Roadmap Enabling Vision and Strategy for ICT-enabled Energy Efficiency

D2.3 - ICT4EE - Impact Assessment Model

Author(s):	**Keith Ellis**	**Intel**
	Charlie Sheridan	**Intel**
Contributors:	**Bruno Fies**	**CSTB**
	Daniel Kuhn	**FHG**
	Antonio Feraco	**Innova**
	Hans Pille	**Kema**
	Nico Vlug	**Kema**
	Steven Firth	**LOU**
	Farid Fouchal	**LOU**
	Tarek Hassan	**LOU**
	Matti Hannus	**VTT**
	Veijo Lappalainen	**VTT**

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Contents

ACRONYMS AND TERMS

BIM	Building Information Model
CMM/F	Capability Maturity Model or Framework
DoW	Description of Work – original research proposal document
ERP	Enterprise Resource Planning
HEM	Home Energy Management
HPC	High Powered Computing
ICT	Information Communication Technology[s]
ICT4EE	Information and Communication Technology four Energy Efficiency
PLM	Product / Production Lifecycle Management
Prosumer	An entity that both consumes and produces energy
REG	REViSITE Expert Group
RES	Renewable Energy Sources
RTD	Research Technology Development
SRA	Strategic Research Agenda
WP	Work Package

1 EXECUTIVE SUMMARY

In 2008, Commission President José Manuel Barroso stated *"...the real gains will come from ICT as an enabler to improve energy efficiency across the economy. ICT matters for energy reduction, especially in transport and the energy intensive sectors. ICTs ability to organise and innovate is a key factor'.* [i]

In a 2010 key communication from the European Commission 'A European strategy for smart, sustainable and inclusive growth' the importance of ICT was reiterated with the communication stating that, *'Member States will need: To incentivise energy saving instruments that could raise efficiency in energy-intensive sectors, such as based on the use of ICTs'.* [ii]

While in January 2011 President Barroso stated *"...Since our best source of energy is in fact energy efficiency, and also considering the prices of energy, I think it is important from all points of view to achieve real progress of energy efficiency very soon…'.* [iii]

In short, the central role of ICT in enabling energy efficiency and sustainability goals is evident, as is the urgency in achieving those goals, and it is within that context REViSITE is set.

The project focuses on developing a community driven Strategic Research Agenda for ICT-enabled energy efficiency in four energy intensive sectors namely - Smart Grids, Buildings, Manufacturing and Lighting. D2.3 'ICT4EE - Impact Assessment Model' is the final deliverable of Work Package 2 within the REViSITE project.

The purpose of this document is to identify the potential relevance of key ICTs with respect to the development of a Strategic Research Agenda, the ultimate goal of which focuses on energy efficiency impact across the target sectors.

The modelled output of this deliverable is based on the qualitative analysis of deliverable D2.2 'ICT4EE- Knowledge and current practices' and utilises the framework developed in deliverable D2.1 'ICT4EE- Data Taxonomy: A common methodology to assess the impact of ICT developments' on energy efficiency.

The report begins with a recap of the framework of deliverable D2.1 together with a discussion as to the value of the approach and how it was used within REViSITE. This is followed by a summary, broken down by sector, of the most promising RTD/ICTs as identified by survey. The survey output is then compared to community discussion and key ICT's identified in the project workshops to date.

Finally, a synthesis of the main common RTD/ICT themes in terms of SRA relevance across the four sectors is presented. It is envisage d, the output of this process/deliverable will input directly to WP3 Roadmap and SRA development.

2 REViSITE INTRODUCTION

It is envisaged that REViSITE will contribute to the formation of a European multidisciplinary 'ICT for energy-efficiency' research community by bringing together the ICT community and four important complementary application sectors: Smart Grids, Buildings, Manufacturing and Lighting.

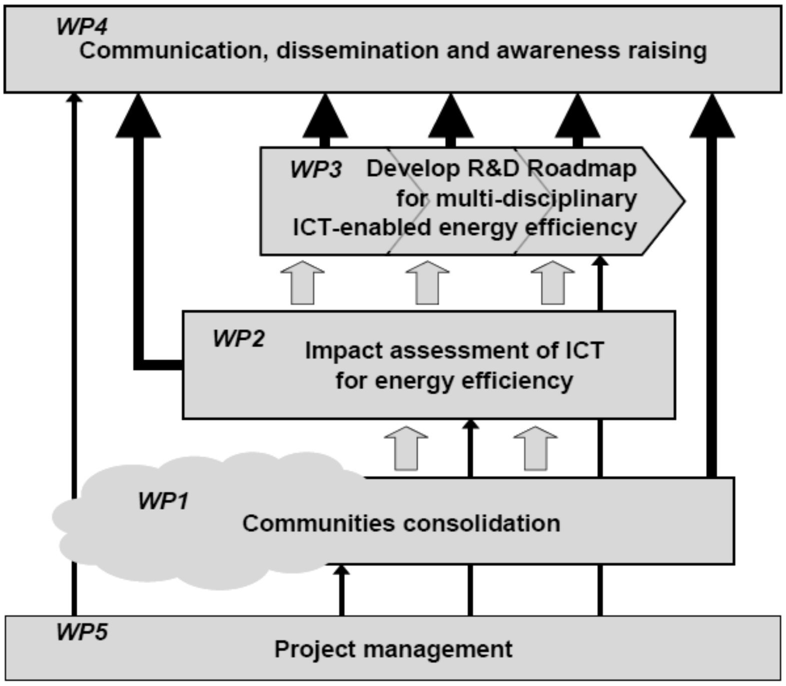

Figure 1 - The REViSITE work package structure

The REViSITE project will co-ordinate co-operation and communication within the ICT4EE research community in Europe. The core of this community will be formed from the European Technologies Platforms (ETPs) that represent RTD in these sectors: ARTEMIS, ECTP, MANUFUTURE, PHOTONICS21, SMARTGRIDS.

WP1 - REViSITE will identify complementarities between the four target sectors: grids, buildings, lighting and manufacturing in the area of ICT for energy efficiency (ICT4EE), harmonising common RTD priorities for ICT4EE in the four sectors, and establishing a cross-sectoral "community" with links to different industry sectors and related ETPs.

WP2 - REViSITE will compile a state-of-current-practice review and develop an impact assessment framework and a causal model regarding ICT impact on energy consumption in 4 key sectors. Based on available statistical data and, where such data is not available, estimations by experts, the project aims to identify RTD priorities for ICT4EE.

WP3 - The project will engage key stakeholders from the 4 sectors via a 'focus group' and a dedicated concise 'expert group' to compare and analyse sector specific RTD agendas such as Strategic Research Agendas (SRAs) of relevant European Technology Platforms (ETPs), European and national RTD initiatives etc. A consolidated roadmap will be derived as a synthesis. This will catalyse synergetic RTD and innovation in multiple sectors by pointing to cross-sectoral RTD opportunities in common areas of interest that have the highest potential impact.

2.1 Deliverable purpose and target audience

The purpose of this document is to develop a causal model outlining the potential impact of key ICTs on energy efficiency in the four target sectors, based on the analysis of D2.2[iv] [T2.2-T2.5] and utilising the framework/methodology developed in D2.1[v] [T2.1]

Deliverable D2.3 aims to analyse, in more depth, those themes and associated ICT/RTDs identified within the D2.2 analysis and project workshops by utilising an adapted Capability Maturity Model/framework to quantify the opinion of the wider community.

In doing so it is envisaged REViSITE will identify clear trajectories for RTD roadmap and SRA development by gaining greater understanding into the potential impact of various ICTs and the context dependant causal relationships which underpin that impact. It should be noted that the process will extend beyond the submittal deadline of this deliverable, with the D2.3 survey and results available online over the course of the project.

This deliverable is a publicly available document however the initial intended audience is the REViSITE consortium itself. The reason being, D2.3 is an input that will influence both roadmap and SRA development within WP3.

2.2 Definitions & Scope

Section 3 gives an overview of the REViSITE methodology/framework for ICT4EE impact assessment. The scope and definitions as outlined in D2.1 and as applied in D2.2 still hold. However some of the most relevant points in terms of this deliverable D2.3 are listed below:

- The geographical frame of reference for the studies is the EU-27.
- The timeframe in terms of impact assessment is 1990 to 2020.
- The four target sectors reviewed within REViSITE are Smart Grids, Buildings, Manufacturing and Lighting.
- REViSITE is focused on ICT4EE. Energy efficiency within REViSITE is defined as 'a process that uses less energy per unit of service'.
    - At a building level energy efficiency relates to less energy consumption while providing the function of the building.
    - Energy efficient lighting refers to less energy consumption per unit of light within buildings and externally within the wider built environment such as on-street lighting and signage.
    - From a manufacturing perspective, energy efficiency relates to less energy consumption per unit produced. Here energy consumption of a production system incorporates building energy consumption.
    - From a grid perspective the unit of service is energy, as such energy efficiency here means more efficient generation together with less transmission and distribution losses in providing energy, a switch to RES is of course a paramount element of

Smart Grids however it is not strictly energy efficiency and is more about low or zero carbon production of energy.

- First order, primary or direct effects refer to the immediate impact of ICTs on energy and carbon emissions i.e. its own footprint or consumption.
- Second order, secondary or indirect effects refer to the impact on other sectors or other systems within the same sector due to the deployment/usage of ICTs.
- Third order or tertiary effects refer to impacts that manifest in terms of new usage patterns/behaviours due to 'longer-term' ICTs usage and may emerge in social, economic or environmental impacts.
- 'Rebound effects' are akin to the system concept of 'unintended consequence' and in an energy context describe the situation whereby users negate savings made by energy efficient initiatives through increased consumption. The extent to which rebound effects negate emission reductions is the subject of much debate and is beyond the scope of REViSITE. For examples of 1st, 2nd, 3rd order and rebound effects see box below.
- A causal relationship – is an information connection between events or happenings whereby one state of affairs is partly or wholly brought about by another (the cause). In the case of REViSITE the cause will always be some effect on energy consumption/efficiency while the cause will be some form of ICT.
- Causal models - are primarily based on 'observation data' and can be represented in narrative text, as tables, as visualisations or as mathematical models (or combinations of these).
- Using visual models, supplemented with mathematical models where feasible, is the preferred method of representation of causal models (outcomes models) within outcomes theory. Within REViSITE we are in the main trying to determine the potential outcome/impact if an ICT is utilised.

Telecommuting example [assumes consumption of work done is equal Home & office]

1st order effects – Additional Electrical consumption of the Virtual Private Network application which enables an employee to connect into their company's network, plus the additional electrical demand placed on the home area network are examples of the direct effects of this ICT.

2nd order effects – The reduced energy consumption in terms of travel is an obvious second order effect of utilising this ICT to telecommute. Reduced energy consumption of the office building due to reduced occupancy is another possible second order effect.

3rd order effects – A possible indirect third order effect in this case might be an increase in urban sprawl. Or increase in ergonomic injury due to incorrect home setup for computer based work.

Rebound effects – the introduction of telecommuting in a facility delivers a net decrease in energy usage but the savings from reduced travel and building consumption are somewhat negated by changes in home consumption as increased use of home space heating and lighting for increases.

Home Energy Management example

1st order effects – Additional Electrical consumption required to implement the HEMs including the HEMs display, sensors and associated wired/wireless network usage.

2nd order effects – The reduced energy consumption in terms of building energy consumption electrical, gas and or oil etc. due to increased awareness of usage patterns.

3rd order effects – A possible indirect third order effect in this case might be the shifting of peak demand or load balancing effects etc. within the grid.

Rebound effects – the energy consumption savings may be somewhat negated by changes in consumption behaviour through the addition of devices or increased consumption to match existing/traditional cost point.

3 REViSITE METHODOLOGY OVERVIEW

3.1 Methodology and taxonomy overview

The REViSITE research of D2.1 and D2.2 is clear, emerging best practice in assessing ICT impact on energy efficiency utilises some form of 'Life Cycle Assessment' (LCA) or 'life cycle thinking'. The REViSITE assessment approach is a hybrid methodology or framework that seeks to combine simplified 'Life cycle assessment' or rather 'Life cycle thinking' and an adapted 'Capability Maturity Model/Framework' (CMM or CMF). By combining existing secondary data, sector specific standards and heuristics it is believed REViSITE can build an 'informed view' (see figure 2) regarding those ICTs best positioned to positively impact on energy efficiency/consumption. The approach cannot and is not intended to replace a more detailed LCA or other detailed quantitative assessment. Such LCA's consider all life cycle phases, the toxicity of the offering and its wider effect on acidification, eutrophication, or land use. The approach is merely to build an informed view that can assist roadmap development.

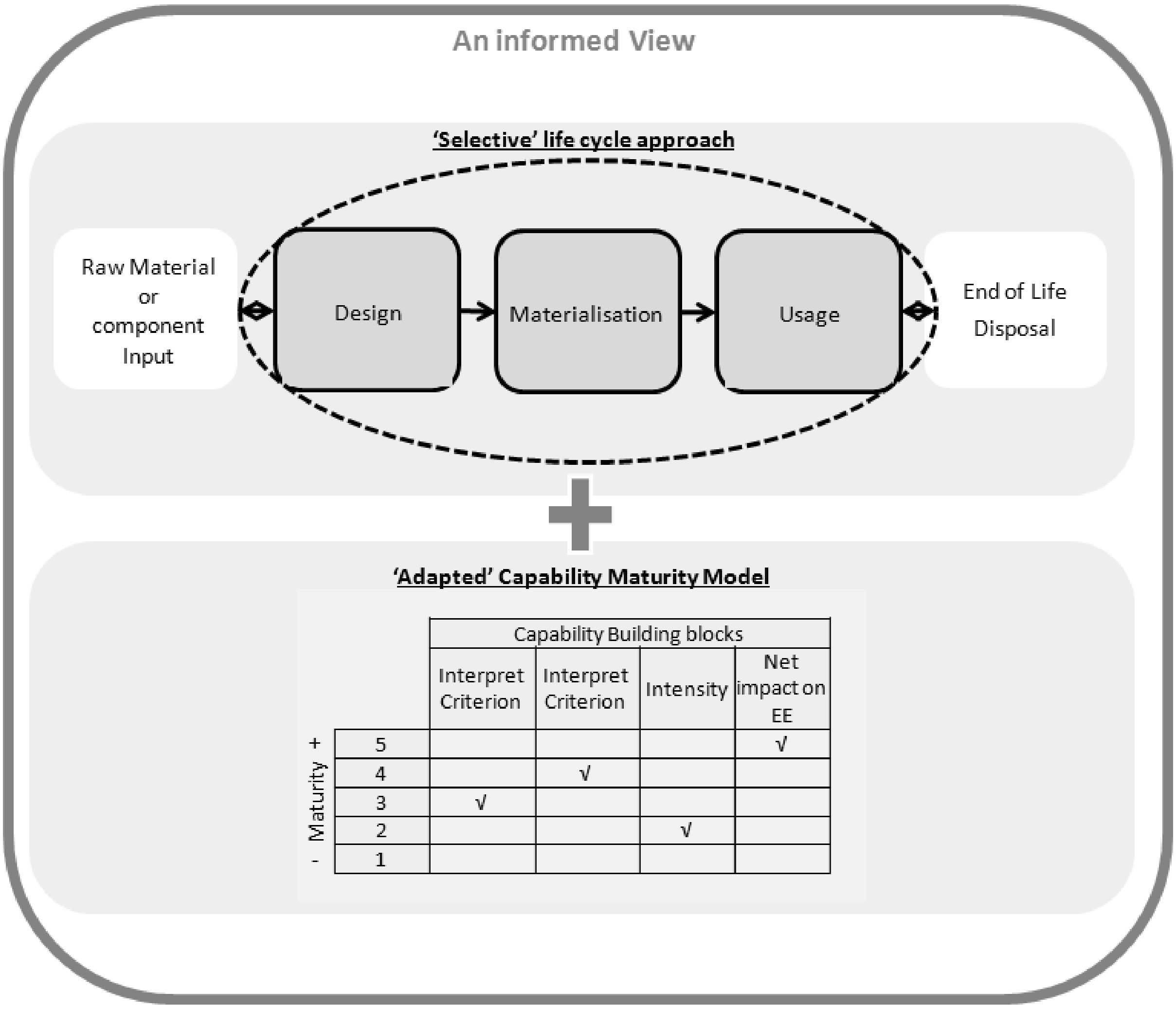

Figure 2 - The REViSITE approach, an informed view

While there are many criterion one might examine, within REViSITE we focused on the following four, with prime focus on the first two:

- Potential net impact on energy efficiency [primarily 1st v 2nd order effects],
- Intensity [current v potential adoption],
- Operational effectiveness [compared to other offerings] and
- Cost of implementation.

The premise is to build an understanding as to the potential impact and barriers of specific ICT/RTDs.

But before one can begin to compare across different domains one must first speak a common technical language in order to compare ‘like with like. The REViSITE developed SMARTT taxonomy utilises six high level categories with sub-categories nested within these. The high level categories are aligned to a generic bounded life cycle (see figure 3).

Both categories and sub-categories are 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 are nested within the sub-categories and are defined by the partners for their sector.

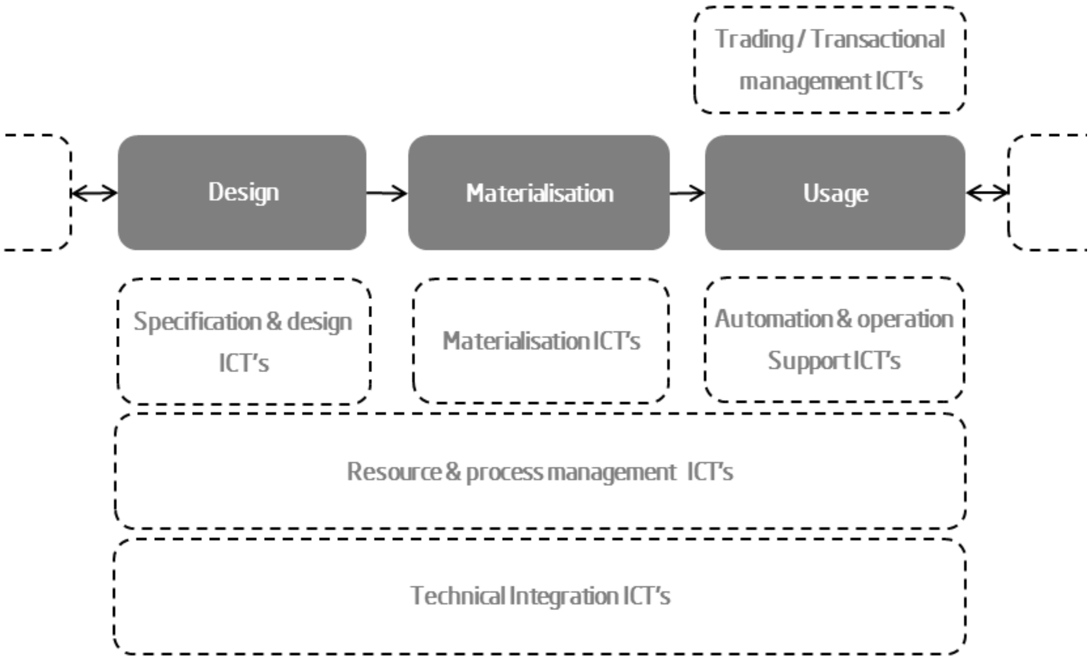

Figure 3 - The SMARTT Taxonomy mapped to Life Cycle phases

The categories ‘Specification & design ICTs’, ‘Materialisation ICTs’ and ‘Automation & operation support ICTs’ all vertically align to the bounded life cycle phases. ‘Resource & process management’ together with ‘Technical integration’ are themes that align horizontally. ‘Trading / transactional management ICTs’ aligns primarily to the ‘usage’ life cycle phase.

Within REViSITE we bound our system of interest at the interface to the ‘raw-material / component input’ phase and the ‘end of life’ phase of the life cycle. This does not exclude ICTs that cross these boundaries but rather excludes impact assessment of ICTs used in these phases as they typically constitute different sectors. For example, in the context of built environments the REViSITE process would include ICTs that allow for embodied energy data, of materials or sub-components, to be accessible to downstream design and construction tasks, but would not assess the energy efficiency impact of ICTs within the 'raw material extraction' industry itself.

The Taxonomy has three levels –

1. **Main category** aligned to the Life cycle phases and following the SMARTT acroynom.
    a. **Sub-category** allowing for more granular categorisation
        i. **RTDs & ICTs** detailing the specfic areas of research and possible devleopment giving existing or envisaged ICT exemplar's

The full list of categories and subcategories is listed below however for further details on the taxonomy and/or the REViSITE methodology view deliverable D2.1 *'ICT4EE- Data Taxonomy: A Common Methodology to assess the impact of ICT developments'.*

1) **Specification & design ICTs**
    a) ***Design conceptualisation:*** requirement engineering/management tools such as Quality Function Deployment tools, concept modelling for design ideation. Building and urban planning applications.
    b) ***Detailed design:*** software design tools, CAD (e.g. Autodesk, 3D studio max), Multimedia (e.g. Flash, Silverlight), Graphics (e.g. Photoshop, Illustrator).
    c) ***Modelling****:* all types of technologies that are utilised to systematically describe the physical reality, Life cycle modelling, computer-aided diagramming (e.g. Sankey, Response flow, Cause and effect, influence diagrams etc.) some Excel and some CAD applications. Also include are models for the rationalisation of decisions for example computer-interpretable representation and exchange of product/material manufacturing information for materials to be used in construction**.**
    d) ***Performance estimation:*** classical financial based IT applications, ROI, NPV, TCO. Various technologies used to analyse the performance of the target system e.g. Life Cycle Analysis, Finite Element Mode analysis and a wide variety of engineering analysis tools that could also be applied in both the design and materialisation phases.
    e) ***Simulation:*** analysis of the dynamic behaviour of a system as part of the design function. All simulation requires modelling but not all modelling leads to simulation. Example technologies include - CFD, power system simulation, thermal simulation, Wide Area Network simulators etc.
    f) ***Specification & Product / component selection:*** technologies for design & specification realisation, component selection e.g. material characteristic database & retrieval. (bridge note)

2) **Materialisation ICTs**
    a) ***Decision support & visualisation***: technologies for visual representation of work flows focused on energy efficient task completion. What if - scenario simulation, & modelling to support real-time decisions in the field. May incorporate automated processing coupled with visual aids or alert mechanisms. Basically, any dynamic technologies that assist with the materialisation of the physical, whether that be a smart grid, building, factory or lighting infrastructure.

b) ***Management & control:*** adherence to performance requirements, conformance validation, commissioning and phase specific task management in terms of efficient materialisation of the physical building, grid, factory process or lighting infrastructure.
c) ***Real-time communication***: any real-time communications that facilitate decision making. E.G. sensor information regarding integrity of building materials during construction integrated into an alert mechanism such as a text or on-screen display.

3) **Automation & operational decision support ICTs**
   a) ***Automated monitoring & control:*** intelligent HVAC, smart lighting, automated backend control with little or no human decision interaction. Smart monitoring (metering). Smart metering linked with machine self-actuation adjustment. E.G. energy consumption managed via intelligent control which responds automatically to say gradual electrical load consumption shifting, wastage of energy due to simultaneous heating and cooling, drifting or malfunctioning equipment operation. *[survey split out software v hardware]*
   b) ***Operational decision support & visualisation:*** performance management in the usage phase as in the occupancy of a building or in the manufacturing of products or in dynamic load provisioning within the grid. Visualisation and cognitive decision support in terms of energy dashboards and real-time communications regarding usage. What if - simulations to support operational changes for optimal running of manufacturing lines, heating systems or micro-power generation.
   c) ***Quality of service:*** backend service provisioning & rightsizing of communication networks. Quality assurance of applications in the field and self-healing of networks, SLA protocols.
   d) ***Wired/Wireless sensor networks:*** secure backend wired/wireless communications, dedicated high speed wired/wireless networks, sensor hardware/software so essential to sub-metering strategies, 6LoWPAN, ZigBee PLC etc. *[survey combined c & d]*

4) **Resource & process management ICTs**
   a) ***Inter-enterprise coordination****:* contract & supply network management, process planning & scheduling, procurement, intra-logistics, elements of ERP systems etc.
   b) ***Process integration:*** collaboration support, groupware tools, electronic conferencing, distributed systems, social-media, business work flows, ERP (front end) systems
   c) ***Knowledge management:*** 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 up the DIKW (Data, Information, Knowledge, Wisdom) chain in order to add value. *[survey split out data analytics]*

5) **Technical Integration ICTs**
   a) ***Technical integration & interoperability****:* context and semantic interoperability is as important as technical integration, for example agreement on business processes is as important as data exchange protocols. But the main focus here will be on technical integration. - Technical protocols, formats and standards for say data exchange. Technologies such as middleware, gateways, interfaces, complex-event processing (CEP) with automated response, service orientated architectures and platforms, BMS/FMS backend infrastructure. Backend infrastructure of BIM or ERP systems etc. *[survey split out standards, protocols versus middleware and CEP type engines]*

6) **Trading / transactional management ICTs**

a) ***District energy management:*** Distributed possibly "cloud" based networks for the holistic and sustainable management, trading and brokering of energy resources beyond the limits of one enterprise. Demand response capabilities, real-time self-assessment, load balancing technologies, energy network and integration management, secure, smart interfaces with smart grids. Market Management Systems (MMS), Distribution Management Systems (DMS), transactional aspects of Energy Management Systems etc.

b) ***Facility energy management:*** energy specific management systems, energy specific integration platforms and middleware. Smart metering infrastructure and protocols, Context Event Processing, on-demand energy management and optimisation, load and distributed energy resources forecast algorithms, smart appliances.

c) ***Citizen (personnel) energy management:*** Personal CO_2 quota system with interpersonal trade of pollution rights (scope is beyond the buildings category and includes activities like car refuelling). However we may want to include interaction of various agents within a district, those agents could be Buildings, Citizens, vehicles etc. *[survey combined a, b & c]*

3.2 Justification, limitations & perceived value of the approach

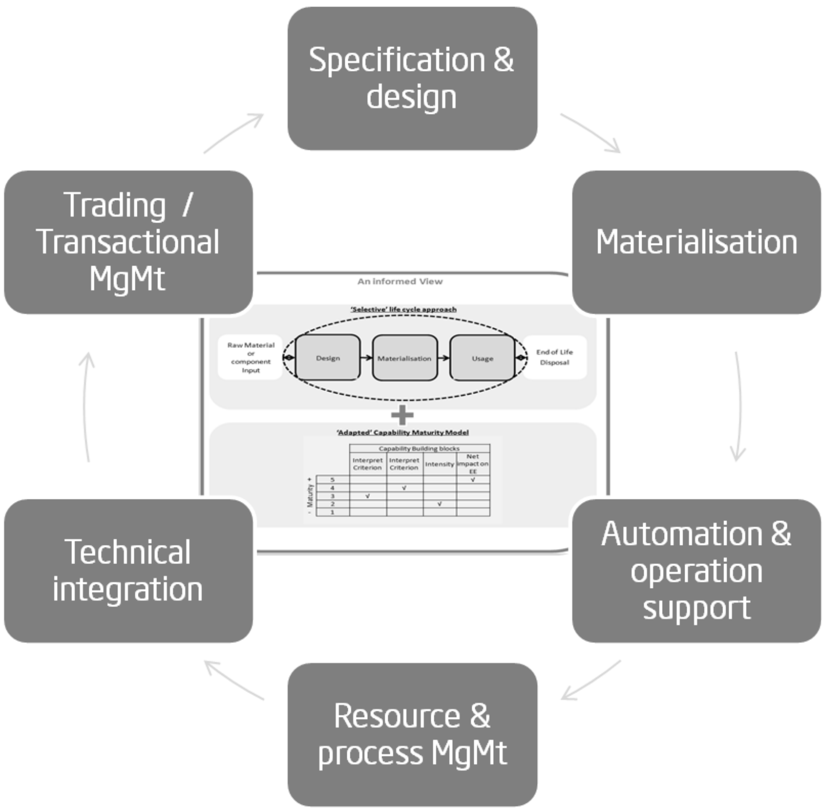

Figure 4 - The REViSITE Framework and SMARTT Taxonomy

As identified by the commission there is a "…*clear need to create a level playing field based on common ways of measuring energy performance … and on a common understanding of commitments, targets and methodology*"[vi]

The role of ICT as an enabler is something that, to most, feels innately apparent. Yet it is often hard to demonstrate that enabling effect. This is often the case because the ICT and non-ICT technological elements are not easily distinguishable or because the impact resides in a different life cycle. Or sometimes it is a case of the ICT and concept being so intertwined it becomes difficult to differentiate between the technology and the practice.

The capacity to quantitatively assess ICT impact is of course desirable. However 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.

It's in that vein, REViSITE position the above framework, which utilised a triangulation of approach[vii] in leveraging the heuristics of domain experts, together with available quantitative and qualitative sources, in identifying those RTDs/ICTs most likely to positively impact on energy efficiency.

This is where the adapted capability maturity analysis comes into play. The value in utilising a capability maturity framework is that it allows REViSITE partners and community members to give a quantitative estimate to what is essentially inductive qualitative research based on case studies and expert opinion.

The REViSITE consortium having utilised the framework deem it to be a useful and feasible means of qualitative common assessment. Specifically the 'value' of the framework is summarised below:

- By understanding the respective 'maturity level' of RTDs or specific ICTs, with regard to defined criteria, the REViSITE framework proved useful in identifying focus areas for development and those ICTs best placed to deliver meaningful impact within sectors.
- The framework more significantly offers 'a common means of understanding' or a 'lens' into the use of ICTs and ICT practices that sit outside traditional sector silos. As such it offers the potential to extract value from exposure to another sectors experience or research.

As such, while developed for internal usage the framework is posited as a possible foundation on which more detailed quantitative measures can be positioned and one which may prove useful to the wider community.

3.3 How the REViSITE methodology was applied in D2.3

The D2.1 developed framework was used throughout deliverable D2.2. Specifically the life cycle aligned SMARTT taxonomy was utilised as an integrative classification system and as an aid to cross sector ICT4EE assessment. The capability maturity element of the framework was not utilised at this stage except to assist partners in conceptualising the likely magnitude of impact with regard to the themes identified.

The adapted capability maturity framework was subsequently used within this deliverable [D2.3] to assess in more detail those themes outlined in D2.2. Essentially, individual REViSITE partners made an assessment of the impact of 23 ICT themes based on heuristics and expertise within their defined sectors. The individual ICT/RTDs were scored based on the scale of figure 5.

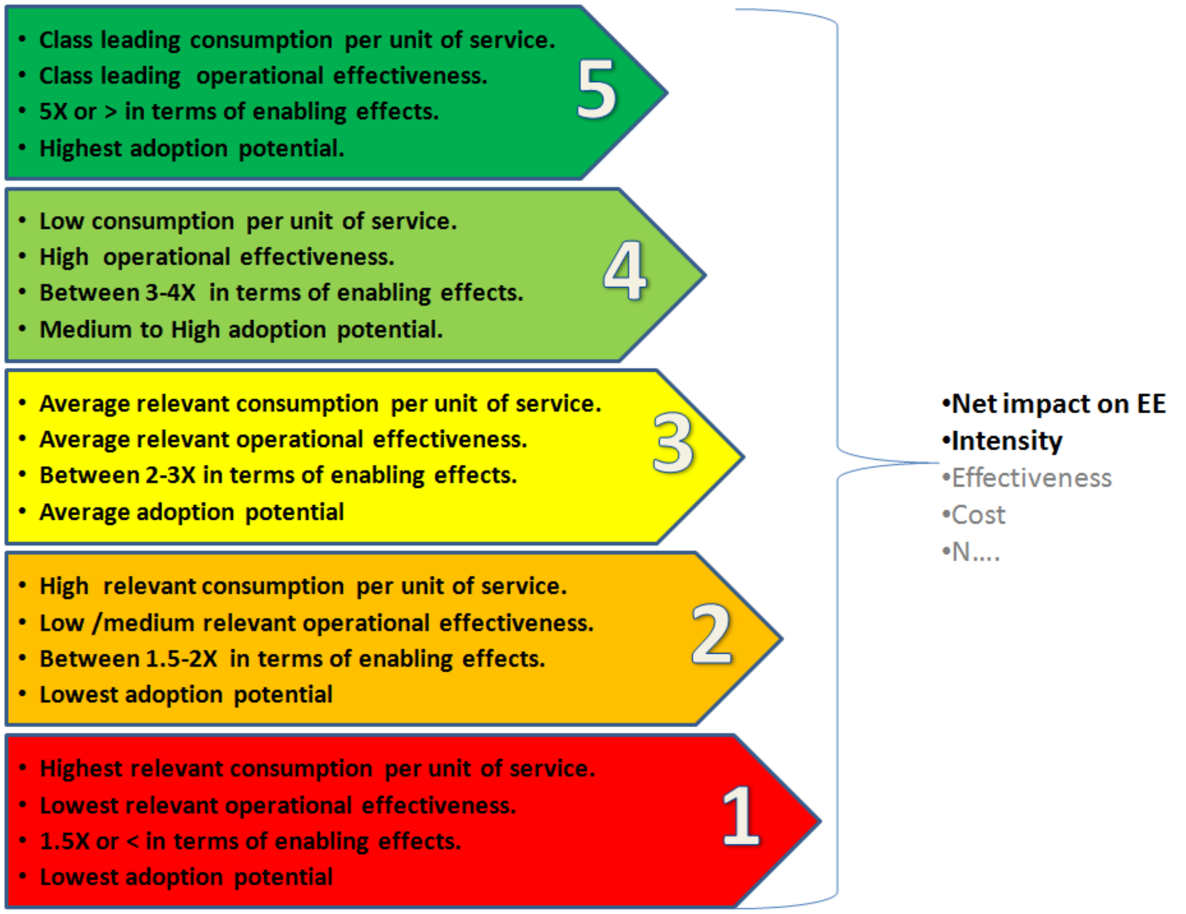

Figure 5 - The REViSITE maturity scale.

At this point it was decided to open up assessment of the 23 themes to a wider audience. The themes were essentially a rewording of the SMARTT taxonomy, the re-wording and splitting out of some themes was necessary for engaging this wider group. At the time of writing the group was restricted to the seventeen members of the REViSITE Expert Group and sixty-six members of the community that had indicated their willingness to engage with the consortium when originally contacted as part of WP1. This was done as an initial control in terms of the 'calibre' of respondents. In terms of practicality that assessment was simplified and distributed by way of an online survey. The Qualtrics / Intel platform was used and the survey questions are listed in the appendix.

Respondents had to choose a sector for which they would answer subsequent questions, namely - Energy Grids, Built Environment, Manufacturing, Lighting or Transport / Logistics, all responses were tracked by a unique identifier. The decision was taken to add the Transport / Logistics sector given its recognised importance by the consortium and the experts we had consulted with. As a result we had made connections with initiatives in that space, specifically the FP7 funded Coordinated Action - Logistics 4 Life. Although transport / logistics were not within our scope it was deemed prudent to make these connections at this stage of community development and to provision for that sector completing the survey.

Within the survey respondents were asked to name 3 ICTs/RTDs that had in their opinion the best potential for positively impacting on the energy efficiency or reduced energy consumption of their identified sector.

Respondents were subsequently asked to rate 3 elements, the ‘potential impact’, ‘potential adoption’ and ‘current adoption’ of the 23 ICT themes, with respect to energy efficiency and /or reduced energy consumption within their identified sector. This was based on a 5 point scale aligned to that of figure 5 above. ‘Potential Impact’ score describes the extent to which a respondent feels a theme can have an enabling impact on energy efficiency. Potential adoption describes the extent to which adoption can scale in terms of energy efficiency whilst current adoption scores the level to which that theme is adopted with respect to energy efficiency or where energy efficiency is a buy-product of its current deployment.

In terms of context, we did not want to bias answers by signposting how a particular ICT might impact on energy efficiency within specific sectors and as such generic terminology and limited examples were used. This approach was chosen for a number of reasons.

We wanted to use the 23 non-sector specific themes as a cross-reference for the 3 key ICTs we asked respondents to identify within the survey. Stripped of sector specific terminology could respondents identify the ICTs as being important to the energy efficiency of their sector? We also wanted respondents to consider ICTs that were not immediately apparent to their context. The premise was simplistic - if we could enable the different sectors to connect their own specificity to a generalised technology/practice, then this might help to overcome siloed approaches to improvement by offering each sector a potentially valuable ‘lens’ into the research, practices and technology skews of the other sectors.

The survey questions were open to interpretation by design. What we wanted to test was how respondents would score ICT themes that had no logical direct enabling impact on the energy efficiency or energy consumption of their sectors. Essentially we were testing if respondents would make any correlation or causation between the theme and some other technology or practice that enabled energy efficiency improvement or reduced consumption within their sector. By rating ‘potential impact’, ‘potential adoption’ and ‘current adoption’ against each of the 23 themes we were testing the estimated strength of correlation/causation and the potential relevance in including a theme within SRA development.

What follows is the initial analysis of that survey. The survey and results will be made available via the REViSITE website and will remain live over the course of the project thus capturing the views and reflecting the opinion of the wider community as it grows.

4 REVISITE INITIAL FRAMEWORK ANALYSIS & OUTPUT

The main body of the survey was based on rating the 'potential impact', 'potential adoption' and 'current adoption' of the below 23 themes relative to energy efficiency or energy consumption reduction in each sector. The 23 themes are based on the SMARTT taxonomy of D2.1 outlined in section 3 above. It was necessary to separate out some ICT themes for the purpose of the survey.

S	1	Design conceptualisation ICTs for requirement engineering & ideation. E.G. Quality Function Deployment, Mind maps etc
S	2	Human factors Engineering ICTs to gather and model data describing the behaviour of end users/energy consumers
S	3	Visual / spatial design ICTs E.G. CAD (Autodesk, 3D studio max), Multimedia (e.g. Flash, Silverlight), Graphics (e.g. Photoshop, Illustrator) for digital mock-up etc
S	4	Causal Modelling ICTs used to describe / predict relationships in physical systems E.G. computer-aided diagramming (e.g. Sankey, Cause and effect, influence diagrams etc), Life cycle modelling, statistical packages such as JMP & MatLab etc
S	5	Simulation ICTs for predicting/estimating the dynamic behaviour of a system as part of the design function E.G. Computational Fluid dynamics, Finite element mode analysis, power system simulation etc
S	6	Product/component specification and selection ICTs E.G. material characteristic database specifying embedded energy, recyclability, thermal performance etc
M	7	Mobile Decision Support ICTs that utilise real-time communication to facilitate in the field decision making particularly in construction or civil engineering tasks
A	8	Secure/resilient wired, wireless and optical infrastructure for operational communication, monitoring & control
A	9	Embedded intelligent devices (micro architecture)for operational control, sensing & actuation at machine, plant or building level
A	10	Software & algorithms for operational monitoring & actuation of devices at machine, plant or building level
A	11	Inference sensing Software & algorithms for pattern & signal identification at machine, plant or building level
A	12	Operational decision support ICTs that integrate high level diverse systemssuch as safety, security, weather and energy etc at individual, building or district level for near real-time decision making
A	13	User Centred Data Visualisation ICTsto support system state awareness by human operators / users
R	14	Inter-Enterprise ICTs for supporting coordination e.g. contract & supply-network management in the context of reduced energy consumption
R	15	Business Process Integration & collaboration ICTs E.g. collaboration support, groupware tools, electronic conferencing, social-media, etc
R	16	Knowledge sharing ICTs, knowledge management, knowledge repositories, knowledge mining and semantic search, linked data, long-term data archival and recovery at enterprise or inter-enterprise level
R	17	ICTs for data mining & analytics in terms of energy consumption & optimisation, pattern identification, predictive diagnostics & analytics at enterprise or network level
R	18	Modelling & simulation ICTs e.g. What-if scenario planning continuous improvement across a sectors life cycle
Tr	19	Trading & Energy Brokerage ICTs e.g. Consumer/Producer forecasting algorithms, energy source tracking, consumption/price negotiation
Te	20	ICT standards and protocols for interoperability across heterogeneous devices at an enterprise, network or environmental level
Te	21	Real-time analytical technologiessuch as Complex Event Processing and in-memory databases for enhanced operational control and awareness
Te	22	Integration technologies / approaches such as service orientation and event driven architectures to facilitate heterogeneous device data interoperability at enterprise, network and environment level
Te	23	Use of cloud based servicesfor tasks such as data management, monitoring and analysis

Figure 6a - The 23 ICT themes surveyed

The survey data was extracted into matrix format, the pattern/trend analysis utilised standard mathematics, conditional formatting and reorderable matrices[viiiix]. This technique allowed us to separate out overall trends while also allowing for identification of difference across themes.

The output for each sector is outlined in the sections below. This is followed by a trend analysis of common patterns between the sectors. The 'transport and logistics' sector was not included in the first round of the survey and was therefore not included in this comparative trend analysis. Again, it is important to note that at the time of writing the analysis is based on responses from within the consortium, the REG and the sixty six initial community members identified as part of WP1, this was done to control the 'calibre' of initial respondents, in total ninety-five were surveyed and the valid response rate was 24%, figure 6b gives the breakdown.

Valid responses	Grids	Built E	Manufacturing	Lighting
23	4	10	5	4

Figure 6b- Survey response breakdown

The survey or a modification of same will be made accessible on-line through the REViSITE website this will increase the statistical relevance of the results. Nevertheless the analysis was/is considered useful for SRA development and discussion .Each of the following sub-sections begins with a sector specific trend graph. In all four cases the following applies:

- Column 1 – is the SMARTT taxonomy category identifier
- Column 2 – is the associated sub-category ICT theme no.
- Column 3 – is the potential impact score 'P imp',
- Column 4 – is the potential adoption score 'P Adopt',
- Column 5 – is the current adoption score 'C Adopt'
- Column 6 – is the Potential SRA Relevance score 'P SRA Relevance'.

To calculate 'P SRA Relevance' for each theme 'P imp' was multiplied by 'P Adopt' minus 'C Adopt' i.e. P SRA = P Imp * (P Adopt- C Adopt).

The blue line graph helps to visualise the importance of the x-axis which is relevance ranking in the context of SRA development. The purple line indicates the specific 'P Impact' scores for each of those themes. The area graphed backdrop indicates the delta between current and potential adoption.

The sector specific graphs are followed in each case by a figure/table that illustrates the 23 ICT themes ranked in terms of greatest SRA Relevance to lowest. The top 11 themes are highlighted. Highlighting the top 11 scores is not to say other themes are to be ignored and is merely to guide conversation in terms of prioritisation. The column furthest right indicates the sector with the highest current adoption of each theme. This may be useful as a reference point for any research into that specific theme by the scoring sector, however, 'Grids' would seem to be the dominant sector in terms of 'current adoption' and this might be a matter of a high scoring response bias.

The delta between current adoption and potential adoption is indicated in the column immediately to the left. While this is an obvious influencer of the overall 'P SRA relevance' calculation it is useful as a visual clue to the potential appropriateness of individual themes is in terms of SRA development.

4.1 Key RTD/ICTs for Grids

		Maturity Scores			
		P Imp	P Adopt	C Adopt	P SRA Relevance
S	2	4.00	4.25	2.25	8.00
A	13	3.50	4.50	2.50	7.00
A	12	4.00	4.00	2.50	6.00
M	7	4.25	4.00	2.75	5.31
R	14	4.25	3.50	2.25	5.31
A	10	4.00	4.25	3.00	5.00
R	18	4.00	3.75	2.50	5.00
S	5	3.75	4.25	3.00	4.69
A	9	3.75	4.00	2.75	4.69
TE	23	3.50	3.75	2.50	4.38
TE	22	3.25	3.50	2.25	4.06
A	11	4.00	4.00	3.00	4.00
S	4	3.00	3.50	2.50	3.00
A	8	3.75	4.00	3.25	2.81
R	17	3.50	3.50	2.75	2.63
TE	20	3.25	3.75	3.00	2.44
TR	19	3.75	4.00	3.50	1.88
S	1	2.25	3.00	2.25	1.69
R	16	3.00	3.00	2.50	1.50
R	15	2.75	3.50	3.00	1.38
S	3	2.25	2.75	2.25	1.13
TE	21	3.25	3.25	3.00	0.81
S	6	3.00	2.75	2.50	0.75

SRA [Relevance] = P Imp * (P Adopt - C Adopt)

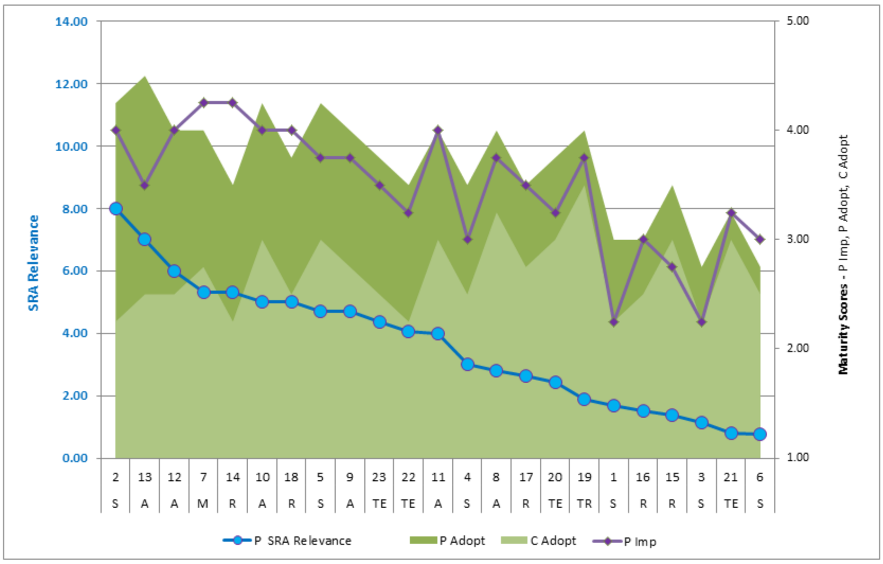

Figure 7 a – Grids ranking table & graph [4 respondents]

Grids : P - SRA [Relevance] = P Imp * (P Adopt - C Adopt)

SMARTT cat.	ICT Theme no.	ICT Theme description	Adoption Delta	Highest C Adopt
S	2	Human factors Engineering ICTs to gather and model data describing the behaviour of end users/energy consumers	2.00	Grids
A	13	User Centred Data Visualisation ICTs to support system state awareness by human operators / users	2.00	Grids
A	12	Operational decision support ICTs that integrate high level diverse systems such as safety, security, weather and energy etc. at individual, building or district level for near real-time decision making	1.50	Grids
M	7	Mobile Decision Support ICTs that utilise real-time communication to facilitate in the field decision making particularly in construction or civil engineering tasks	1.25	Grids
R	14	Inter-Enterprise ICTs for supporting coordination e.g. contract & supply-network management in the context of reduced energy consumption	1.25	MFG / Grids
A	10	Software & algorithms for operational monitoring & actuation of devices at machine, plant or building level	1.25	Grids
R	18	Modelling & simulation ICTs e.g. What-if scenario planning continuous improvement across a sectors life cycle	1.25	MFG
S	5	Simulation ICTs for predicting/estimating the dynamic behaviour of a system as part of the design function E.G. Computational Fluid dynamics, Finite element mode analysis, power system simulation etc.	1.25	MFG / Grids
A	9	Embedded intelligent devices (micro architecture)for operational control, sensing & actuation at machine, plant or building level	1.25	Grids
TE	23	Use of cloud based services for tasks such as data management, monitoring and analysis	1.25	Grids
TE	22	Integration technologies / approaches such as service orientation and event driven architectures to facilitate heterogeneous device data interoperability at enterprise, network and environment level	1.25	MFG
A	11	Inference sensing Software & algorithms for pattern & signal identification at machine, plant or building level	1.00	Grids
S	4	Causal Modelling ICTs used to describe / predict relationships in physical systems E.G. computer-aided diagramming (e.g. Sankey, Cause and effect, influence diagrams etc.), Life cycle modelling, statistical packages such as JMP & MatLab etc.	1.00	MFG
A	8	Secure/resilient wired, wireless and optical infrastructure for operational communication, monitoring & control	0.75	Grids
R	17	ICTs for data mining & analytics in terms of energy consumption & optimisation, pattern identification, predictive diagnostics & analytics at enterprise or network level	0.75	Grids
TE	20	ICT standards and protocols for interoperability across heterogeneous devices at an enterprise, network or environmental level	0.75	Light / Grid
TR	19	Trading & Energy Brokerage ICTs e.g. Consumer/Producer forecasting algorithms, energy source tracking, consumption/price negotiation	0.50	Grids
S	1	Design conceptualisation ICTs for requirement engineering & ideation. E.G. Quality Function Deployment, Mind maps etc.	0.75	MFG
R	16	Knowledge sharing ICTs, knowledge management, knowledge repositories, knowledge mining and semantic search, linked data, long-term data archival and recovery at enterprise or inter-enterprise level	0.50	MFG / Grid
R	15	Business Process Integration & collaboration ICTs E.g. collaboration support, groupware tools, electronic conferencing, social-media, etc.	0.50	MFG
S	3	Visual / spatial design ICTs E.G. CAD (Autodesk, 3D studio max), Multimedia (e.g. Flash, Silverlight), Graphics (e.g. Photoshop, Illustrator) for digital mock-up etc.	0.50	MFG
TE	21	Real-time analytical technologies such as Complex Event Processing and in-memory databases for enhanced operational control and awareness	0.25	Grids
S	6	Product/component specification and selection ICTs E.G. material characteristic database specifying embedded energy, recyclability, thermal performance etc.	0.25	Grids / Built E

Figure 7 b – Grids Potential SRA ranking

Figures 7a and 7b show the results of the survey and analysis. The results can be compared against the following key RTDs that were identified by the Grids consortium/REG break-out group (see deliverable D4.3-1b International Workshop Report 2: Vision validation')[x].

- **Monitoring and control systems of distribution networks:**
  - Include monitoring and control of DES (Distributed Energy Resources), RES (Retail Energy Suppliers) and DSM (Demand Side Managed consumers).
  - Link the control of local energy generators to the control of large scale energy generators.
  - Total energy generation (large scale and small scale) and total consumption must be balanced at all time. The complexity of the control algorithms and the coordination between all controllers is not available yet.
- **Energy market and electricity price determination:** market participants will change. The market rules should probably be changed, price calculation algorithms should definitely be changed:
  - Optimisation of financial result, environmental parameters and the stability of the grids, and security of energy supply to consumers
  - Economic: providing best value through innovation, efficient energy management and 'level playing field' competition and regulation
  - Accessible: granting connection access to all network users, particularly for renewables
  - Market structures should allow for intermittent generators
- **Prosumers Interfaces:** The local interfaces in households, to the installations that monitor and control the local consumption / generation should provide advice and a clear overview of possible scenarios and options with the effects of each possibility.

These key RTDs are generally consistent with the qualitative survey answers but the analysis shown above offers greater detail for SRA consideration. Of particular note are the two themes below which were somewhat at odds with sector specific discussions.

Theme [19] 'Trading and Transactional ICTs' scored lower down on the SRA relevance list than expected. The reason for this was interpreted as being a result of higher than expected current adoption scores. The average score for Grids was 2X the other sectors. This low position is not supported by the above key ICTs identified in the workshop nor does it tally with the conversations we have had with experts in the Grids domain. One reason we can suggest is that current adoption was miss-interpreted or that the experts had specific knowledge of standalone cases of adoption, another is that there is a difference between the currently implemented ICTs meant for few large scale generators and future yet to be developed ICTs meant to handle large numbers of small scale generators, and this difference is not always recognised. This would need further discussion as part of SRA development in D3.2.

Theme [20] also scored quite low, although it was felt this was more justified given various initiatives in terms of standardisation within the Smart grids domain. Nevertheless, in discussions to date the message is clear - standards require further advancement in terms of industrial 'in-the-field' adoption, and this is not well reflected in the above analysis. Of course response rate could be a factor here.

4.2 Key RTD/ICTs for Buildings

		Maturity Scores			
		P Imp	P adopt	C Adopt	P SRA Relevance
TE	20	4.25	4.25	1.50	11.69
TE	23	4.00	4.25	1.38	11.50
R	17	4.75	4.13	1.75	11.28
A	12	4.25	4.00	1.75	9.56
S	2	4.38	3.88	1.88	8.75
A	9	4.25	3.63	1.75	7.97
R	18	4.13	3.88	2.00	7.73
S	5	4.63	4.13	2.50	7.52
S	6	4.00	4.25	2.50	7.00
A	11	3.63	3.63	1.75	6.80
M	7	4.00	3.50	1.88	6.50
A	8	4.00	3.88	2.25	6.50
A	10	4.00	3.75	2.13	6.50
S	3	4.25	4.50	3.13	5.84
A	13	3.75	3.63	2.13	5.63
TE	21	3.00	3.25	1.50	5.25
R	14	3.50	3.13	1.63	5.25
TR	19	3.50	3.25	1.75	5.25
TE	22	3.38	3.25	1.75	5.06
S	4	3.50	3.13	2.00	3.94
R	15	3.25	3.63	2.63	3.25
R	16	3.25	3.00	2.25	2.44
S	1	3.13	2.75	2.00	2.34

SRA [Relevance] = P Imp * (P Adopt - C Adopt)

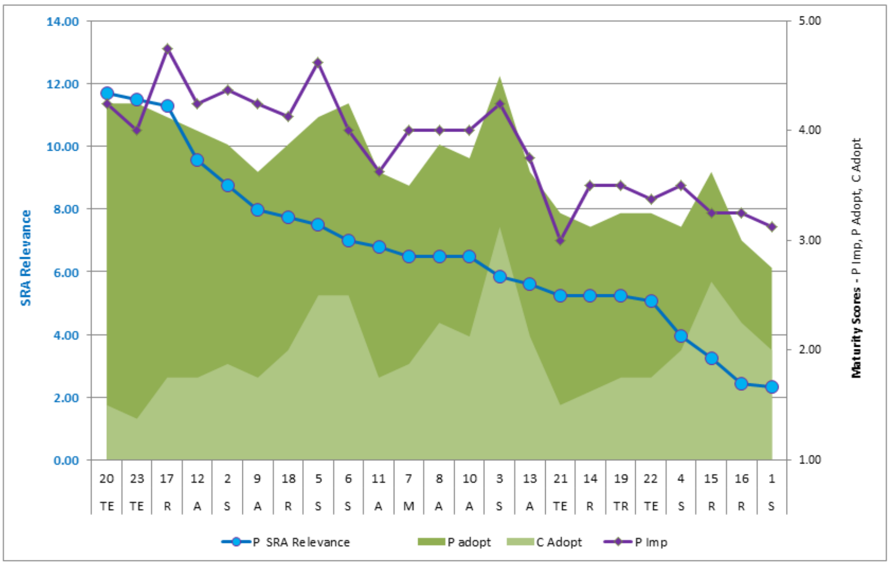

Figure 8 a – Built environment ranking table & graph [10 respondents]

Built E : P - SRA [Relevance] = P Imp * (P Adopt - C Adopt)

SMARTT cat.	ICT Theme no.	ICT Theme description	Adoption Delta	Highest C Adopt
TE	20	ICT standards and protocols for interoperability across heterogeneous devices at an enterprise, network or environmental level	2.75	Light / Grids
TE	23	Use of cloud based services for tasks such as data management, monitoring and analysis	2.88	Grids
R	17	ICTs for data mining & analytics in terms of energy consumption & optimisation, pattern identification, predictive diagnostics & analytics at enterprise or network level	2.38	Grids
A	12	Operational decision support ICTs that integrate high level diverse systems such as safety, security, weather and energy etc. at individual, building or district level for near real-time decision making	2.25	Grids
S	2	Human factors Engineering ICTs to gather and model data describing the behaviour of end users/energy consumers	2.00	Grids
A	9	Embedded intelligent devices (micro architecture)for operational control, sensing & actuation at machine, plant or building level	1.88	Grids
R	18	Modelling & simulation ICTs e.g. What-if scenario planning continuous improvement across a sectors life cycle	1.88	MFG
S	5	Simulation ICTs for predicting/estimating the dynamic behaviour of a system as part of the design function E.G. Computational Fluid dynamics, Finite element model analysis, power system simulation etc.	1.63	MFG / Grids
S	6	Product/component specification and selection ICTs E.G. material characteristic database specifying embedded energy, recyclability, thermal performance etc.	1.75	Built E / Grids
A	11	Inference sensing Software & algorithms for pattern & signal identification at machine, plant or building level	1.88	Grids
M	7	Mobile Decision Support ICTs that utilise real-time communication to facilitate in the field decision making particularly in construction or civil engineering tasks	1.63	Grids
A	8	Secure/resilient wired, wireless and optical infrastructure for operational communication, monitoring & control	1.63	Grids
A	10	Software & algorithms for operational monitoring & actuation of devices at machine, plant or building level	1.63	Grids
S	3	Visual / spatial design ICTs E.G. CAD (Autodesk, 3D studio max), Multimedia (e.g. Flash, Silverlight), Graphics (e.g. Photoshop, Illustrator) for digital mock-up etc.	1.38	MFG
A	13	User Centred Data Visualisation ICTs to support system state awareness by human operators / users	1.50	Grids
TE	21	Real-time analytical technologies such as Complex Event Processing and in-memory databases for enhanced operational control and awareness	1.75	Grids
R	14	Inter-Enterprise ICTs for supporting coordination e.g. contract & supply-network management in the context of reduced energy consumption	1.50	MFG / Grids
TR	19	Trading & Energy Brokerage ICTs e.g. Consumer/Producer forecasting algorithms, energy source tracking, consumption/price negotiation	1.50	Grids
TE	22	Integration technologies / approaches such as service orientation and event driven architectures to facilitate heterogeneous device data interoperability at enterprise, network and environment level	1.50	MFG
S	4	Causal Modelling ICTs used to describe / predict relationships in physical systems E.G. computer-aided diagramming (e.g. Sankey, Cause and effect, influence diagrams etc.), Life cycle modelling, statistical packages such as JMP & MatLab etc.	1.13	MFG
R	15	Business Process Integration & collaboration ICTs E.g. collaboration support, groupware tools, electronic conferencing, social-media, etc.	1.00	MFG
R	16	Knowledge sharing ICTs, knowledge management, knowledge repositories, knowledge mining and semantic search, linked data, long-term data archival and recovery at enterprise or inter-enterprise level	0.75	MFG / Grids
S	1	Design conceptualisation ICTs for requirement engineering & ideation. E.G. Quality Function Deployment, Mind maps etc.	0.75	MFG

Figure 8 b – Built Environment Potential SRA ranking

Figures 8a and 8b show the results of the survey and analysis. The results can be compared against the following key RTDs that were identified by the Built environment consortium/REG break-out group (see deliverable **D4.3-1b)**

- **BIM:** The extension of BIM & Real time building management systems, incorporating energy efficient design
- **Proactive technologies:** embedded devices for intelligent monitoring and control in terms of energy efficiency
- **Standards:** high and low level interoperability in terms of monitoring and control of elements within the built environment

The key RTDs are consistent with the qualitative survey answers. However, the above trending offers greater detail for SRA consideration. What follows is some brief commentary on the above results.

The number one position of theme [20] 'ICT standards and protocols for interoperability…' is aligned to the above key themes identified by the Built environment consortium/REG break-out group, as is theme [9] 'embedded intelligent devices…'.

Our interpretation is that the key ICT theme of BIM is also supported by the above analysis given the high scoring of the following 'Specification & design' themes namely themes [2], [5] and [6] and due to the position of themes [12]' Operational decision support ICTs that integrate high level diverse systems...', [17] 'ICTs for data mining & analytics…' and [18] 'Modelling & simulation ICTs … across a sectors life cycle'. These themes are consistent with the augmented vision of existing design based tools towards a more holistic lifecycle model that is typically articulated as BIM.

The scoring of theme [7] maybe biased given the explicit association to civil engineering and construction, nevertheless the theme is important for civil engineering and logistical in-the-field optimised execution.

The scoring of theme [23] is higher than the consortium expected and this may be due to a hype-curve bias, however in discussions to date 'cloud base services' have been seen as key to opening up accessibility to powerful analytics and services seen as crucial to energy impact. Another possible reason for its high position relates to the high adoption delta between potential and current adoption. The current adoption being low is expected and typical to the built environment sector, as the industry typically lags in terms of ICT adoption. The high potential adoption of cloud computing may be a result of perception with regard ease of implementation as the infrastructure already exists, doesn't need sophisticated set up, is not expensive and is almost immediately deployable.

This theme would have to be investigated further as part of D3.2 discussions while extension of the survey may of course see positional changes.

4.3 Key RTD/ICTs for Manufacturing

		Maturity Scores			
		P Imp	P adopt	C Adopt	P - SRA Relevance
A	11	4.50	4.75	1.75	13.50
A	10	4.50	4.50	2.25	10.13
R	17	4.50	4.25	2.00	10.13
A	12	4.00	4.25	1.75	10.00
A	9	4.75	4.50	2.50	9.50
TR	19	3.50	3.75	1.25	8.75
TE	21	4.00	4.00	2.00	8.00
S	6	4.50	4.00	2.25	7.88
A	13	3.75	4.25	2.25	7.50
R	14	3.75	4.25	2.25	7.50
TE	23	3.25	3.75	1.50	7.31
A	8	4.00	4.25	2.50	7.00
S	2	3.25	3.75	2.00	5.69
R	16	3.75	4.00	2.50	5.63
R	18	4.25	4.50	3.25	5.31
TE	22	3.50	4.00	2.50	5.25
M	7	3.25	3.50	2.00	4.88
S	5	4.50	4.00	3.00	4.50
TE	20	3.50	4.00	2.75	4.38
S	4	4.00	4.00	3.00	4.00
R	15	2.75	4.25	3.25	2.75
S	1	2.75	3.75	3.25	1.38
S	3	3.50	4.00	3.75	0.88

SRA [Relevance] = P Imp * (P Adopt - C Adopt)

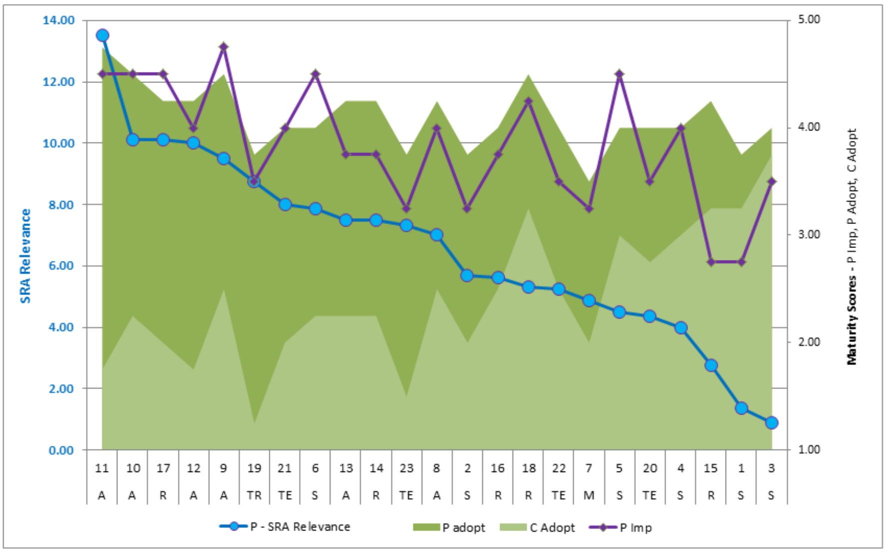

Figure 9 a – Manufacturing ranking table & graph [5 respondents]

MFG : P - SRA [Relevance] = P Imp * (P Adopt - C Adopt)

SMARTT cat.	ICT Theme no.	ICT Theme description	Adoption Delta	Highest C Adopt
A	11	Inference sensing Software & algorithms for pattern & signal identification at machine, plant or building level	3.00	Grids
A	10	Software & algorithms for operational monitoring & actuation of devices at machine, plant or building level	2.25	Grids
R	17	ICTs for data mining & analytics in terms of energy consumption & optimisation, pattern identification, predictive diagnostics & analytics at enterprise or network level	2.25	Grids
A	12	Operational decision support ICTs that integrate high level diverse systems such as safety, security, weather and energy etc. at individual, building or district level for near real-time decision making	2.50	Grids
A	9	Embedded intelligent devices (micro architecture)for operational control, sensing & actuation at machine, plant or building level	2.00	Grids
TR	19	Trading & Energy Brokerage ICTs e.g. Consumer/Producer forecasting algorithms, energy source tracking, consumption/price negotiation	2.50	Grids
TE	21	Real-time analytical technologies such as Complex Event Processing and in-memory databases for enhanced operational control and awareness	2.00	Grids
S	6	Product/component specification and selection ICTs E.G. material characteristic database specifying embedded energy, recyclability, thermal performance etc.	1.75	Built E / Grids
A	13	User Centred Data Visualisation ICTs to support system state awareness by human operators / users	2.00	Grids
R	14	Inter-Enterprise ICTs for supporting coordination e.g. contract & supply-network management in the context of reduced energy consumption	2.00	MFG / Grids
TE	23	Use of cloud based services for tasks such as data management, monitoring and analysis	2.25	Grids
A	8	Secure/resilient wired, wireless and optical infrastructure for operational communication, monitoring & control	1.75	Grids
S	2	Human factors Engineering ICTs to gather and model data describing the behaviour of end users/energy consumers	1.75	Grids
R	16	Knowledge sharing ICTs, knowledge management, knowledge repositories, knowledge mining and semantic search, linked data, long-term data archival and recovery at enterprise or inter-enterprise level	1.50	MFG / Grids
R	18	Modelling & simulation ICTs e.g. What-if scenario planning continuous improvement across a sectors life cycle	1.25	MFG
TE	22	Integration technologies / approaches such as service orientation and event driven architectures to facilitate heterogeneous device data interoperability at enterprise, network and environment level	1.50	MFG
M	7	Mobile Decision Support ICTs that utilise real-time communication to facilitate in the field decision making particularly in construction or civil engineering tasks	1.50	Grids
S	5	Simulation ICTs for predicting/estimating the dynamic behaviour of a system as part of the design function E.G. Computational Fluid dynamics, Finite element mode analysis, power system simulation etc.	1.00	MFG / Grid
TE	20	ICT standards and protocols for interoperability across heterogeneous devices at an enterprise, network or environmental level	1.25	Light / Grids
S	4	Causal Modelling ICTs used to describe / predict relationships in physical systems E.G. computer-aided diagramming (e.g. Sankey, Cause and effect, influence diagrams etc.), Life cycle modelling, statistical packages such as JMP & MatLab etc.	1.00	MFG
R	15	Business Process Integration & collaboration ICTs E.g. collaboration support, groupware tools, electronic conferencing, social-media, etc.	1.00	MFG
S	1	Design conceptualisation ICTs for requirement engineering & ideation. E.G. Quality Function Deployment, Mind maps etc.	0.50	MFG
S	3	Visual / spatial design ICTs E.G. CAD (Autodesk, 3D studio max), Multimedia (e.g. Flash, Silverlight), Graphics (e.g. Photoshop, Illustrator) for digital mock-up etc.	0.25	MFG

Figure 9 b – Manufacturing Potential SRA ranking

Figures 9a and 9b show the results of the survey and analysis. The results can be compared against the following key RTDs that were identified by the manufacturing sector consortium/REG break-out group (see deliverable **D4.3-1b)**

- Including energy related methods and functions in planning and design tools for production systems (digital factory)
- Scheduling ICTs (ERP, MES, PPC) with respect to energy efficiency
- considering energy efficiency as an optimization criterion for control systems of machines (e.g. path planning for NC machines or robots, selective switch off of components,)
- Decision support tools for designing global value creation networks (logistics)
- Smart motor systems for machines and other production equipment [As per GeSI Smart 2020 definition - A motor is “smart” when it can be controlled to adjust its power usage to a required output, usually through a VSD and intelligent motor controller (IMC), a piece of hardware controlling the VSD.]
- Intelligent control of compressed air systems

The key RTDs are in the main consistent with the qualitative survey answers. However, the above trending offers greater detail for SRA consideration and some initial observations follow:

Sensing and understanding exactly where energy is consumed within the factory is the prime issue within Manufacturing. This is supported by the fact that four of top five ICTs from figure 9a relate to sensing, monitoring, data mining and analysing the energy consumption of the operational phase on different levels (from process up to plant level). Automation is clearly the category with highest relevance this is to be expected however, it may be a case of response bias as automation is the most easily relatable to direct energy impact.

Analysing the top 11 it would seem there is need for strong interoperability with smart grids given the automation focus and real-time decisions that will drive sustainable manufacturing. That relationship will most likely be channelled through the factories building infrastructure. Data visualisation and operational support will be paramount as will energy trading and consumer producer forecasting given the likely volatility of energy markets.

ICTs for design ranked lower than expected given the main aspects of energy consumption are defined in this phase? The reason may be that while recognised as important the design phase is generally already well supported albeit energy is currently only partly taken into account in practice. This interpretation is supported in the figures whereby we have high ‘potential impact’ and ‘potential adoption’ but low SRA relevance given high ‘current adoption’ scores, [S4 & S5 above being examples of this]

4.4 Key RTD/ICTs for Lighting

		Maturity Scores			P - SRA Relevance
		P Imp	P adopt	C Adopt	
A	12	4.33	4.00	1.33	11.56
A	9	4.33	4.33	2.00	10.11
S	2	3.67	3.33	1.33	7.33
A	10	3.67	4.33	2.33	7.33
A	13	3.00	3.33	1.33	6.00
R	16	3.00	3.33	1.33	6.00
S	4	3.00	3.67	2.00	5.00
A	11	3.00	3.00	1.33	5.00
R	17	3.67	3.67	2.33	4.89
S	1	3.33	3.33	2.00	4.44
TE	22	2.67	2.67	1.00	4.44
S	6	3.33	3.33	2.33	3.33
TR	19	2.33	2.33	1.00	3.11
A	8	4.33	3.67	3.00	2.89
TE	23	2.00	2.67	1.33	2.67
TE	21	2.33	3.00	2.00	2.33
R	18	3.33	3.33	2.67	2.22
TE	20	3.33	3.67	3.00	2.22
S	5	3.00	3.33	2.67	2.00
S	3	2.33	3.33	3.00	0.78
R	14	2.33	2.67	2.33	0.78
M	7	2.33	2.00	2.00	0.00
R	15	2.67	2.67	2.67	0.00

SRA [Relevance] = P Imp * (P Adopt - C Adopt)

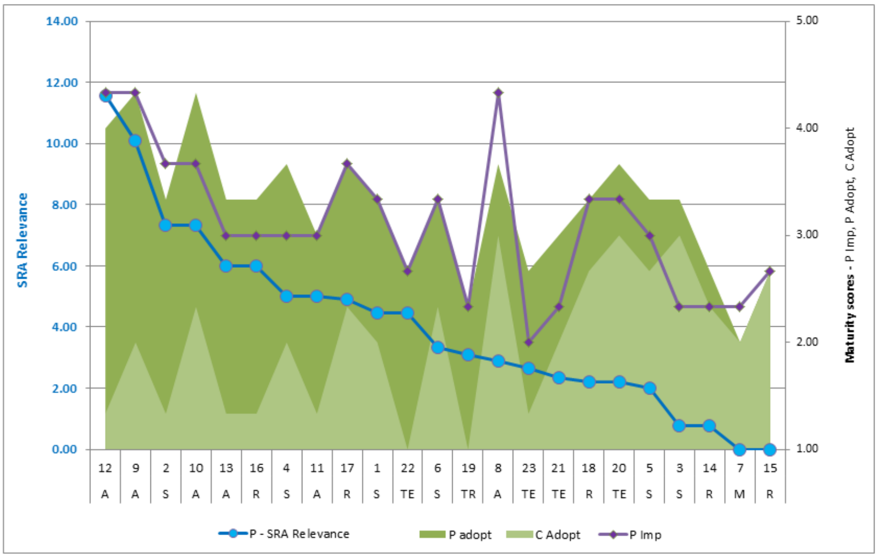

Figure 10 a – Light ranking table & graph [4 respondents]

Light : P - SRA [Relevance] = P Imp * (P Adopt - C Adopt)

SMARTT cat.	ICT Theme no.	ICT Theme description	Adoption Delta	Highest C Adopt
A	12	Operational decision support ICTs that integrate high level diverse systemssuch as safety, security, weather and energy etc at individual, building or district level for near real-time decision making	2.67	Grids
A	9	Embedded intelligent devices (micro architecture)for operational control, sensing & actuation at machine, plant or building level	2.33	Grids
S	2	Human factors Engineering ICTs to gather and model data describing the behaviour of end users/energy consumers	2.00	Grids
A	10	Software & algorithms for operational monitoring & actuation of devices at machine, plant or building level	2.00	Grids
A	13	User Centred Data Visualisation ICTsto support system state awareness by human operators / users	2.00	Grids
R	16	Knowledge sharing ICTs, knowledge management, knowledge repositories, knowledge mining and semantic search, linked data, long-term data archival and recovery at enterprise or inter-enterprise level	2.00	MFG / Grids
S	4	Causal Modelling ICTs used to describe / predict relationships in physical systems E.G. computer-aided diagramming (e.g. Sankey, Cause and effect, influence diagrams etc), Life cycle modelling, statistical packages such as JMP & MatLab etc	1.67	MFG
A	11	Inference sensing Software & algorithms for pattern & signal identification at machine, plant or building level	1.67	Grids
R	17	ICTs for data mining & analytics in terms of energy consumption & optimisation, pattern identification, predictive diagnostics & analytics at enterprise or network level	1.33	Grids
S	1	Design conceptualisation ICTs for requirement engineering & ideation. E.G. Quality Function Deployment, Mind maps etc	1.33	MFG
TE	22	Integration technologies / approaches such as service orientation and event driven architectures to facilitate heterogeneous device data interoperability at enterprise, network and environment level	1.67	MFG
S	6	Product/component specification and selection ICTs E.G. material characteristic database specifying embedded energy, recyclability, thermal performance etc	1.00	Built E / Grids
TR	19	Trading & Energy Brokerage ICTs e.g. Consumer/Producer forecasting algorithms, energy source tracking, consumption/price negotiation	1.33	Grids
A	8	Secure/resilient wired, wireless and optical infrastructure for operational communication, monitoring & control	0.67	Grids
TE	23	Use of cloud based servicesfor tasks such as data management, monitoring and analysis	1.33	Grids
TE	21	Real-time analytical technologies such as Complex Event Processing and in-memory databases for enhanced operational control and awareness	1.00	Grids
R	18	Modelling & simulation ICTs e.g. What-if scenario planning continuous improvement across a sectors life cycle	0.67	MFG
TE	20	ICT standards and protocols for interoperability across heterogeneous devices at an enterprise, network or environmental level	0.67	Light / Grids
S	5	Simulation ICTs for predicting/estimating the dynamic behaviour of a system as part of the design function E.G. Computational Fluid dynamics, Finite element mode analysis, power system simulation etc	0.67	MFG / Grids
S	3	Visual / spatial design ICTs E.G. CAD (Autodesk, 3D studio max), Multimedia (e.g. Flash, Silverlight), Graphics (e.g. Photoshop, Illustrator) for digital mock-up etc	0.33	MFG
R	14	Inter-Enterprise ICTs for supporting coordination e.g. contract & supply-network management in the context of reduced energy consumption	0.33	MFG / Grids
M	7	Mobile Decision Support ICTs that utilise real-time communication to facilitate in the field decision making particularly in construction or civil engineering tasks	0.00	Grids
R	15	Business Process Integration & collaboration ICTs E.g. collaboration support, groupware tools, electronic conferencing, social-media, etc	0.00	MFG

Figure 10 b – Light Potential SRA ranking

Figures 10a and 10b show the results of the survey and analysis. The results can be compared against the following key RTDs that were identified by the Built environment consortium/REG break-out group (see deliverable D4.3-1b**)**

- **Lighting Control:** Integration with day-lighting
- **Total building design:** Methods, Tools, Templates; Utilisation of integrated solutions (lighting + components)
- **Maintenance support:** Working conditions and performance monitoring, Lighting facility management

The key RTDs are in the main consistent with the qualitative survey answers. However the above trending offers greater detail for SRA consideration.

As is the case with all four sectors the emphasis on ‘automation and operational decisions support ICTs’ may be biased due to the fact that it is easier to attribute energy efficiencies to these technologies. However, this does support the importance of ‘Control’ as identified above.

Although the calibre of respondents lends legitimacy to the analysis the number of responses is low and ideally this needs to be increased. Profiles of respondents could be considered to eliminate possible bias.

‘Automation and operational decision support’ themes aside ‘Specification and Design ICTs’ rated the highest in terms of relevance. From a general perspective this supports the assertion that respondents were making correlations or causal connections between energy impact and themes that have no logical direct impact on energy efficiency or consumption. From a Lighting Sector perspective it aligns to the identified importance of ‘total building design’ above.

4.5 ICT4EE - REViSITE output synthesis and interpretation

Having established individual sector trends we set about trying to understand common patterns amongst sectors. Figure 11 below lists the occurrence of themes as they appear in the top 11 (i.e. the top median) of the above sector specific 'P SRA relevance' scores. Six themes appeared in the top median of three sectors with two in all four sectors. Six themes appeared in top median of two sectors and five themes appeared once in the top median of an individual sector.

Appeared in 1 Sector	Appeared in 2 Sectors	Appeared in 3 Sectors	Appeared in 4 Sectors
1	5	2	9
4	6	10	12
19	7	11	
20	14	13	
21	18	17	
	22	23	

Figure 11 – Occurrence of themes within the top median of the four sectors

Figure 12 below, represents mean scores [mean of individual survey respondents by sector] for each theme in terms of 'Potential Impact', 'Current adoption' and 'Potential adoption'.

	Grids Potential Impact	Built E Potential Impact	MFG Potential Impact	Light Potential Impact		Grids Current Adoption	Built E Current Adoption	MFG Current Adoption	Light Current Adoption		Grids Potential Adoption	Built E Potential Adoption	MFG Potential Adoption	Light Potential Adoption
1	2.25	3.13	2.75	3.33	1	2.25	2.00	3.25	2.00	1	3.00	2.75	3.75	3.33
2	4.00	4.38	3.25	3.67	2	2.25	1.88	2.00	1.33	2	4.25	3.88	3.75	3.33
3	2.25	4.25	3.50	2.33	3	2.25	3.13	3.75	3.00	3	2.75	4.50	4.00	3.33
4	3.00	3.50	4.00	3.00	4	2.50	2.00	3.00	2.00	4	3.50	3.13	4.00	3.67
5	3.75	4.63	4.50	3.00	5	3.00	2.50	3.00	2.67	5	4.25	4.13	4.00	3.33
6	3.00	4.00	4.50	3.33	6	2.50	2.50	2.25	2.33	6	2.75	4.25	4.00	3.33
7	4.25	4.00	3.25	2.33	7	2.75	1.88	2.00	2.00	7	4.00	3.50	3.50	2.00
8	3.75	4.00	4.00	4.33	8	3.25	2.25	2.50	3.00	8	4.00	3.88	4.25	3.67
9	3.75	4.25	4.75	4.33	9	2.75	1.75	2.50	2.00	9	4.00	3.63	4.50	4.33
10	4.00	4.00	4.50	3.67	10	3.00	2.13	2.25	2.33	10	4.25	3.75	4.50	4.33
11	4.00	3.63	4.50	3.00	11	3.00	1.75	1.75	1.33	11	4.00	3.63	4.75	3.00
12	4.00	4.25	4.00	4.33	12	2.50	1.75	1.75	1.33	12	4.00	4.00	4.25	4.00
13	3.50	3.75	3.75	3.00	13	2.50	2.13	2.25	1.33	13	4.50	3.63	4.25	3.33
14	4.25	3.50	3.75	2.33	14	2.25	1.63	2.25	2.33	14	3.50	3.13	4.25	2.67
15	2.75	3.25	2.75	2.67	15	3.00	2.63	3.25	2.67	15	3.50	3.63	4.25	2.67
16	3.00	3.25	3.75	3.00	16	2.50	2.25	2.50	1.33	16	3.00	3.00	4.00	3.33
17	3.50	4.75	4.50	3.67	17	2.75	1.75	2.00	2.33	17	3.50	4.13	4.25	3.67
18	4.00	4.13	4.25	3.33	18	2.50	2.00	3.25	2.67	18	3.75	3.88	4.50	3.33
19	3.75	3.50	3.50	2.33	19	3.50	1.75	1.25	1.00	19	4.00	3.25	3.75	2.33
20	3.25	4.25	3.50	3.33	20	3.00	1.50	2.75	3.00	20	3.75	4.25	4.00	3.67
21	3.25	3.00	4.00	2.33	21	3.00	1.50	2.00	2.00	21	3.25	3.25	4.00	3.00
22	3.25	3.38	3.50	2.67	22	2.25	1.75	2.50	1.00	22	3.50	3.25	4.00	2.67
23	3.50	4.00	3.25	2.00	23	2.50	1.38	1.50	1.33	23	3.75	4.25	3.75	2.67

Figure 12 – base unsorted mean scores

Using the reorderable matrix technique we developed the three matrices and corresponding graphs of Figures 13, 14 and 15. Again the benefit of this technique is that it enables identification of overall trends while allowing for identification of variation within individual themes. ICT theme numbers together with the corresponding SMARTT category indicators [i.e. the first two columns of the tables of figures] were hidden during this process to minimise influencing pattern generation. The section that follows offers an interpretation of trends and posits a prioritised list [figure 17] of ICT themes, to be used as an input to the SRA development within deliverable D3.2.

		Light Potential Impact	Grids Potential Impact	MFG Potential Impact	Built E Potential Impact
R	15	2.67	2.75	2.75	3.25
S	1	3.33	2.25	2.75	3.13
S	3	2.33	2.25	3.50	4.25
TE	21	2.33	3.25	4.00	3.00
TE	23	2.00	3.50	3.25	4.00
TE	22	2.67	3.25	3.50	3.38
R	16	3.00	3.00	3.75	3.25
TR	19	2.33	3.75	3.50	3.50
S	4	3.00	3.00	4.00	3.50
A	13	3.00	3.50	3.75	3.75
M	7	2.33	4.25	3.25	4.00
R	14	2.33	4.25	3.75	3.50
TE	20	3.33	3.25	3.50	4.25
S	6	3.33	3.00	4.50	4.00
A	11	3.00	4.00	4.50	3.63
S	2	3.67	4.00	3.25	4.38
R	18	3.33	4.00	4.25	4.13
S	5	3.00	3.75	4.50	4.63
A	8	4.33	3.75	4.00	4.00
A	10	3.67	4.00	4.50	4.00
R	17	3.67	3.50	4.50	4.75
A	12	4.33	4.00	4.00	4.25
A	9	4.33	3.75	4.75	4.25

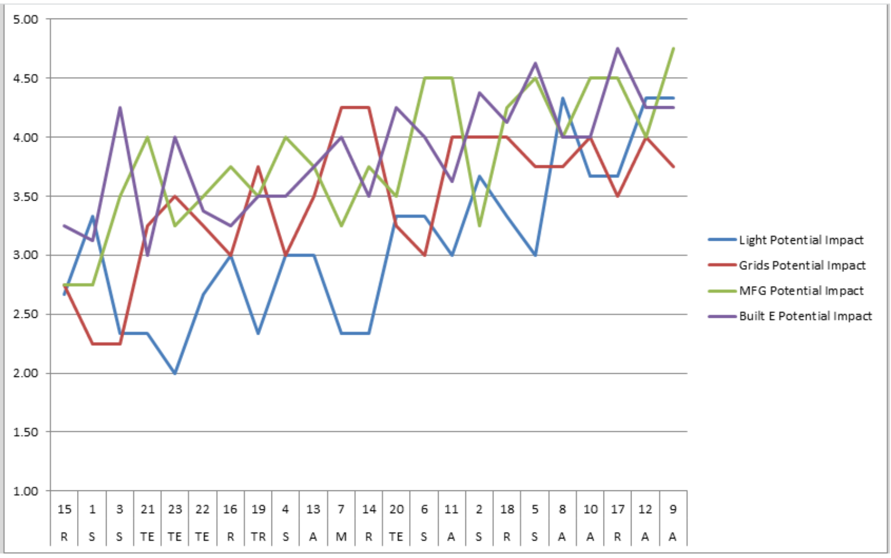

Figure 13 – Potential impact trend all 4 sectors

		Light Potential Adoption	Grids Potential Adoption	Built E Potential Adoption	MFG Potential Adoption
S	1	3.33	3.00	2.75	3.75
M	7	2.00	4.00	3.50	3.50
TR	19	2.33	4.00	3.25	3.75
R	16	3.33	3.00	3.00	4.00
TE	22	2.67	3.50	3.25	4.00
TE	21	3.00	3.25	3.25	4.00
R	14	2.67	3.50	3.13	4.25
R	15	2.67	3.50	3.63	4.25
S	4	3.67	3.50	3.13	4.00
S	6	3.33	2.75	4.25	4.00
TE	23	2.67	3.75	4.25	3.75
S	3	3.33	2.75	4.50	4.00
S	2	3.33	4.25	3.88	3.75
A	11	3.00	4.00	3.63	4.75
R	18	3.33	3.75	3.88	4.50
R	17	3.67	3.50	4.13	4.25
TE	20	3.67	3.75	4.25	4.00
S	5	3.33	4.25	4.13	4.00
A	13	3.33	4.50	3.63	4.25
A	8	3.67	4.00	3.88	4.25
A	12	4.00	4.00	4.00	4.25
A	9	4.33	4.00	3.63	4.50
A	10	4.33	4.25	3.75	4.50

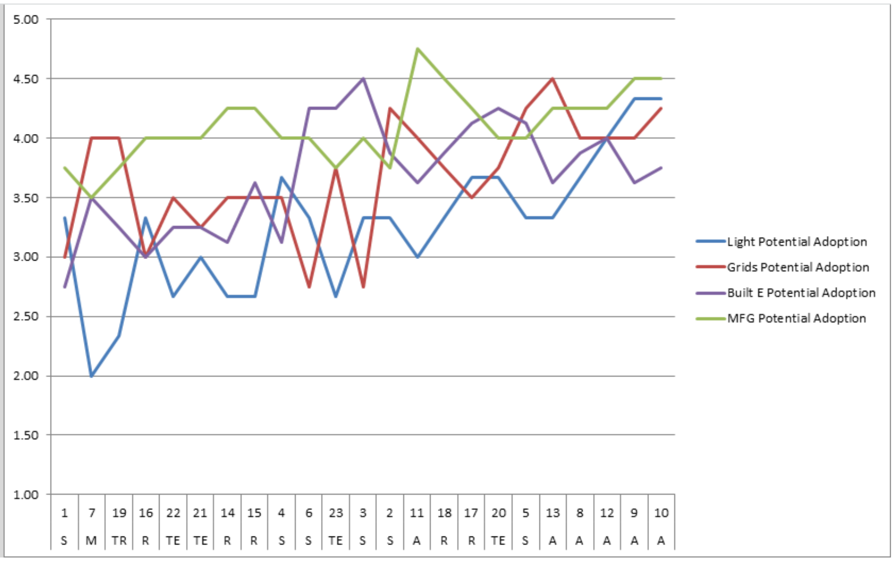

Figure 14 – Potential adoption trend all 4 sectors

		Light Current Adoption	Built E Current Adoption	MFG Current Adoption	Grids Current Adoption
TE	23	1.33	1.38	1.50	2.50
A	12	1.33	1.75	1.75	2.50
S	2	1.33	1.88	2.00	2.25
TR	19	1.00	1.75	1.25	3.50
TE	22	1.00	1.75	2.50	2.25
A	11	1.33	1.75	1.75	3.00
A	13	1.33	2.13	2.25	2.50
R	14	2.33	1.63	2.25	2.25
TE	21	2.00	1.50	2.00	3.00
R	16	1.33	2.25	2.50	2.50
M	7	2.00	1.88	2.00	2.75
R	17	2.33	1.75	2.00	2.75
A	9	2.00	1.75	2.50	2.75
S	1	2.00	2.00	3.25	2.25
S	4	2.00	2.00	3.00	2.50
S	6	2.33	2.50	2.25	2.50
A	10	2.33	2.13	2.25	3.00
TE	20	3.00	1.50	2.75	3.00
R	18	2.67	2.00	3.25	2.50
A	8	3.00	2.25	2.50	3.25
S	5	2.67	2.50	3.00	3.00
R	15	2.67	2.63	3.25	3.00
S	3	3.00	3.13	3.75	2.25

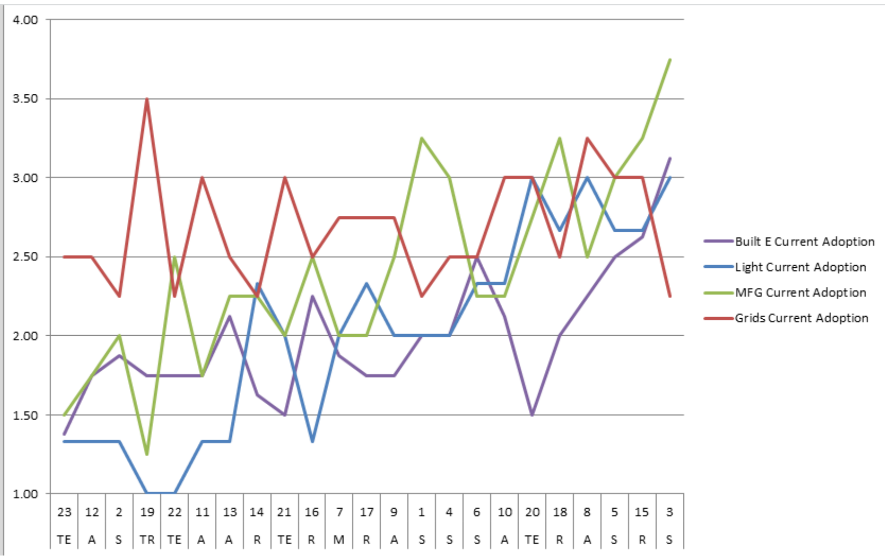

Figure 15 – Current adoption trend all 4 sectors

From figure's 13 and 14 we can see that 'potential impact' and 'potential adoption' trends are quite well matched with an overall shift downward in terms of 'current adoption' notable in figure 15. There is a distinct trend towards SMARTT category 'A' [automation and operational decision support] in terms of 'potential impact' and 'potential adoption' across all sectors. As identified above, this is perhaps unsurprising given the category is easily relatable to direct impact on energy efficiency while other themes have a less direct association.

While the dominance of 'A' is clear other categories show positive trends in terms of impact and potential adoption most notably 'R' [Resource and process management] and 'S' [Specification and design]. Again, this indicates that although no direct energy efficiency impact could be typically related to these themes, respondents had made 'causal connections' in terms of these ICTs indirectly enabling energy efficiency.

For example, returning to the sector specifics of figure 11, 'S' 'specification and design' ICTs feature quite prominently, with theme [2] 'Human factors Engineering ICTs…' appearing in the top median of three sectors, while theme [5] 'Simulation ICTs for predicting/estimating … as part of the design function' and [6] 'Product/component specification and selection ICTs' appeared in the top median of two.

Staying with figure 11 two 'R' themes that featured as having high impact potential were [18] 'Modelling & simulation ICTs…' appearing in the top median of two sectors and [17] 'ICTs for data mining & analytics…' which appeared in the top median of three. Again having no logical direct effect on energy this suggests respondents were inferring causation when answering the survey.

Figure 16 below represents the mean of all four sector scores for each theme ranked in order of importance for both 'potential impact' and 'potential SRA relevance'. As in the sector specific cases P SRA = P Impact * (P Adoption – C Adoption). The interesting element in comparing 'P Impact' and 'P SRA' is that while some elements may score highly in terms of impact, and hence need to be considered, they may not be the most appropriate theme in terms of SRA development.

Apart from some positional differences the top 11 themes had limited changes, with themes [5] and [6] dropping outside the top median with [13] and [23] moving in. Theme [6] 'Product/component specification and selection ICTs …' while shifting out of the top median moved only three positions to 13th. From initial qualitative discussions, theme [6] is seen to be an important element in terms of the augmentation of existing 'visual / spatial design ICTs' towards integrative models such as BIM. Theme [5] 'Simulation ICTs for predicting/estimating the dynamic behaviour of a system as part of the design function' scored highly in terms of 'P impact' however its adoption delta score and its overall low scoring in the Lighting sector accounted for a 10 place positional drop when it came to a potential SRA relevance. Both theme [5] and [6] serve as prime examples as to why 'P impact' scores need to be considered in conjunction with 'P SRA' scores and qualitative discussion in building up a useful picture.

Theme [13] 'User Centred Data Visualisation ICTs to support system state awareness by human operators / users' did not appear in the top 11 of any sector in terms of 'potential impact' ranking just outside in all cases. However, when it came to 'potential adoption' theme [13] scored as number one in Grids and number seven in Manufacturing while maintaining top 11 positions in the other two sectors. This is one example of a theme were the adoption delta between 'P Adopt' and 'C adopt' pushing up the overall score. One interpretation for this specific case might be that ease of adoption and the potential for scalability particularly in the residential space results in a greater aggregated impact than would otherwise be envisaged in standalone scenarios. Nevertheless, upward movement of theme [13] is entirely consistent with the 'prosumer interfaces' called for in the Grid space, the need for greater operation decision support tools called for in the manufacturing space and the deployment for home energy management [HEMs] type devices called for within the built environment domain.

P Impact		P SRA		P-SRA >>>>>> P-Imp
SMARTT Cat.	ICT Theme No.	ICT Theme No.	SMARTT Cat.	
A	9	12	A	(+1)
A	12	9	A	(-1)
R	17	**2**	**S**	**(+5)**
A	10	**11**	**A**	**(+5)**
A	**8**	10	A	(-1)
S	**5**	17	R	(-3)
R	18	**13**	**A**	**(+5)**
S	2	**23**	**TE**	**(+11)**
A	11	20	TE	(+2)
S	6	18	R	(-3)
TE	20	**8**	**A**	**(+6)**
A	13	**19**	**TR**	**(+4)**
R	14	6	S	(-3)
M	7	14	R	(-1)
S	**4**	22	TE	(+3)
TR	**19**	**5**	**S**	**(-10)**
R	16	7	M	(-3)
TE	22	21	TE	(+2)
TE	**23**	**4**	**S**	**(-4)**
TE	21	16	R	(-3)
S	3	1	S	(+1)
S	1	3	S	(-1)
R	15	15	R	0

Figure 16 – Sectorial difference [P impact] versus [P SRA]

Another interesting aspect of the 'P Impact' ranking of figure 16 is the rank positions relating to 'technical integration' themes. Qualitative survey answers and conversations with stakeholders would suggest the overwhelming importance of technical integration and interoperability yet only theme [20] 'ICT standards and protocols for interoperability across heterogeneous devices …' ranked in the top median of 'P Impact'.

When it came to 'P SRA' mean scores the 'technical integration' themes all moved up in position. For themes [20], [21] and [22] this was a two to three position change however in the case of [23] 'Cloud computing' the shift was plus eleven places.

It is unsurprising to see theme [20] ‘ICT standards and protocols for interoperability…’ in the top median however this was predominantly driven by its No. 1 ranking within the Built Environment (see section 4.2), the fact that it scored outside the top median in all other sectors with respect to ‘P SRA’ is somewhat surprising. But this is one example where the ‘adoption delta multiplier’ breaks down somewhat. Conversations suggest this theme is paramount to ICT4EE impact but that advancement is often more about harmonisation as opposed to development and this could explain the smaller adoption delta, which as a multiplier affects the overall ranking. Again while the overall P SRA analysis is useful one needs to leverage other reference points.

Theme [23] ‘Cloud based services’ is somewhat curious, perhaps its high ranking is down to a hype curve bias, perceived ease of adoption or perhaps it reflects a belief that ‘Cloud’ will allow SME level access to the type of analytical and HPC services that are typically at the behest of larger organisations. Whatever the reasoning, this is a subject that will need to be teased out as part of D3.2.

Another interesting element is the low scoring of themes [21] ‘Real-time analytical technologies such as Complex Event Processing and in-memory databases …’ and [22] ‘Integration technologies / approaches such as service orientation and event driven architectures …’ Only Manufacturing scored theme [21] in the top median in terms of ‘P Impact’. Again given that interoperability, integration and analytics are so prominent in our discussions it would seem strange that these ICTs would not score higher. Is this a lack of understanding with regard the importance such ICTs play with regard higher order services such as [17] ‘data analytics’? or is it simply a case that the description was not well enough defined within the survey or that respondents simply do not see these themes as important, this is a question that would need to be discussed as part of D3.2 development.

The five place positional rise of theme [2] ‘Human factors Engineering ICTs …’ and [11] ‘Inference sensing Software & algorithms …’ would seem to make sense given initial stakeholder discussions and the scored adoption delta.

The six place positional drop in terms of theme [8] ‘Secure/resilient wired, wireless and optical infrastructure…’ also seems logical. While seen as key enabler, current adoption is quite high and this would explain the drop, harmonisation of standards was again raised here in initial discussions.

The move to position 12 by theme [19] ‘Trading & Energy Brokerage ICTs…’ would seem logical in the context of a Smart grid vision however overall ‘P Impact’ scores were lower than one might have expected. The push up in terms of ‘P SRA relevance’ was due to the adoption delta. However an interesting element here is that this delta was not as broad as one might have envisaged due to 2x current adoption delta score within Grids. Again this would need to be discussed as part of SRA development.

SMARTT cat.	ICT Theme no.	ICT Theme description	adoption delta
A	12	Operational decision support ICTs that integrate high level diverse systems such as safety, security, weather and energy etc. at individual, building or district level for near real-time decision making	2.23
A	9	Embedded intelligent devices (micro architecture)for operational control, sensing & actuation at machine, plant or building level	1.86
S	2	Human factors Engineering ICTs to gather and model data describing the behaviour of end users/energy consumers	1.94
A	11	Inference sensing Software & algorithms for pattern & signal identification at machine, plant or building level	1.89
A	10	Software & algorithms for operational monitoring & actuation of devices at machine, plant or building level	1.78
R	17	ICTs for data mining & analytics in terms of energy consumption & optimisation, pattern identification, predictive diagnostics & analytics at enterprise or network level	1.68
A	13	User Centred Data Visualisation ICTs to support system state awareness by human operators / users	1.88
Te	23	Use of cloud based services for tasks such as data management, monitoring and analysis	1.93
Te	20	ICT standards and protocols for interoperability across heterogeneous devices at an enterprise, network or environmental level	1.35
R	18	Modelling & simulation ICTs e.g. What-if scenario planning continuous improvement across a sectors life cycle	1.26
A	8	Secure/resilient wired, wireless and optical infrastructure for operational communication, monitoring & control	1.20
Tr	19	Trading & Energy Brokerage ICTs e.g. Consumer/Producer forecasting algorithms, energy source tracking, consumption/price negotiation	1.46
S	6	Product/component specification and selection ICTs E.G. material characteristic database specifying embedded energy, recyclability, thermal performance etc.	1.19
R	14	Inter-Enterprise ICTs for supporting coordination e.g. contract & supply-network management in the context of reduced energy consumption	1.27
Te	22	Integration technologies / approaches such as service orientation and event driven architectures to facilitate heterogeneous device data interoperability at enterprise, network and environment level	1.48
S	5	Simulation ICTs for predicting/estimating the dynamic behaviour of a system as part of the design function E.G. Computational Fluid dynamics, Finite element mode analysis, power system simulation etc.	1.14
M	7	Mobile Decision Support ICTs that utilise real-time communication to facilitate in the field decision making particularly in construction or civil engineering tasks	1.09
Te	21	Real-time analytical technologies such as Complex Event Processing and in-memory databases for enhanced operational control and awareness	1.25
S	4	Causal Modelling ICTs used to describe / predict relationships in physical systems E.G. computer-aided diagramming (e.g. Sankey, Cause and effect, influence diagrams etc.), Life cycle modelling, statistical packages such as JMP & MatLab etc.	1.20
R	16	Knowledge sharing ICTs, knowledge management, knowledge repositories, knowledge mining and semantic search, linked data, long-term data archival and recovery at enterprise or inter-enterprise level	1.19
S	1	Design conceptualisation ICTs for requirement engineering & ideation. E.G. Quality Function Deployment, Mind maps etc.	0.83
S	3	Visual / spatial design ICTs E.G. CAD (Autodesk, 3D studio max), Multimedia (e.g. Flash, Silverlight), Graphics (e.g. Photoshop, Illustrator) for digital mock-up etc.	0.61
R	15	Business Process Integration & collaboration ICTs E.g. collaboration support, groupware tools, electronic conferencing, social-media, etc.	0.63

Figure 17 – Cross-Sectorial SRA themes ranked in terms of potential relevance

We conclude the interpretation section by summarising the cross-sector themes ranked in terms of ‘P SRA relevance’. Figure 17 above is the overall resulting output from the exercise and offers a prioritised list of ICT themes to be considered, figure 18 below is a graphical representation of the same, while figure 19 is a an un-sorted histogram comparing SRA relevance across the sectors.

The purpose of the framework of D2.1 and its output in the survey of D2.3 was to qualitatively test the ‘causal’ association of ICT themes, their impact on energy efficiency and relevance in terms of SRA inclusion. We propose the above analysis helps to make such connections.

Figure 17, the sector specific tables above and the qualitative discussion they will generate shall, in the opinion of the consortium, be critical to shaping the SRA of D3.2. As stated above, the survey and results will be made available through the REViSITE website and will remain live over the course of the project, thus continuing to inform the SRA and Implementation Action Plan [IAP].

Figure 18 – Graphical view Cross-sectorial SRA themes

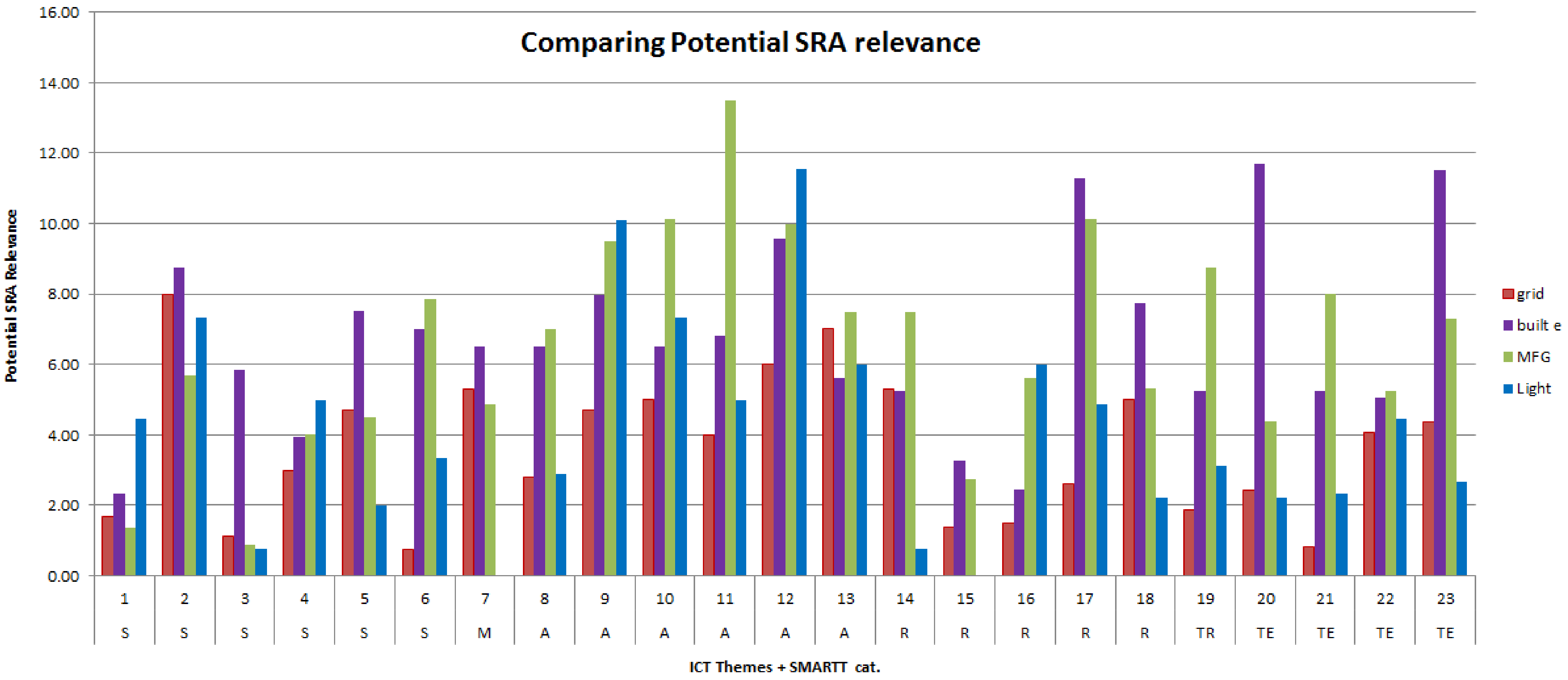

Figure 19 – Comparing Potential SRA relevance between sectors [unsorted]

5 CONSIDERATIONS AND CONCLUSIONS

Given the arduous nature in quantitatively assessing the impact of ICT on energy efficiency, we have throughout work package 2, posited the utilisation of an adapted capability maturity framework coupled with Life cycle thinking in leveraging the heuristics of sector experts.

The purpose of this document was to develop a model outlining key ICTs with respect to energy efficiency for SRA development, based on the analysis of deliverable D2.2 and utilising the framework/methodology developed in deliverable D2.1.

We believe we have achieved this aim with deliverable D2.3 offering a more in-depth analysis of ICT themes identified within the D2.2 and project workshops. The deliverable survey and trend analysis offers, in the opinion of the consortium, trajectories for SRA discussion.

The plan going forward is to allow for continued input to this analysis via the REViSITE website. In essence it is envisaged D2.3 will become a living document that captures the views and reflects the opinion of the wider community as it grows.

6 ACKNOWLEDGEMENTS

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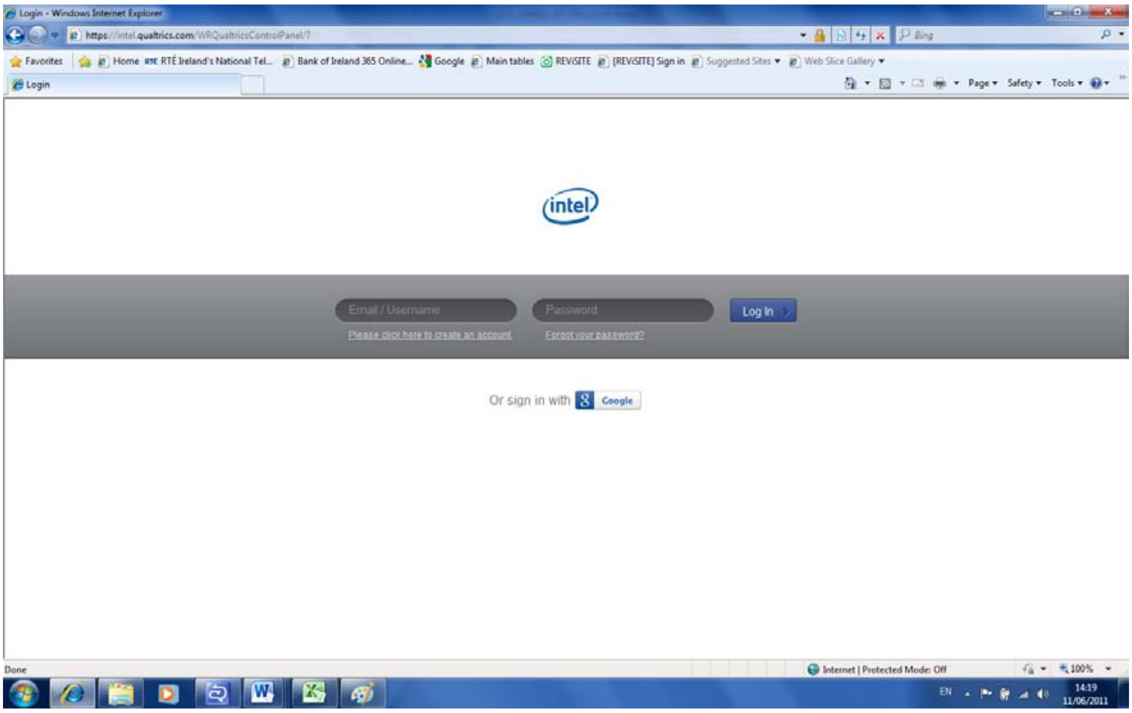
The authors wish to acknowledge the Commission for their support, the efforts of the partners and the contributions of all those involved in REViSITE especially REG members and Dr Connor Upton [Intel].

7 APPENDICES & REFERENCES

Appendix 1 [Survey screen captures]



REViSITE ICT 4 Energy Efficiency Survey

Thank you for taking time-out to respond to this survey. Rest assured it will be time well spent as your inputs will help shape a Strategic Research Agenda that will influence future EC Framework Programs.

The survey should take approx 15-25 minutes to complete.

Please note - it is recognised that in many situations - economic, social and political issues or sector specific non-ICT technologies can offer greater significance in terms of enabling energy efficiency or energy consumption reductions.

However, the focus here is on Information Communication Technologies or ICT related Research Technology Developments [RTDs] that have the potential to enable energy efficiency or energy consumption reduction in other non-ICT sectors.

In responding, you may feel unable or unqualified to answer some questions however we ask that you merely offer an opinion, 'gut-feeling' in such cases.

All results will be made public on the REViSITE website

Thank you again

The REViSITE Team

Please identify a sector for which you will answer / relate all subsequent questions

- Energy Grids
- Built Environment
- Manufacturing
- Lighting
- Transport logistics

Name 3 ICTs / RTDs that have, in your opinion, the best potential for positively impacting on the energy efficiency / consumption of your identified sector

1

2

3

Can you identify any specific ICTs and/or practices used for qualitatively or quantitatively assessing the enabling impact of ICTs on energy efficiency

<< >>

With respect to **energy efficiency** and/or **reduced energy consumption** within your identified sector, rate each theme below in terms of :-

1) potential impact **2)** current adoption & **3)** potential adoption

	Potential Impact					Current adoption					Potential adoption				
	Very Low	Low	Med	High	Very High	Very Low	Low	Med	High	Very High	Very Low	Low	Med	High	Very High
1) Design conceptualisation ICTs for requirement engineering & ideation. E.G. Quality Function Deployment, Mind maps etc															
2) Human factors Engineering ICTs to gather and model data describing the behaviour of end users/energy consumers															
3) Visual / spatial design ICTs. E.G. such as CAD (e.g. Autodesk, 3D studio max), Multimedia (e.g. Flash, Silverlight), Graphics (e.g. Photoshop, Illustrator) for digital mock-up etc															
4) Causal Modelling ICTs used to describe / predict relationships in physical systems. E.G. computer-aided diagramming (e.g. Sankey, Cause and effect, influence diagrams etc), Life cycle modelling, statistical packages such as JMP & MatLab etc															
5) Simulation ICTs for predicting/estimating the dynamic behaviour of a system as part of the design function. E.G. Computational Fluid dynamics, Finite element mode analysis, power system simulation etc															
6) Product/component specification and selection ICTs E.G. material characteristic database specifying embedded energy, recyclability, thermal performance etc															
7) Mobile Decision Support ICTs that utilise real-time communication to facilitate "in the field" decision making particularly in construction or civil engineering tasks															

[Optional] feel free to add comments regarding interpretation of the questions asked above......please make reference to the question number when doing so

With respect to energy efficiency and/or reduced energy consumption within your identified sector, rate each theme below in terms of :-

1) potential impact **2)** current adoption & **3)** potential adoption

	Potential Impact					Current adoption					Potential adoption				
	Very Low	Low	Med	High	Very high	Very Low	Low	Med	High	Very High	Very Low	Low	Med	High	Very High
1) Secure/resilient wired, wireless and optical infrastructure for operational communication, monitoring & control															
2) Embedded intelligent devices (micro architecture) for operational control, sensing & actuation at machine, plant or building level															
3) Software & algorithms for operational monitoring & actuation of devices at machine, plant or building level															
4) Inference sensing Software & algorithms for pattern & signal identification at machine, plant or building level															
5) Operational decision support ICTs that integrate high level diverse systems such as safety, security, weather and energy etc at individual, building or district level for near real-time decision making															
6) User Centred Data Visualisation ICTs to support system state awareness by human operators / users															

[Optional] feel free to add comments regarding interpretation of the questions asked above......please make reference to the question number when doing so.

<< >>

With respect to energy efficiency and/or reduced energy consumption within your identified sector, rate each theme below in terms of :-

1) potential impact **2)** current adoption & **3)** potential adoption

	Potential impact					Current adoption					Potential adoption				
	Very Low	Low	Med	High	Very high	Very Low	Low	Med	High	Very High	Very Low	Low	Med	High	Very High
1) Inter-Enterprise ICTs for supporting coordination e.g. contract & supply-network management in the context of reduced energy consumption															
2) Business Process Integration & collaboration ICTs. E.g. collaboration support, groupware tools, electronic conferencing, social-media, etc															
3) Knowledge sharing ICTs, knowledge management, knowledge repositories, knowledge mining and semantic search, linked data, long-term data archival and recovery at enterprise or inter-enterprise level															
4) ICTs for data mining & analytics in terms of energy consumption & optimisation, pattern identification, predictive diagnostics & analytics at enterprise or network level															
5) Modelling & simulation ICTs e.g. "What-if" scenario planning & continuous improvement across a sectors life cycle															

[Optional] feel free to add comments regarding interpretation of the questions asked above......please make reference to the question number when doing so.

<< >>

With respect to **energy efficiency** and/or **reduced energy consumption** within your identified sector, rate each theme below in terms of :-

1) potential impact **2)** current adoption & **3)** potential adoption

	Potential Impact					Current adoption					Potential adoption				
	Very Low	Low	Med	High	Very high	Very Low	Low	Med	High	Very High	Very Low	Low	Med	High	Very High
1) **Trading & Energy Brokerage ICTs** e.g. Consumer/Producer forecasting algorithms, energy source tracking, consumption/price negotiation															
2) **ICT standards and protocols for interoperability** across heterogeneous devices at an enterprise, network or environmental level															
3) **Real-time analytical technologies** such as Complex Event Processing and in-memory databases for enhanced operational control and awareness															
4) **Integration technologies / approaches** such as **service orientation and event driven architectures** to facilitate heterogeneous device data interoperability at enterprise, network and environment level															
5) Use of **cloud based services** for tasks such as data management, monitoring and analysis															
6) **ICTs & Practices for** qualitatively or quantitatively **assessing the enabling impact of ICT** on energy efficiency															

[Optional] feel free to add comments regarding interpretation of the questions asked above......please make reference to the question number when doing so.

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