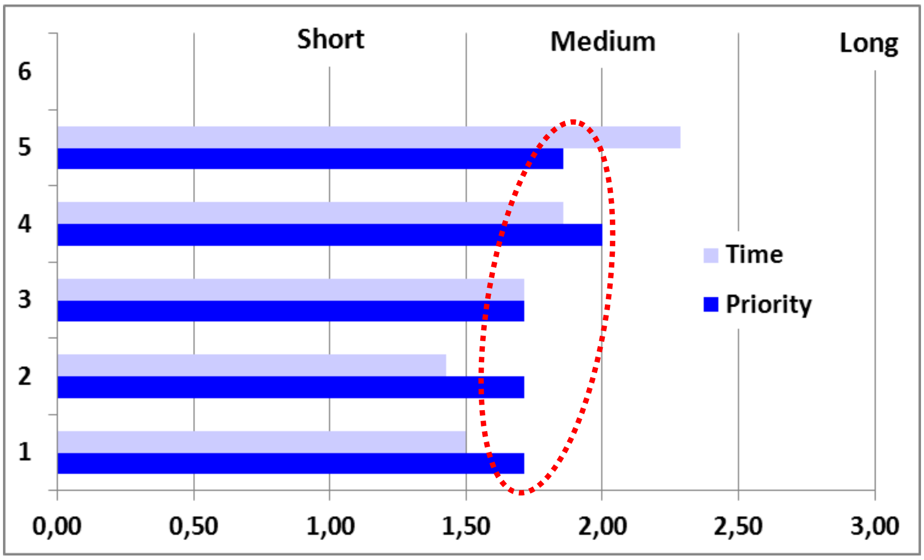

Figure: Production management

4. Automation & Operational Decision Support

4.1	**Automation & control**	**Prior&**	**Time#**
1	System concepts.	1,82	1,73
2	BEMS - Building energy management systems.	1,90	1,40
3	Software & algorithms.	2,10	2,00
4	Instrumentation, sensors, actuators, smart meters, smart appliances.	**1,55**	1,60
5	Intelligent HVAC, lighting, microgeneration & storage.	1,91	1,80
6	Predictive / learning control. Pattern recognition.	1,82	2,20
7	Operational decision support.	2,18	1,91
8	*Other:* Simulation assisted automation testing	2,00	1,00
	Average	**1,91**	**1,70**
Relevant standardisation bodies			

&Priority: 1=Low, 2=Medium, 3=High #Time: 1=Short, 2=Medium, 3=Long term

This subcategory has the 3rd lowest priority of all. Topic “instrumentation” has the 2nd lowest priority of all. The feedback indicates need for incremental development.

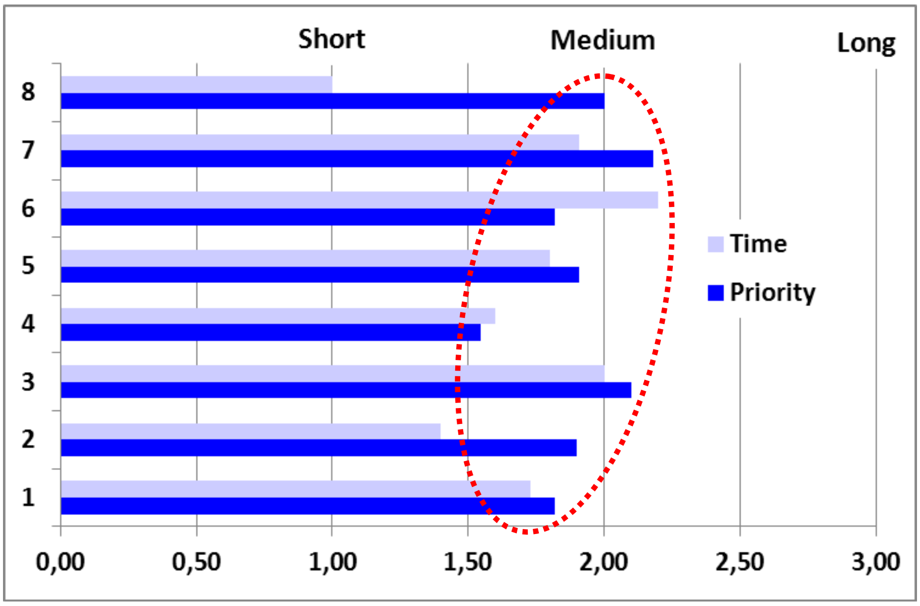

Figure: Automation & control

4.2	Infrastructure for operations communications	Prior[&]	Time[#]
1	Hardware, embedded intelligent devices, smart appliances.	1,90	1,80
2	Secure wired / wireless / optical networks.	1,82	2,10
3	Integration & service platforms, middleware, gateways.	2,20	1,80
4	*Other:* None		
	Average	**1,97**	**1,90**
Relevant standardisation bodies			

[&]Priority: 1=Low, 2=Medium, 3=High [#]Time: 1=Short, 2=Medium, 3=Long term

The feedback indicates need for incremental development.

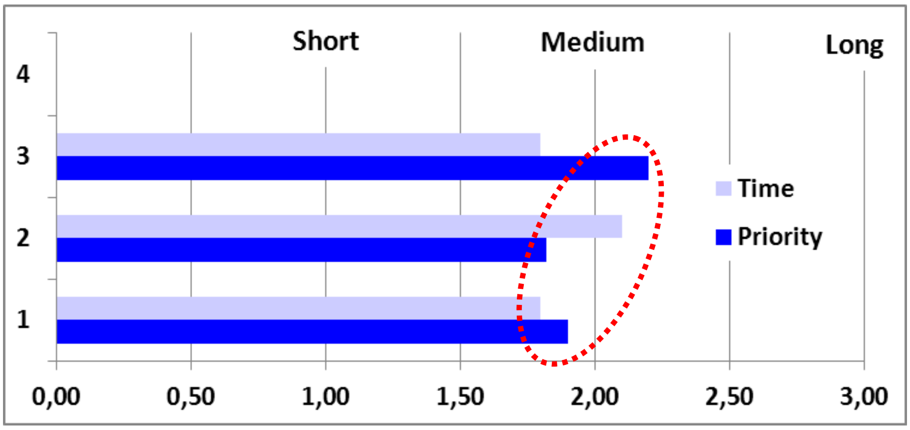

Figure: Infrastructure for operations communications

4.3	Monitoring	Prior[&]	Time[#]
1	Diagnostics, performance analysis, evaluation & conformance validation.	2,00	1,20
2	Commissioning, energy audits, labelling.	2,00	1,60
3	Operational decision support.	2,10	1,80
4	*Other:* None		
	Average	**2,03**	**1,53**
Relevant standardisation bodies			

[&]Priority: 1=Low, 2=Medium, 3=High [#]Time: 1=Short, 2=Medium, 3=Long term

The feedback indicates need for incremental development.

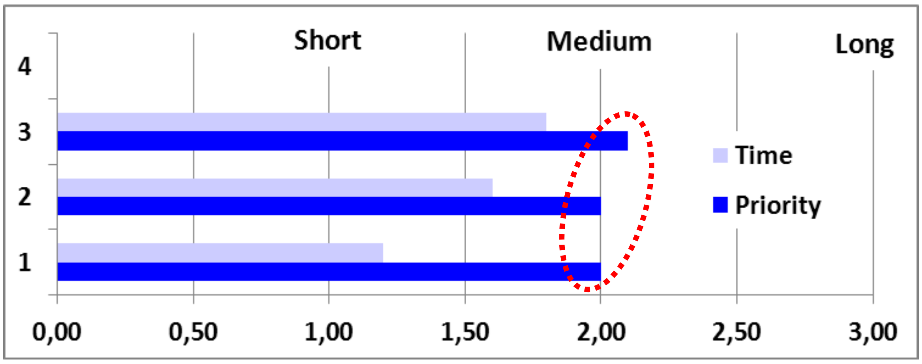

Figure: Monitoring

4.4	User awareness	Prior[&]	Time[#]
1	Human factors Engineering Modelling user behaviour.	2,00	1,82
2	User centered, situation based data visualisation.	2,09	2,00
3	Support for behavioural change, social pressure.	1,90	2,00
4	*Other:* None		
	Average	**2,00**	**1,94**
Relevant standardisation bodies			

[&]Priority: 1=Low, 2=Medium, 3=High [#]Time: 1=Short, 2=Medium, 3=Long term

The feedback suggests medium priority research in medium term.

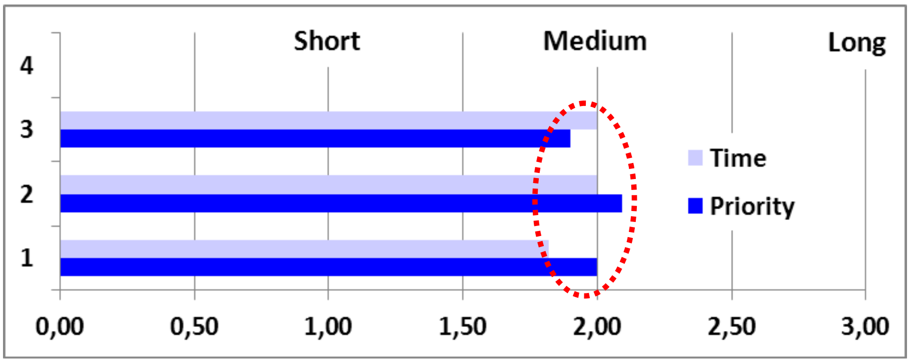

Figure: User awareness

5. Resource & process management

5.1	Process integration	Prior[&]	Time[#]
1	Business and process models.	2,00	1,70
2	Inter-enterprise coordination, collaboration & communication.	2,10	1,80
3	Distributed systems.	2,36	2,00
4	*Other:* None		
	Average	**2,15**	**1,83**
Relevant standardisation bodies			

The feedback suggests medium priority research in medium term.

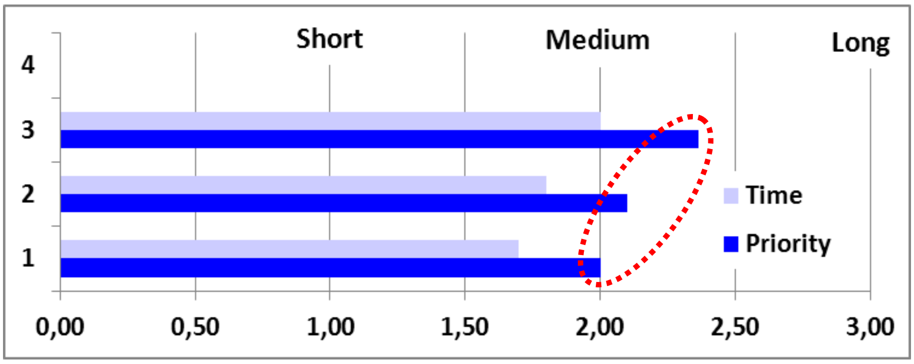

Figure: Process integration

5.2	**Knowledge sharing**	**Prior[&]**	**Time[#]**
1	Knowledge capture, formalisation and consolidation.	2,18	2,10
2	Knowledge repositories, data mining, semantic search, long-term archival & recovery.	**2,42**	1,90
3	Knowledge analytics of energy consumption & optimisation, pattern identification etc.	2,23	2,09
4	*Other:* None		
	Average	**2,28**	**2,03**
Relevant standardisation bodies			

This subcategory "knowledge sharing" has the second highest priority in this survey. The topic "knowledge repositories" has also the second highest priority of all. Overall the feedback suggests medium priority research in medium term.

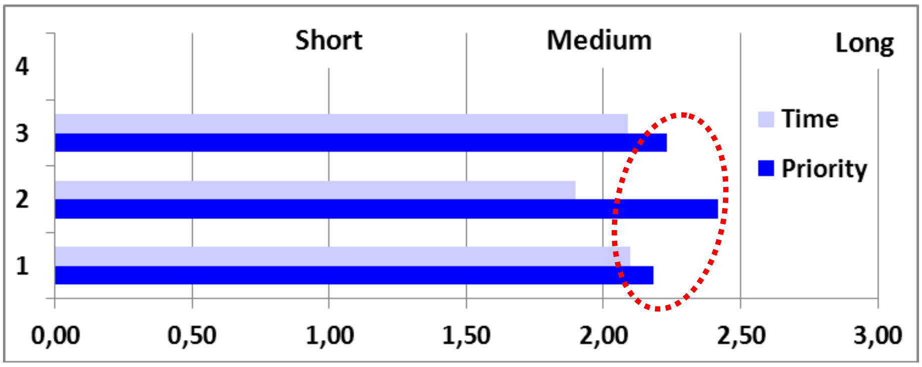

Figure: Knowledge sharing

5.3	**Whole life cycle management**	**Prior[&]**	**Time[#]**
1	Modelling & simulation e.g. "what-if" scenario planning & continuous improvement.	2,17	2,00
2	*Other:* None		
	Average	**2,17**	**2,00**
Relevant standardisation bodies			

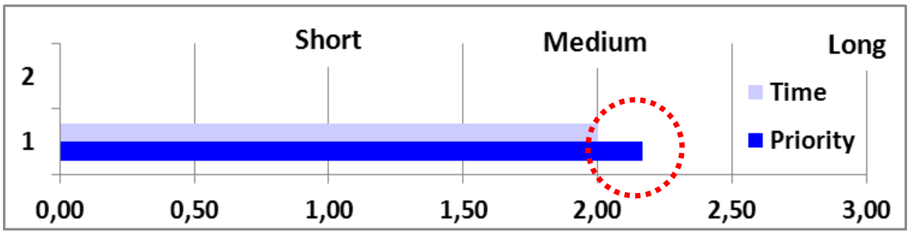

Figure: Whole life cycle management

6. Energy trade & trans-actional management

6.1	**District energy management beyond buildings**	**Prior[&]**	**Time[#]**
1	District energy management systems.	2,10	2,50
2	ICT architectures and infrastructures for districts.	2,20	2,10
3	Management of local generation, distribution and storage.	2,10	2,10
4	Energy trading & brokerage, prosumer forecasting, resource tracking, consumption/price negotiation.	2,11	2,11
5	*Other:* None		
	Average	**2,13**	**2,20**
Relevant standardisation bodies			

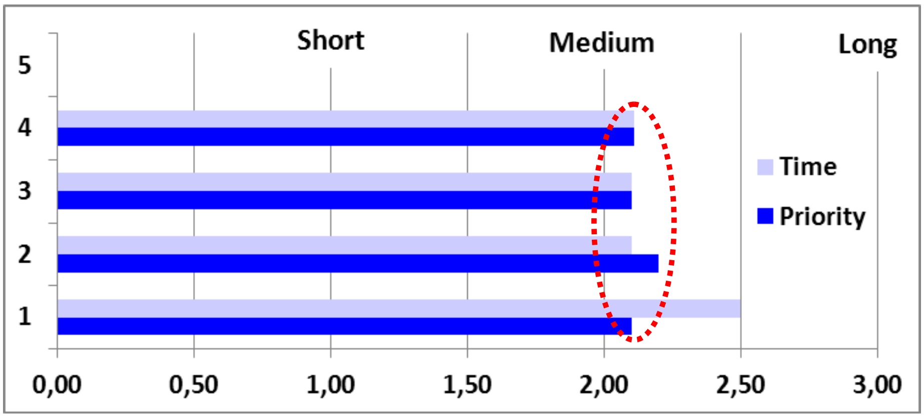

Figure: District energy management beyond buildings

6.2	**Smart grids and the built environment**	**Prior[&]**	**Time[#]**
1	Smart metering.	1,50	1,90
2	Balancing between users' need (e.g. comfort) and supply side constraints (demand control).	2,00	2,10
3	*Other:* None		
	Average	**1,75**	**2,00**
Relevant standardisation bodies			

The topic "smart metering" has the lowest priority of all. Consequently this subcategory on ”smart grids" also has the lowest priority. Probably the respondents regarded smart metering to be out of scope. The other topic "balancing" has medium priority.

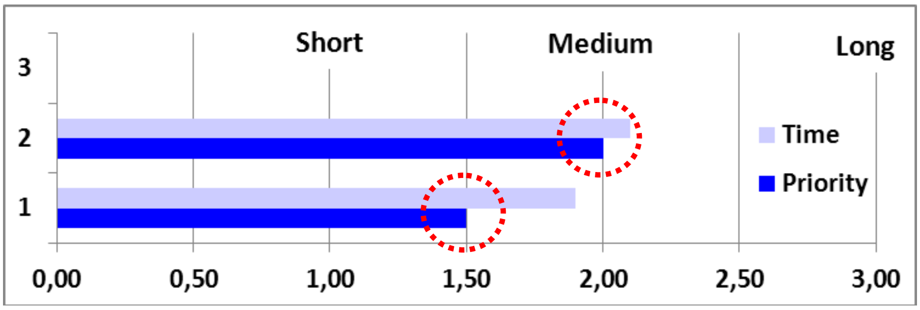

Figure: Smart grids and the built environment

7. System Integration

7.1	System integration	Prior[&]	Time[#]
1	Plug & play connections/interfaces.	1,87	1,67
2	Integration platforms, gateways, middleware.	**2,29**	1,69
3	Service oriented architectures, web services, cloud based services, event driven architectures.	**2,36**	1,69
4	Integration of BIM to real time operational systems.	**2,40**	2,08
5	Integration of external monitoring and services with building operation & management.	2,00	1,92
6	*Other:* None		
	Average	**2,18**	**1,81**
Relevant standardisation bodies			

Three topics in this subcategory have higher than average priority: “BIM integration”, ”architectures” and “platforms”.

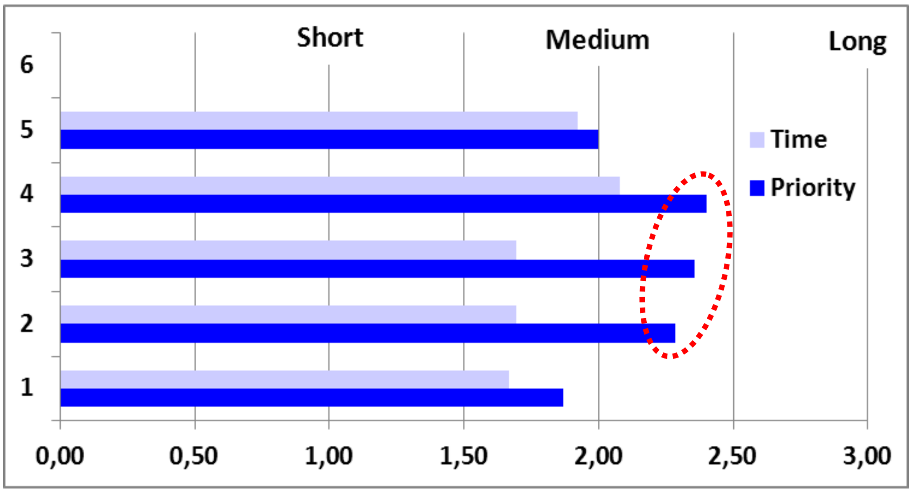

Figure: System integration

Free Comments

8.1	Free Comments
	The research needs common shared public platforms (Sofware and Data) to demonstrate novel methods. Existing software can be used.
	Integration of information. IFC/SAP <=> Ontology/Semantic Web <=> CityGML/XML

Feedback to the questionnaire embedded in the draft short version of D3.2, 29 February 2012

Appendix 6 to: D3.2 Multi-disciplinary Strategic Research Agenda for ICT-enabled Energy Efficiency

Author: Matti Hannus VTT
Antonio Feraco Innova

Contributions from the following experts are acknowledged:

- Hamid Asgari, Thales Research and Technology (UK) Limited
- Ken Brown, University College Cork
- Siobhan Clarke, Trinity College Dublin
- Edward Curry, Digital Enterprise Research Institute
- Marta Fernandez, Arup
- Vernon Fox, Mainstream Renewable Power
- Henning Fuhrmann, Innovation Manager, Siemens Building Technologies Division
- John Hall, Continental Automated Buildings Association (CABA)
- Eilif Hjelseth, Norwegian University of Life Sciences (UMB)
- Deborah Pullen, MBEKTN
- Frens Jan Rumph, TNO
- Odilo SCHOCH, BUAS Berne University of Applied Sciences
- Chris White, EPSRC

Disclaimer: The feedback represents personal viewpoints.

QUESTIONNAIRE

In January-February a short version of the draft D3.2 was prepared. It included Introduction and Instruction to readers, the 6 roadmap tables together with a textual narrative of each one and a questionnaire with the below items:

The REVISTE project aims to recommend the topics on the right for further research, development and standardisation.

Question 1:
Are any important research topics missing? If 'yes' please specify:

Question 2:
What proposed research topics are most relevant to your own organisational perspective?
Please tick on the right. ⇨

Question 3:
Are the suggested timelines discussed appropriate?
If 'no' please elaborate:

Question 4:
Any other comments?
Please describe below.

1. Specification & design ICTs	
• Design conceptualisation	
• Detailed design	
• Modelling	
• Performance estimation	
• Simulation	
• Specification & product/component selection	
2. Materialisation ICTs	
• Decision support & visualisation	
• Planning & management	
• Real-time communication	
3. Automation and Operational Decision Support ICTs	
• Automated monitoring & control	
• Operational decision support & visualisation	
• Secure wired / wireless sensor networks & quality of service	
4. Resource and Process Management ICTs	
• Interenterprise coordination	
• Business process integration	
• Information/knowledge management & analytics	
5. Technical & sematic interoperability ICTs	
• Integration technologies & infrastructures	
• Interoperability & standards	
6. Trading and transactional management ICTs	
• Regional energy management	
• District energy management	
• Facility energy management	
• Personal energy management	

Respondent:	Sector:	Energy		Other, plse specify:
Organisation		Manufng		
Person		Buildings		Organisation type:
Email		Lighting		Industry / private
Date		ICT		Research / public

SUMMARY OF FEEDBACK

The feedback is summarised in the tables below.

Most relevant research topics to the respondents' organisation	Number
1. Specification & design ICTs	
1.1 Design conceptualisation	**6**
1.2 Detailed design	**5**
1.3 Modelling	**7**
1.4 Performance estimation	**9**
1.5 Simulation	**7**
1.6 Specification & product/component selection	**5**
2. Materialisation ICTs	
2.1 Decision support & visualisation	**6**
2.2 Planning & management	**5**
2.3 Real-time communication	**5**
3. Automation and Operational Decision Support ICTs	
3.1 Automated monitoring & control	**9**
3.2 Operational decision support & visualisation	**8**
3.3 Secure wired / wireless sensor networks & quality of service	**8**
4. 4. Resource and Process Management ICTs	
4.1 Inter-enterprise coordination	**5**
4.2 Business process integration	**7**
4.3 Information/knowledge management & analytics	**7**
5. Technical & sematic interoperability ICTs	
5.1 Integration technologies & infrastructures	**7**
5.2 Interoperability & standards	**9**
6. Trading and transactional management ICTs	
6.1 Regional energy management	**6**
6.2 District energy management	**10**
6.3 Facility energy management	**9**
6.4 Personal energy management	**8**

Are any important research topics missing? - Answers:

- The outcome can e.g. be used as: Foundation for standardisation, CEN, national Foundation for BREEAM assessment Integration with buildingSMART.
- Future Internet initiatives; Internet of Things; Ubiquitous computing; Cloud-based computing and applications; Smart objects and their applications and demands especially in mobile industry.
- The Future Internet and Internet of Things research topics may be relevant for the underlying implementation of the research visions. Also Citizen-sensing may be very relevant.
- Cross-boundary Geopolitical Challenges: While I believe that the cross-geographic boundary challenge of bringing these initiatives to life is covered adequately in the

research topics. The concept of Pan-European collaboration should be covered in a layer above interoperability and standards possibly.

- There needs to be research on the role of ICT in interacting with the end-user of technology - the home occupier, the building occupant, etc.. The behaviour of the end-user is critical for energy efficiency.
- Tools for performance based design. Tools for performance based maintenance. Energy management tools for multi- estate owners.
- Comments are predominantly about the buildings area but may apply more broadly. There appeared to be little mention of the wider "social web" and the influence this could have, particularly within 6, trading. Additionally the report focuses on supply and not on the likely heterogeneous supply and micro generation outcome. I imagine that both will require different management strategies. Within 1, design, there is little on collaborative design with users/clients being involved in the design of the energy efficiency. This would be reflected most through more detailed visualisation (BIM) and involving users/clients in the design phase.
- Please consider those cultural elements that network with ICT such as "life-style" & "tradition"Plus "unifying semantics" or "parametric description". As well decision support frameworks -a theme we work on.

Are the suggested timelines discussed appropriate? - Answers:

- Some of the timelines I agree with however some technological advances may impact the validity and indeed render these as too long (cloud advances for example)
- Timelines look reasonable. As a funder of research within the medium to long term all looked ok.

Any other comments? - Answers:

- The marks in right side list are areas where I can contribute. Interest from the industry is expected to be much broader.
- Security & cyber security; Intelligent Transport Systems and their impact; Pay attention to standardisation activities of: IRTF, IETF, IEEE Smart Grid standardisation (e.g., P2030), OMA, etc.
- Very nice overview of future research directions. I would also encourage the inclusion of more citizen-centric information sources within the research directions.
- Overall - having recently re-engaged on the initiative I see significant progress has been made by the group and the material produced is of a high level of quality.
- This is an impressive summary.
- I was unclear about the term energy efficiency. Does this relate to electricity only, or include other forms such as oil and gas etc., which are commonly used in buildings and manufacturing. Also, should the transport sector be included?
- There is some mention of the interoperability of the systems with wider infrastructure and I am aware that the scope is limited but there does need to be linkages from buildings/lighting to wider infrastructure such as transport, waste, water and utilities generally. Additionally EPSRC are keen on pushing the area of infrastrastructure to take a more holistic view encompassing resource efficiency, resilience, sustainability within a whole systems view. There is a recent EPSRC project on feasibility of a single utility providing all the water/electricity/gas etc. for a dwelling called Land of The Muscos, an

interesting take on the future of the utilities area. The feedback given should be considered to be a personal synthesis of issues that I have identified as missing or requiring more detailed analysis and not as formal EPSRC corporate feedback. Of the topics that are featured EPSRC, from a building and manufacturing point of view, would most associate with 1, 2 and 3 but would fund or have active projects across the whole range.

- We are happy about your approach to consider major parts of the life-cycle in our built environment and across scales. Very good.
- The topic 'Interoperability & standards' is described as being on a higher level than the other 20 topics. We do not see a direct need for a research priority on 'Interoperability & standards' specifically within the context of energy efficiency. This does not imply that interoperability of systems or standards are not important in general. However, within the context of ICTs for energy efficiency, this is a 'quality' of ICTs developed which has to be addressed per ICT and not as a research area as such. The research into interoperability and standards - interoperability, standards and their dynamics' as object of study - has a context much broader than just energy efficiency. In the description of the 'Interoperability and standards' topic this is already apparent in that the level of concreteness of this description is much lower in comparison to the other research topics.

<table>
<tr><th colspan="5">Profiles of respondents</th><th>Persons</th></tr>
<tr><td colspan="5">Energy</td><td>1</td></tr>
<tr><td colspan="5">Manufacturing</td><td>0</td></tr>
<tr><td colspan="5">Buildings</td><td>3</td></tr>
<tr><td colspan="5">Lighting</td><td>0</td></tr>
<tr><td colspan="5">ICT</td><td>3</td></tr>
<tr><td>Other:</td><td colspan="4">University (2), Industry (1), Engineering (1),
Research (1), Process modelling (1)</td><td>6</td></tr>
<tr><td>Industry / private</td><td>6</td><td>Research / public</td><td>7</td><td>Total</td><td>13</td></tr>
</table>

Prioritization of Research & Development Topics

1. What is your first name?

	Response Count
	14
answered question	14
skipped question	2

2. What is your last name?

	Response Count
	14
answered question	14
skipped question	2

3. Please indicate your Organization's Name

	Response Count
	14
answered question	14
skipped question	2

4. Please insert your email address

	Response Count
	13
answered question	13
skipped question	3

5. Which stakeholder class do you represent?

	Response Percent	Response Count
Building Client / Owner / Developer / housing orgnisation	7.1%	1
Designer (AEC)	0.0%	0
Project Manager (consultant)	21.4%	3
Construction Company / Subcontractor (buildings, building services systems)	14.3%	2
Supplier (material / product)	0.0%	0
Manufacturer (material / component, system)	0.0%	0
Building automation company (manufacturer / constructor / system integrator)	0.0%	0
Building Operator / facility manager	0.0%	0
Building Occupant	0.0%	0
Public authority (for Buildings)	0.0%	0
ICT provider / developer	7.1%	1
Energy Utility	7.1%	1

Research Institute / University / Research Funding Organisation	**50.0%**	**7**
Financial Organisation / Business Developer	0.0%	0
Other (please specify)	7.1%	1
	answered question	**14**
	skipped question	**2**

6. Your main area(s) of expertise

	Response Percent	Response Count
Building Design	7.1%	1
Construction / Renovation	7.1%	1
Building Materials / Components	0.0%	0
Building use / operation / monitoring / maintenance	21.4%	3
Building automation / Electrical Building Services	7.1%	1
Energy Management at building / district level	14.3%	2
ICT Software / services	21.4%	3
R&D	**64.3%**	**9**
Other (please specify)	14.3%	2
	answered question	**14**
	skipped question	**2**

7. Please indicate your level of expertise in Data Models, Interoperability & Standards

	Response Percent	Response Count
Low	9.1%	1
Medium	**81.8%**	**9**
High	9.1%	1
	answered question	**11**
	skipped question	**5**

8. BIM – Building Information models (design stage)

Priority

	low	Medium	H
Enhancement of BIM with energy-related data (coverage of energy related information needed & provided by various disciplines).	22.2% (2)	22.2% (2)	**55.6**
Interoperability between BIM-based design, analysis, and planning tools (availability of necessary data from BIM for various application tools).	0.0% (0)	**60.0% (3)**	40.0
Interoperability between BIM and assessment & simulation tools (availability of necessary data from BIM for static & dynamic energy performance estimation).	0.0% (0)	**60.0% (3)**	40.0
Interoperability of reference data (e.g. catalogues of materials, products, best practices) with BIM.	25.0% (1)	**50.0% (2)**	25.0
Harmonisation of building regulations with BIM (availability of necessary data from BIM for assessing compliance).	**40.0% (2)**	**40.0% (2)**	20.0
Harmonisation of design and construction standards with BIM and related process definitions.	**60.0% (3)**	0.0% (0)	40.0

Interoperability of BIM with collaborative working environments (metadata, semantic mapping).	40.0% (2)	0.0% (0)	**60.0**
Interoperability between BIM and visualisation & decision support (availability of necessary data from BIM).	**40.0% (2)**	20.0% (1)	**40.0**
Interoperability of BIM and GIS (urban plans, infrastructure networks, local energy-related services etc.)	20.0% (1)	**40.0% (2)**	**40.0**

Time

	Short	**Medium**	**L**
Enhancement of BIM with energy-related data (coverage of energy related information needed & provided by various disciplines).	28.6% (2)	**71.4% (5)**	0.0
Interoperability between BIM-based design, analysis, and planning tools (availability of necessary data from BIM for various application tools).	40.0% (2)	**60.0% (3)**	0.0
Interoperability between BIM and assessment & simulation tools (availability of necessary data from BIM for static & dynamic energy performance estimation).	20.0% (1)	**60.0% (3)**	20.0

Interoperability of reference data (e.g. catalogues of materials, products, best practices) with BIM.	25.0% (1)	**75.0% (3)**	0.0
Harmonisation of building regulations with BIM (availability of necessary data from BIM for assessing compliance).	20.0% (1)	**40.0% (2)**	**40.0**
Harmonisation of design and construction standards with BIM and related process definitions.	**40.0% (2)**	20.0% (1)	**40.0**
Interoperability of BIM with collaborative working environments (metadata, semantic mapping).	**60.0% (3)**	20.0% (1)	20.0
Interoperability between BIM and visualisation & decision support (availability of necessary data from BIM).	**40.0% (2)**	**40.0% (2)**	20.0
Interoperability of BIM and GIS (urban plans, infrastructure networks, local energy-related services etc.)	**60.0% (3)**	20.0% (1)	20.0

Related Standard body

	ETSI	ITU	BuildingSMART	CEN	ISO	OASIS	OMG	SBA	W3C	IEC
Enhancement of BIM with energy-related data (coverage of energy related information needed & provided by various disciplines).	20.0% (1)	0.0% (0)	**40.0% (2)**	0.0% (0)	20.0% (1)	0.0% (0)	0.0% (0)	20.0% (1)	0.0% (0)	0.0% (0)

Interoperability between BIM-based design, analysis, and planning tools (availability of necessary data from BIM for various application tools).	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	**75.0% (3)**	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	25.0% (1)
Interoperability between BIM and assessment & simulation tools (availability of necessary data from BIM for static & dynamic energy performance estimation).	0.0% (0)	0.0% (0)	**25.0% (1)**	**25.0% (1)**	**25.0% (1)**	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	**25.0% (1)**
Interoperability of reference data (e.g. catalogues of materials, products, best practices) with BIM.	**33.3% (1)**	0.0% (0)	**33.3% (1)**	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	**33.3% (1)**
Harmonisation of building regulations with BIM (availability of necessary data from BIM for assessing compliance).	0.0% (0)	25.0% (1)	25.0% (1)	0.0% (0)	**50.0% (2)**	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)
Harmonisation of design and construction standards with BIM and related process definitions.	0.0% (0)	0.0% (0)	**33.3% (1)**	0.0% (0)	**33.3% (1)**	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	**33.3% (1)**
Interoperability of BIM with collaborative working environments (metadata, semantic mapping).	0.0% (0)	0.0% (0)	**50.0% (2)**	0.0% (0)	25.0% (1)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	25.0% (1)
Interoperability between BIM and visualisation & decision support (availability of necessary data from BIM).	0.0% (0)	0.0% (0)	**66.7% (2)**	33.3% (1)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)
Interoperability of BIM and GIS										

(urban plans, infrastructure networks, local energy-related services etc.)	0.0% (0)	0.0% (0)	**50.0% (2)**	0.0% (0)	**50.0% (2)**	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)

Other (please specify with priority, time

9. BEMS – Building Energy Management Systems (usage stage)

Priority

	Low	Medium	High	Response Count
Energy performance metrics supported by ICT (definition of indicators based on available data from BIM & BEMS).	40.0% (2)	0.0% (0)	**60.0% (3)**	5
Interoperability between BEMS and BIM (availability of necessary data from BIM to support operation). Harmonisation of BIM and BEMS data models regarding common objects (e.g. spaces).	20.0% (1)	**60.0% (3)**	20.0% (1)	5
Interoperability of real time operational systems with energy producing and energy consuming equipment.	0.0% (0)	12.5% (1)	**87.5% (7)**	8

Time

	Short	Medium	Long	Response Count
Energy performance metrics supported by ICT (definition of indicators based on available data from BIM & BEMS).	**80.0% (4)**	20.0% (1)	0.0% (0)	5
Interoperability between BEMS and BIM (availability of necessary data				

from BIM to support operation). Harmonisation of BIM and BEMS data models regarding common objects (e.g. spaces).	40.0% (2)	**60.0% (3)**	0.0% (0)	5
Interoperability of real time operational systems with energy producing and energy consuming equipment.	**57.1% (4)**	42.9% (3)	0.0% (0)	7

Related Standard body

	ETSI	ITU	BuildingSmart	IEC	CENELEC	OTHER	Response Count
Energy performance metrics supported by ICT (definition of indicators based on available data from BIM & BEMS).	**33.3% (1)**	**33.3% (1)**	**33.3% (1)**	0.0% (0)	0.0% (0)	0.0% (0)	3
Interoperability between BEMS and BIM (availability of necessary data from BIM to support operation). Harmonisation of BIM and BEMS data models regarding common objects (e.g. spaces).	0.0% (0)	0.0% (0)	**66.7% (2)**	33.3% (1)	0.0% (0)	0.0% (0)	3
Interoperability of real time operational systems with energy producing and energy consuming equipment.	0.0% (0)	**33.3% (2)**	**33.3% (2)**	16.7% (1)	16.7% (1)	0.0% (0)	6

Other (please specify with priority, time and Related Standard Body)	0
answered question	**8**

	skipped question	8

10. NEMS – Neighborhood Energy Management Systems (usage stage)

Priority

	Low	Medium	High	Response Count
Interoperability of NEMS with BEMS and with local generation and storage systems.	12.5% (1)	25.0% (2)	**62.5% (5)**	8
Energy trading & brokerage protocols between buildings and local energy sources at neighbourhood/district level.	28.6% (2)	**42.9% (3)**	28.6% (2)	7

Time

	Short	Medium	Long	Response Count
Interoperability of NEMS with BEMS and with local generation and storage systems.	42.9% (3)	**57.1% (4)**	0.0% (0)	7
Energy trading & brokerage protocols between buildings and local energy sources at neighbourhood/district level.	33.3% (2)	**66.7% (4)**	0.0% (0)	6

Related Standard body

	ETSI	ITU	BuildingSmart	IEC	CENELEC	OTHER	Response Count
Interoperability of NEMS with BEMS and with local generation and storage systems.	0.0% (0)	**40.0% (2)**	20.0% (1)	20.0% (1)	20.0% (1)	0.0% (0)	5
Energy trading & brokerage protocols between buildings and local energy sources at neighbourhood/district level.	**66.7% (2)**	33.3% (1)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	3
Other (please specify with priority, time and Related Standard Body)							0
answered question							**8**
skipped question							**8**

11. Grids (usage stage)

Priority

	Low	Medium	High	Response Count
Interoperability of BEMS & NEMS with smart metering infra¬struc-tu¬res and energy grids (availability of necessary data for holistic optimisation at building & neighbourhood & grid levels).	12.5% (1)	0.0% (0)	**87.5% (7)**	8
Energy trading & brokerage protocols between buildings/ neighbourhoods/districts and energy grids.	28.6% (2)	**57.1% (4)**	14.3% (1)	7

Time

	Short	Medium	Long	Response Count
Interoperability of BEMS & NEMS with smart metering infra¬struc-tu¬res and energy grids (availability of necessary data for holistic optimisation at building & neighbourhood & grid levels).	**62.5% (5)**	37.5% (3)	0.0% (0)	8
Energy trading & brokerage protocols between buildings/ neighbourhoods/districts and energy grids.	14.3% (1)	**57.1% (4)**	28.6% (2)	7

Related Standard body

	ETSI	ITU	Building Smart	IEC	CENELEC	OTHER	Response Count
Interoperability of BEMS & NEMS with smart metering infra¬struc-tu¬res and energy grids (availability of necessary data for holistic optimisation at building & neighbourhood & grid levels).	**25.0% (1)**	**25.0% (1)**	**25.0% (1)**	**25.0% (1)**	0.0% (0)	0.0% (0)	4
Energy trading & brokerage protocols between buildings/ neighbourhoods/districts and energy grids.	**50.0% (2)**	25.0% (1)	0.0% (0)	25.0% (1)	0.0% (0)	0.0% (0)	4

Other (please specify with priority, time and Related Standard Body)	0
answered question	**8**
skipped question	**8**

12. Free Comments

	Response Count
	0
answered question	**0**
skipped question	**16**

13. Please indicate your level of expertise in Specification & Design

	Response Percent	Response Count
Low	0.0%	0
Medium	28.6%	2
High	**71.4%**	**5**
	answered question	**7**
	skipped question	**9**

14. Design

Priority

	Low	Medium	High	Response Count
Requirement engineering.	14.3% (1)	14.3% (1)	**71.4% (5)**	7
Concept design.	14.3% (1)	28.6% (2)	**57.1% (4)**	7
Detailed design, CAD, component/solution libraries.	28.6% (2)	**42.9% (3)**	28.6% (2)	7
Configuration management, mass-customisation.	16.7% (1)	**50.0% (3)**	33.3% (2)	6
Visualisation of design solutions.	14.3% (1)	**42.9% (3)**	**42.9% (3)**	7

Time

	Short	Medium	Long	Response Count
Requirement engineering.	**66.7% (4)**	33.3% (2)	0.0% (0)	6
Concept design.	**66.7% (4)**	33.3% (2)	0.0% (0)	6
Detailed design, CAD, component/solution libraries.	16.7% (1)	**66.7% (4)**	16.7% (1)	6
Configuration management, mass-customisation.	20.0% (1)	**60.0% (3)**	20.0% (1)	5
Visualisation of design solutions.	28.6% (2)	**42.9% (3)**	28.6% (2)	7

Other (please specify with priority, time and Related Standard Body)	0
answered question	**7**
skipped question	**9**

15. Modelling

Priority

	Low	Medium	High	Response Count
Modelling components, systems, buildings, districts.	20.0% (1)	0.0% (0)	**80.0% (4)**	5
Modelling & understanding ICT impacts on energy efficiency.	20.0% (1)	20.0% (1)	**60.0% (3)**	5
Model/BIM-based design tools (see table 6 for interoperability , data models, standards, ontologies).	0.0% (0)	40.0% (2)	**60.0% (3)**	5
Semantic mapping, co-use of different semantics.	0.0% (0)	**100.0% (4)**	0.0% (0)	4

Time

	Short	Medium	Long	Response Count
Modelling components, systems, buildings, districts.	40.0% (2)	**60.0% (3)**	0.0% (0)	5

Modelling & understanding ICT impacts on energy efficiency.	40.0% (2)	**60.0% (3)**	0.0% (0)	5
Model/BIM-based design tools (see table 6 for interoperability , data models, standards, ontologies).	20.0% (1)	**80.0% (4)**	0.0% (0)	5
Semantic mapping, co-use of different semantics.	0.0% (0)	**100.0% (4)**	0.0% (0)	4
			Other (please specify with priority, time and Related Standard Body)	0
			answered question	**6**
			skipped question	**10**

16. Performance specification & estimation

Priority

	Low	Medium	High	Response Count
Performance metrics & criteria.	0.0% (0)	0.0% (0)	**100.0% (4)**	4
Performance specification tools.	0.0% (0)	25.0% (1)	**75.0% (3)**	4
Performance estimation methods and tools for simulation	0.0% (0)	**50.0% (2)**	**50.0% (2)**	4
Performance esti¬mation methods and tools for Life cycle cost analysis	0.0% (0)	40.0% (2)	**60.0% (3)**	5
Performance esti¬mation methods and tools for Life ciycle impact assessment	20.0% (1)	**40.0% (2)**	**40.0% (2)**	5

Time

	Short	Medium	Long	Response Count
Performance metrics & criteria.	**100.0% (4)**	0.0% (0)	0.0% (0)	4
Performance specification tools.	25.0% (1)	**75.0% (3)**	0.0% (0)	4
Performance estimation methods and tools for simulation	25.0% (1)	**75.0% (3)**	0.0% (0)	4
Performance esti¬mation methods				

and tools for Life cycle cost analysis	**40.0% (2)**	**40.0% (2)**	20.0% (1)	5
Performance esti¬mation methods and tools for Life ciycle impact assessment	20.0% (1)	**60.0% (3)**	20.0% (1)	5
			Other (please specify with priority, time and Related Standard Body)	0
			answered question	**5**
			skipped question	**11**

17. Please indicate your level of expertise in Construction

		Response Percent	Response Count
Low		**42.9%**	**3**
Medium		**42.9%**	**3**
High		14.3%	1
		answered question	**7**
		skipped question	**9**

18. Contracting

Priority

	Low	Medium	High	Response Count
Contract & supply network management.	**33.3% (1)**	**33.3% (1)**	**33.3% (1)**	3
Management of performance based contracts.	0.0% (0)	33.3% (1)	**66.7% (2)**	3

Time

	Short	Medium	Long	Response Count
Contract & supply network management.	0.0% (0)	**66.7% (2)**	33.3% (1)	3
Management of performance based contracts.	33.3% (1)	**66.7% (2)**	0.0% (0)	3

Other (please specify with priority, time and Related Standard Body)	0
answered question	**3**
skipped question	**13**

19. Production management

Priority

	Low	Medium	High	Response Count
Material/product/component/system specification, selection & procurement.	25.0% (1)	25.0% (1)	**50.0% (2)**	4
Product tagging & tracking (e.g. RFID)	0.0% (0)	**66.7% (2)**	33.3% (1)	3
Site-bound logistics.	0.0% (0)	**66.7% (2)**	33.3% (1)	3
On/off-site production strategy and management.	0.0% (0)	0.0% (0)	**100.0% (3)**	3
Mobile data access, guidance, decision support etc. “in the field”.	0.0% (0)	33.3% (1)	**66.7% (2)**	3

Time

	Short	Medium	Long	Response Count
Material/product/component/system specification, selection & procurement.	**66.7% (2)**	0.0% (0)	33.3% (1)	3
Product tagging & tracking (e.g. RFID)	33.3% (1)	**66.7% (2)**	0.0% (0)	3
Site-bound logistics.	0.0% (0)	**100.0% (3)**	0.0% (0)	3

On/off-site production strategy and management.	**66.7% (2)**	33.3% (1)	0.0% (0)	3
Mobile data access, guidance, decision support etc. “in the field”.	**33.3% (1)**	**33.3% (1)**	**33.3% (1)**	3
			Other (please specify with priority, time and Related Standard Body)	0
			answered question	**4**
			skipped question	**12**

20. Please indicate your level of expertise in Automation & operational decision support

	Response Percent	Response Count
Low	14.3%	1
Medium	0.0%	0
High	**85.7%**	**6**
answered question		**7**
skipped question		**9**

21. Automation & control

Priority

	Low	Medium	High	Response Count
System concepts.	0.0% (0)	**75.0% (3)**	25.0% (1)	4
BEMS - Building energy management systems.	0.0% (0)	0.0% (0)	**100.0% (3)**	3
Software & algorithms.	0.0% (0)	20.0% (1)	**80.0% (4)**	5
Instrumentation, sensors, actuators, smart meters, smart appliances.	0.0% (0)	16.7% (1)	**83.3% (5)**	6
Intelligent HVAC, lighting, microgeneration & storage.	0.0% (0)	40.0% (2)	**60.0% (3)**	5
Predictive / learning control. Pattern recognition.	0.0% (0)	40.0% (2)	**60.0% (3)**	5
Operational decision support.	0.0% (0)	20.0% (1)	**80.0% (4)**	5

Time

	Short	Medium	Long	Response Count
System concepts.	**33.3% (1)**	**33.3% (1)**	**33.3% (1)**	3
BEMS - Building energy management systems.	33.3% (1)	**66.7% (2)**	0.0% (0)	3

Software & algorithms.	25.0% (1)	**50.0% (2)**	25.0% (1)	4
Instrumentation, sensors, actuators, smart meters, smart appliances.	**60.0% (3)**	40.0% (2)	0.0% (0)	5
Intelligent HVAC, lighting, microgeneration & storage.	**50.0% (2)**	25.0% (1)	25.0% (1)	4
Predictive / learning control. Pattern recognition.	25.0% (1)	**50.0% (2)**	25.0% (1)	4
Operational decision support.	25.0% (1)	**50.0% (2)**	25.0% (1)	4

Other (please specify with priority, time and Related Standard Body)	0
answered question	**6**
skipped question	**10**

22. Infrastructure for operations communications

Priority

	Low	Medium	High	Response Count
Hardware, embedded intelligent devices, smart appliances.	0.0% (0)	16.7% (1)	**83.3% (5)**	6
Secure wired/wireless/optical networks.	16.7% (1)	16.7% (1)	**66.7% (4)**	6
Integration & service platforms, middleware, gateways.	0.0% (0)	16.7% (1)	**83.3% (5)**	6

Time

	Short	Medium	Long	Response Count
Hardware, embedded intelligent devices, smart appliances.	33.3% (2)	**66.7% (4)**	0.0% (0)	6
Secure wired/wireless/optical networks.	**80.0% (4)**	0.0% (0)	20.0% (1)	5
Integration & service platforms, middleware, gateways.	40.0% (2)	**60.0% (3)**	0.0% (0)	5

Other (please specify with priority, time and Related Standard Body)	0
answered question	**6**
skipped question	**10**

23. Monitoring

Priority

	Low	Medium	High	Response Count
Diagnostics, performance analysis, evaluation & conformance validation.	0.0% (0)	40.0% (2)	**60.0% (3)**	5
Commissioning, energy audits, labelling.	25.0% (1)	**50.0% (2)**	25.0% (1)	4
Operational decision support.	0.0% (0)	33.3% (1)	**66.7% (2)**	3

Time

	Short	Medium	Long	Response Count
Diagnostics, performance analysis, evaluation & conformance validation.	20.0% (1)	**80.0% (4)**	0.0% (0)	5
Commissioning, energy audits, labelling.	0.0% (0)	**66.7% (2)**	33.3% (1)	3
Operational decision support.	33.3% (1)	**66.7% (2)**	0.0% (0)	3
			Other (please specify with priority, time and Related Standard Body)	0
			answered question	**6**

skipped question	**10**

24. User awareness

Priority

	Low	Medium	High	Response Count
Human factors Engineering Modelling user behaviour.	20.0% (1)	**40.0% (2)**	**40.0% (2)**	5
User centered, situation based data visualisation.	0.0% (0)	**60.0% (3)**	40.0% (2)	5
Support for behavioural change, social pressure & incentives.	**40.0% (2)**	**40.0% (2)**	20.0% (1)	5

Time

	Short	Medium	Long	Response Count
Human factors Engineering Modelling user behaviour.	25.0% (1)	**75.0% (3)**	0.0% (0)	4
User centered, situation based data visualisation.	0.0% (0)	**75.0% (3)**	25.0% (1)	4
Support for behavioural change, social pressure & incentives.	25.0% (1)	0.0% (0)	**75.0% (3)**	4

Other (please specify with priority, time and Related Standard Body)	0
answered question	**5**

skipped question	11

25. Please indicate your level of expertise in Resource & process management

	Response Percent	Response Count
Low	33.3%	2
Medium	**50.0%**	**3**
High	16.7%	1
	answered question	6
	skipped question	10

26. Process integration

Priority

	Low	Medium	High	Response Count
Business and process models.	25.0% (1)	**50.0% (2)**	25.0% (1)	4
Inter-enterprise coordination, collaboration & communication.	0.0% (0)	25.0% (1)	**75.0% (3)**	4
Distributed systems.	25.0% (1)	**75.0% (3)**	0.0% (0)	4

Time

	Short	Medium	Long	Response Count
Business and process models.	0.0% (0)	**66.7% (2)**	33.3% (1)	3
Inter-enterprise coordination, collaboration & communication.	**66.7% (2)**	33.3% (1)	0.0% (0)	3
Distributed systems.	0.0% (0)	**100.0% (3)**	0.0% (0)	3

Other (please specify with priority, time and Related Standard Body)	0
answered question	**4**
skipped question	**12**

27. Knowledge sharing

Priority

	Low	Medium	High	Response Count
Knowledge capture, formalisation and consolidation.	0.0% (0)	25.0% (1)	**75.0% (3)**	4
Knowledge repositories, data mining, semantic search, long-term archival & recovery.	0.0% (0)	**66.7% (2)**	33.3% (1)	3
Knowledge analytics of energy consumption & optimisation, pattern identification etc.	0.0% (0)	33.3% (1)	**66.7% (2)**	3

Time

	Short	Medium	Long	Response Count
Knowledge capture, formalisation and consolidation.	**66.7% (2)**	33.3% (1)	0.0% (0)	3
Knowledge repositories, data mining, semantic search, long-term archival & recovery.	0.0% (0)	**100.0% (3)**	0.0% (0)	3
Knowledge analytics of energy consumption & optimisation, pattern identification etc.	0.0% (0)	**100.0% (3)**	0.0% (0)	3

Other (please specify with priority, time and Related Standard Body) 0

answered question	**4**
skipped question	**12**

28. Whole life cycle management

Priority

	Low	Medium	High	Response Count
Modelling & simulation e.g. "what-if" scenario plan¬ning & continuous improvement.	0.0% (0)	25.0% (1)	**75.0% (3)**	4

Time

	Short	Medium	Long	Response Count
Modelling & simulation e.g. "what-if" scenario plan¬ning & continuous improvement.	25.0% (1)	**50.0% (2)**	25.0% (1)	4

Other (please specify with priority, time and Related Standard Body)	0
answered question	**4**
skipped question	**12**

29. Please indicate your level of expertise in Energy trade & transactional management

	Response Percent	Response Count
Low	**80.0%**	**4**
Medium	20.0%	1
High	0.0%	0
answered question		**5**
skipped question		**11**

30. District / neighborhood energy management beyond buildings

Priority

	Low	Medium	High	Response Count
District energy management systems.	0.0% (0)	**75.0% (3)**	25.0% (1)	4
ICT architectures and infrastructures for districts.	0.0% (0)	**50.0% (2)**	**50.0% (2)**	4
Management of local generation, distribution and storage.	0.0% (0)	0.0% (0)	**100.0% (4)**	4
Energy trading & brokerage, prosumer forecasting, resource tracking, consumption/price negotiation.	25.0% (1)	**50.0% (2)**	25.0% (1)	4

Time

	Short	Medium	Long	Response Count
District energy management systems.	33.3% (1)	**66.7% (2)**	0.0% (0)	3
ICT architectures and infrastructures for districts.	0.0% (0)	**66.7% (2)**	33.3% (1)	3
Management of local generation, distribution and storage.	33.3% (1)	**66.7% (2)**	0.0% (0)	3

Energy trading & brokerage, prosumer forecasting, resource tracking, consumption/price negotiation.	**33.3% (1)**	**33.3% (1)**	**33.3% (1)**	3
			Other (please specify with priority, time and Related Standard Body)	0
			answered question	**4**
			skipped question	**12**

31. Smart grids and the built environment

Priority

	Low	Medium	High	Response Count
Smart metering.	0.0% (0)	0.0% (0)	**100.0% (4)**	4
Balancing between users' need (e.g. comfort) and supply side constraints (demand control).	0.0% (0)	20.0% (1)	**80.0% (4)**	5

Time

	Short	Medium	Long	Response Count
Smart metering.	**50.0% (2)**	25.0% (1)	25.0% (1)	4
Balancing between users' need (e.g. comfort) and supply side constraints (demand control).	40.0% (2)	**60.0% (3)**	0.0% (0)	5

Other (please specify with priority, time and Related Standard Body)	0
answered question	**5**
skipped question	**11**

32. Please indicate your level of expertise in System integration

	Response Percent	Response Count
Low	0.0%	0
Medium	**66.7%**	**4**
High	33.3%	2
	answered question	**6**
	skipped question	**10**

33. System integration

Priority

	Low	Medium	High	Response Count
Plug & play connections/interfaces.	0.0% (0)	0.0% (0)	**100.0% (5)**	5
Integration platforms, gateways, middleware.	0.0% (0)	20.0% (1)	**80.0% (4)**	5
Service oriented architectures, web services, cloud based services, event driven architectures.	20.0% (1)	**40.0% (2)**	**40.0% (2)**	5
Integration of BIM to real time operational systems.	0.0% (0)	20.0% (1)	**80.0% (4)**	5
Integration of BEMS with external monitoring and services.	0.0% (0)	**75.0% (3)**	25.0% (1)	4

Time

	Short	Medium	Long	Response Count
Plug & play connections/interfaces.	25.0% (1)	**75.0% (3)**	0.0% (0)	4
Integration platforms, gateways, middleware.	**50.0% (2)**	**50.0% (2)**	0.0% (0)	4
Service oriented architectures, web services, cloud based services, event driven architectures.	0.0% (0)	**75.0% (3)**	25.0% (1)	4

Integration of BIM to real time operational systems.	25.0% (1)	**75.0% (3)**	0.0% (0)	4
Integration of BEMS with external monitoring and services.	0.0% (0)	**75.0% (3)**	25.0% (1)	4

Other (please specify with priority, time and Related Standard Body)	0
answered question	**5**
skipped question	**11**

34. Please provide us with any free comments

	Response Count
	0
answered question	**0**
skipped question	**16**