AN APPROACH TO IMPACT ASSESSMENT OF ICTS FOR ENERGY EFFICIENCY

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ABSTRACT

The importance of information and communication technologies (ICTs) as an enabler for energy efficiency is well understood, however there is no one agreed common methodology for assessing the impact of ICTs on energy efficiency. In order to promote legitimacy, transparency and real progress in the application of ICTs to improving energy efficiency there is a clear need for common ways of assessing energy performance based on a common understanding of commitments, targets and methodology. In this paper, common means for assessing the impact of ICTs on energy efficiency are reviewed and the approaches of organisations focused on the development of ICT impact assessment methodologies are discussed. Subsequently, a potentially useful means of qualitative impact assessment is suggested. The proposed methodology aims to leverage the heuristics of domain experts and is based on life cycle thinking coupled with elements of an adapted capability maturity model/framework. The SMARTT taxonomy developed as part of the overall approach for common assessment is also described. SMARTT stands for **S**pecification and design, **M**aterialisation, **A**utomation and operational decision support, **R**esource and process management, **T**echnical integration and **T**rading/transactional management. Aligned to these six high level categories are twenty sub-categories to which user-defined ICTs/research and technology developments (RTDs) are mapped. An impact assessment example is given to illustrate how the proposed approach can be used at the offering level. The SMARTT taxonomy and common methodology are deemed by the authors to be as a useful means of assessing the impact of ICTs on energy efficiency both within and across sectors and potentially offers a foundation on which to base more quantitative methods to assess the impact of ICTs on energy efficiency.

Keywords: Impact assessment, ICTs, Energy efficiency, ICTs for energy efficiency, Impact quantification.

1 INTRODUCTION

The European Union (EU) has set its specific target of a 20% energy saving in energy consumption by 2020 (EU Council 2007). Achieving this goal will require major breakthroughs in research and technology developments (RTDs). The EU Commission has recognised information and communication technologies (ICTs) as an enabler that will play a key role in reducing energy consumption and increasing energy efficiency across the whole economy (Barroso 2008). It has also identified a clear need for common ways of measuring energy performance and a common understanding of commitments, targets and methodology (EU Commission 2009).

A widespread data gathering and analysis exercise has revealed that, while the ICT industry accounts for about 2% of global CO_2 emissions, ICTs can have a significant enabling capacity of reducing the remaining 98% of carbon emissions which come from the other sectors of the economy and of society (Gartner 2007). The focus of this research is on the impact of ICTs in four target sectors, namely smart buildings, manufacturing, grids and lighting, since these four sectors often come together in delivering infrastructures and environments for production, service, business and living, and together they produce and consume a significant proportion of Europe's energy (Ye et al 2010a). Although versatile statistical information is available on energy saving in different sectors, there is still limited knowledge of the potential of ICTs to improve energy efficiency in the identified four sectors. Furthermore, assessing the impact of ICTs on energy efficiency is an onerous task made more complex when bridging varied domains (e.g. buildings, manufacturing, grids and lighting). Within this context, the need for a common approach and taxonomy to assess the impact of ICTs on energy efficiency is apparent. Such an approach will aid awareness raising and exchange of best practices, reinforcing RTDs, promoting take-up and fostering novel ICT-based solutions so that the energy use in these sectors can be further reduced by adding intelligence to components, equipments, processes and services.

This paper begins with a description of the state of the art in energy consumption across the four identified sectors. The approaches of other organisations focused on developing methods to assess ICT impacts on energy efficiency are then reviewed. A new methodology for impact assessment of ICTs for energy efficiency (ICT4EE) is then described based on the concepts of life cycle assessment (LCA) and an adapted capability maturity model/framework (CMM/F). The SMARTT taxonomy, developed as part of the overall approach for common impact assessment, is also discussed as a main component of this research and an impact assessment example is given to illustrate how the proposed approach can be used. Finally, conclusions are summarised and follow-up research recommendations are provided.

2 STATE OF THE ART OF ICT IMPACT ASSESSMENT METHODS

2.1 Energy profile of target sectors

Global figures for the four identified sectors reference the 2008 Global e-Sustainability Initiative (GeSI) smart 2020 report (GeSI 2008) and the International Energy Agency (IEA) report (IEA 2009). Figure 1 below identifies the projected prime energy of each of the sectors in 2020 and is taken from a desktop synthesis of sources including Eurostat tables and the 'European Energy and Transport Trends to 2030' report (Mantzos et al 2003).

As shown in Figure 1, total prime energy consumption in each sector is identified in million tonne of oil equivalent (Mtoe). The total potential saving based on the data gathering and analysis exercise is presented and the total million tonnes of CO_2 equivalent (MtCO2e) saving attributable to ICTs is calculated from total savings based on world % as per the GeSI smart 2020 report. Note that lighting is included within buildings in the GeSI report and an adjustment to building sector total was made in separating this out.

	Source: own analysis based on 2007 EU trends to 2030		Source: GeSI Smart 2020		Source: various ETP sources		
	2020 Baseline		Projected ICT Enabled Abatements		Sector Total Projected Abatements		ICT enabled as a % of Total
	Mtoe	MtCO2e	%	MtCO2e	%	MtCO2e	
Total	**1,961**	**5,207**		**493**		**880**	**56.0%**
Energy transformation	457	1,213	14.26%	219	20.0%	**257**	73.5%
Energy branch consumption	95	252	less user	-30	5.0%		
Energy branch Losses	27	72	abatements =	**189**	3.0%		
non-energy uses	*125*	*332*					
exchange, returns & stat differences	*-40*	*-107*					
Total Final energy consumption	**1,298**	**3,447**					
Buildings	437	1,160	13.30%	**154**	27.0%	**313**	49.3%
Manufacturing	346	919	14.90%	**137**	25.0%	**230**	59.6%
Lighting	60	159	7.60%	**12**	50.0%	**80**	15.2%
Transport	*433*	*1,150*					
Agriculture	*22*	*58*					

Figure 1: Energy potential 2020 sectoral breakdown

If assumptions made in the GeSI smart 2020 report were valid, ICT enabled changes could account for about 56% of the four identified sector specific abatements. If ICT enabled abatements alone were implemented the projected 2020 CO2e values would be approx 15% below 1990 levels as opposed to 6.4%. Estimated abatements identified in the 'Action Plan for Energy Efficiency' (EU Commission 2006) for buildings and manufacturing are indicative of much of the literature relating to these sectors (27% and 25%) and were used here to calculate sector specific abatements. Smart grid projections are taken from various European Technology Platform (ETP) sources and Eurostat data regarding transformation efficiencies, integration of renewable, energy branch consumption and losses projections. Lighting here represents about 13% of the building figure and is stripped out and presented separately. It is estimated that changes to lighting technologies like light emitting diode (LED) and long-life organic LED could save as much as 50% on current levels (EU Commission 2006). However the emphasises here is ICT enabled change. Abatements due to lighting automation referenced in the GeSI report are taken to be indicative of what can be achieved.

2.2 Existing taxonomies and assessment methods

It is apparent that the task of assessing the energy profile of the various sectors at the EU level is a considerable task. Even more arduous is the task of estimating the impact of ICTs on energy efficiency and consumption of the four target sectors. When dealing with four different sectors with their own units of measurement, practices and terminology it is important to offer a means of shared understanding. Essentially, a common methodology and taxonomy for categorising technologies is required.

The research began with a review of existing methodologies and taxonomies that might be utilised or adapted in offering a common means of assessment to all four sectors. Literature review had revealed that there was no commonly known taxonomy for the categorisation of ICTs relevant to a specific sector or sector specific life cycle which could be applied and utilised across the four identified sectors (buildings, manufacturing, grids and lighting). The single most relevant taxonomy was that developed by the REEB (European Strategic Research Roadmap to ICT enabled Energy-Efficiency in Building and Construction) project (REEB 2010 and Ye et al 2010b). Another similar example is the European Construction Technology Platform (ECTP) strategic research agenda (SRA) and implementation action plan (IAP) which currently includes 59 RTD items organised into nine priorities (ECTP 2007). Both are building specific and there are no links to other sectors like manufacturing, grids and lighting.

Table 1: What others are doing in terms of impact assessment

Organisation	**Method**	**Footprint**	**Enabling Effects**
International Telecoms Union (**ITU**)	Hybrid LCA	Yes	Yes
European Telecoms Standard Institute (**ETSI**)	Hybrid LCA	Yes	Yes
International Electronics Manufacturing Institute (**iNEMI**)	Process-LCA	Yes	No
International Electrotechnical Commission (**IEC**)	Process-LCA	Yes	No
Global e-Sustainability Initiative (**GeSI**)	Hybrid LCA	Yes	Yes
Alliance for Telecom Industry Solutions (**ATIS**)	Process-LCA	Yes	Yes

Table 1 lists some of the organisations who are currently developing ICT impact assessment tools frameworks. They all advocate some form of life cycle thinking or assessment. However, again there is no one agreed methodology for assessing the impact of ICT on the specific variable of - energy efficiency, and easily re-applicable quantitative methods are effectively non-existent.

3 THE REVISITE APPROACH

Considering the existing methodologies, taxonomies and information discussed in Section 2.2 above, it was concluded that no one existing methodology was appropriate for our research in the REViSITE (Roadmap Enabling Vision and Strategy for ICT-enabled Energy Efficiency) project (REViSITE 2010). As such, a list of criteria was prepared in order to guide new methodology and taxonomy development. It was deemed that any approach should:

- Be generically applicable to any identified sector but specific enough to be of value in analysing the impact of ICTs on energy efficiency and by association CO2e in specific sectors.
- Be applicable to identified stakeholders;
- Consider current best practices in capturing both the consumption and enabling impact of ICTs;
- Assess impact of ICTs where it makes sense to do so in life cycle;
- Assist in understanding causal relationships;
- If possible utilise a single taxonomy for categorising RTDs/technologies in order to make cross-sector comparison more feasible.

3.1 REViSITE methodology overview

It was apparent that emerging best practices in assessing the impact of ICT4EE utilised some form of LCA approach or life cycle thinking. It was also clear that LCAs, in the main, focused at the offering level where one has an existing product/service/process that is to be augmented or replaced by a new ICT i.e. a direct comparison can be made, product versus product. This is fine from a product/service or company perspective. However, gaining a regional or sector perspective is a different matter. Economic input output assessment somewhat aims to address this – however, data is often patchy. Some works, such as ‘ICT impact assessment by linking data across sources and countries’, offer a useful lens, nevertheless there was a recognised need to develop a means of evaluating the ICT types best positioned to drive energy and CO2e reductions while also highlighting gaps that require future ICT investment.

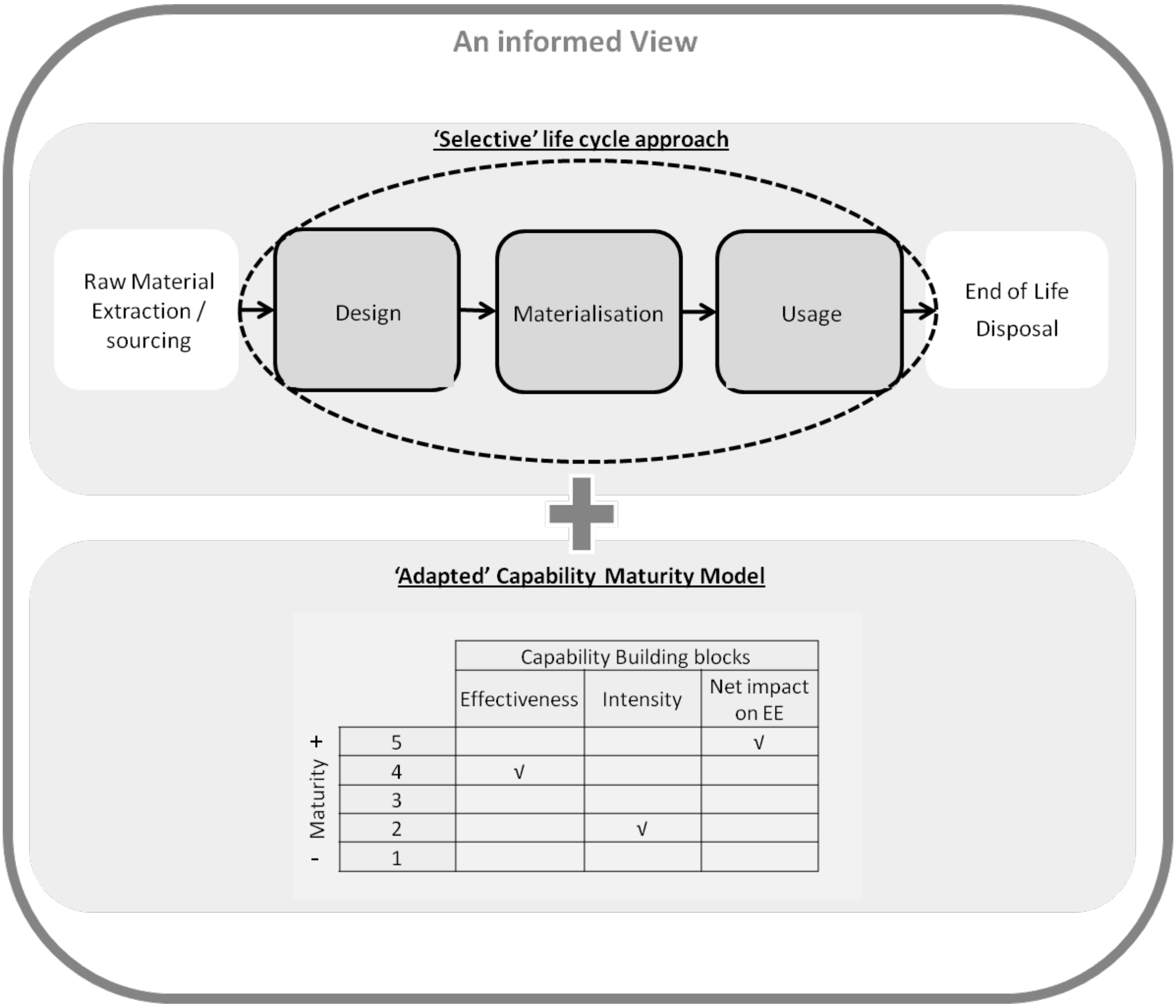

Figure 2: The REViSITE approach: an informed view

The REViSITE methodology is a hybrid that seeks to combine simplified LCA or rather life cycle thinking and an adapted capability maturity model/framework (CMM/F) or model. By combining existing LCA data, secondary sources, sector specific standards and heuristics, it is believed the REViSITE approach can build an informed view (see Figure 2) regarding those ICTs best positioned to impact on energy efficiency.

Full LCAs are heavily data dependant and specific in nature. REViSITE partners had deemed it appropriate to utilise simplified LCAs for inclusion in their research. However, in the main the proposed approach is more in keeping with the holistic spirit or life cycle thinking, as opposed to detailed assessment. The approach cannot, and is not, intended to replace a more detailed, expansive LCA. Such LCAs are typically product specific and consider all life cycle phases, the toxicity of the offering and its wider effect on acidification, eutrophication, or land use. The REViSITE approach focuses on a systems life cycle processes and the energy intensity of those processes in order to build an informed view. It was envisaged that view would assist subsequent roadmap development in the REVISITE project.

To summaries the approach, where there are gaps in available primary data and analysis, experts make an assessment of the impact of ICTs based on heuristics and expertise within their defined sectors. This is where the simplified capability maturity analysis comes into play. By understanding the respective maturity level of specific ICTs or RTDs, one can begin to identify those ICTs best placed to deliver meaningful impact. Section 3.2 below will give some insight into the choice of CMF as a framework. This is followed by Section 4 that details the proposed SMARTT taxonomy which is posited as a useful means of ICTs/RTDs categorisation.

3.2 Impact quantification and capability maturity model/framework

As shown in Figure 2, selective life cycle thinking together with adapted CMM are employed to frame the REViSITE approach to assess different ICTs with different impact potential on energy efficiency. The use of CMF is simplified to the extent that it involves a template with an uncomplicated cause and effect type matrix. The REViSITE approach focused on two key criterion namely net impact on energy efficiency and intensity (potential versus actual). ICTs/RTDs identified in each sector are scored on these two criterion. Additional interpretive criteria (e.g. effectiveness and cost) can be also assessed in conjunction with the two fixed elements in helping to build a holistic and realistic picture as to differences between potential and current/actual ICT impact. In the example that follows in Section 5 two additional criterion are assessed - effectiveness (how well does the ICT measure up to current state of the art) and cost (are there economic considerations impacting on adoption). Interpretative criterion are individually scored but not used for overall scores in our study.

Utilising elements of the CMF, together with a common taxonomy, will allow for effective harmonisation of sector research. While the template is simplistic the effort in assessing is totally reliant on the users expertise. Nevertheless, it was envisaged the contextual richness of the qualitative research, augmented by a quantitative estimate of the potential intensity and potential net energy efficiency impact of ICTs, would reliably inform roadmap development in the REViSITE project. That, in essence, is the power of a CMF, in that it allows partners to quantitatively illustrate and analyse what is essentially inductive qualitative research based on heuristics.

4 REVISITE SMARTT TAXONOMY

The REViSITE taxonomy utilises six high level categories and is a variation on the SMARTT acronym (**S**pecification and design, **M**aterialisation, **A**utomation and operational decision support, **R**esource and process management, **T**echnical integration and **T**rading/transactional management). There are twenty less abstract sub-categories nested within the six main categories. Both categories and sub-categories are fixed for partners. ICT/RTD topics are defined by partners and are nested within and aligned to the sub-categories.

The categories ‘Specification and design ICTs’, ‘Materialisation ICTs’ and ‘Automation and operation support ICTs’ all vertically align to the bounded life cycle phases. ‘Resource and process management’ together with ‘Technical integration’ are themes that align horizontally. ‘Trading / transactional management ICTs’ aligns primarily to the ‘usage’ life cycle phase, as shown in Figure 3.

Table 2: Taxonomy of ICT applications in the four sectors

Specification and design ICTs

- ***Design conceptualisation:*** Requirement engineering/management tools, concept modelling for design ideation, building and urban planning applications.
- ***Performance estimation:*** Classical financial based IT applications, various technologies used to analyse the performance of the target system.
- ***Detailed design:*** Software design tools, computer aided design (CAD), multimedia, graphics, etc.
- ***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.
- ***Modelling:*** All types of technologies that are utilised to systematically describe the physical reality, life cycle modelling, computer-aided diagramming.
- ***Specification and product / component selection***: Technologies for design and specification realisation, component selection.

Materialisation ICTs

- ***Decision support and visualisation:*** Technologies for visual representation of work flows focused on energy efficient task completion. What if - scenario simulation, and 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.
- ***Management and 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.
- ***Real-time communication:*** Any real-time communications that facilitate decision making.

Automation and operational decision support ICTs

- ***Automated monitoring and control***: Intelligent heating, ventilating, and air conditioning (HVAC), smart lighting, automated backend control with little or no human decision interaction. Smart monitoring (metering). Smart metering linked with machine self-actuation adjustment.
- ***Operational decision support and 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.
- ***Quality of service:*** Backend service provisioning and rightsizing of communication networks. quality assurance of applications in the field and self-healing of networks, service level agreement protocols.
- ***Wired/Wireless sensor networks***: Secure backend wired/wireless communications, dedicated high speed wired/wireless networks, sensor hardware/software so essential to sub-metering strategies, IPv6 over Low power Wireless Personal Area Networks (6LoWPAN), ZigBee Powerline Communication (PLC), etc.

Resource and process management ICTs

- ***Inter-enterprise coordination:*** Contract and supply network management, process planning and scheduling, procurement, intra-logistics, elements of enterprise resource planning (ERP) systems.
- ***Process integration:*** Collaboration support, groupware tools, electronic conferencing, distributed systems, social-media, business work flows, ERP (front end) system.
- ***Knowledge sharing:*** 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.

Technical Integration ICTs

- ***Technical integration and 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, building management systems (BMS) / facility management systems (FMS) backend infrastructure. Backend infrastructure of building information modelling (BIM) or ERP systems, etc.

Trading / transactional management ICTs

- ***District energy management:*** Distributed '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.
- ***Facility energy management:*** energy specific management systems, energy specific integration platforms and middle-ware. Smart metering infrastructure and protocols, context event processing, on-demand energy management and optimi-sation, load and distributed energy resources forecast algorithms, smart appliances.
- ***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.

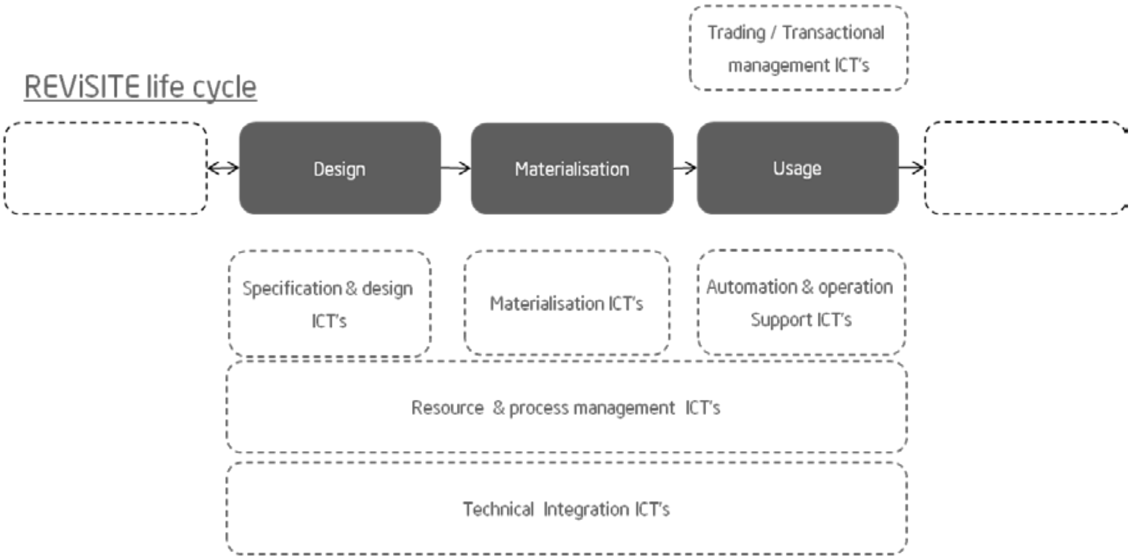

Figure 3: The SMARTT taxonomy mapped to life cycle phases

The SMARTT taxonomy has three levels, as shown in Table 2 in details –

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

5 USING THE REVISITE APPROACH

The following example - Home Energy Management System (HEMS) is designed to demonstrate how the REViSITE approach can be used to estimate the impact of an ICT on energy usage and efficiency in a particular sector. The example is detailed for illustration purposes. The impact assessment process has three steps: 1. define and categorise; 2. refine; and 3. assess and estimate (as shown in Tables 3-5).

Table 3: Impact assessment process: define and categorise

Define and categorise	
Intended audience	Home owners, utility providers, policy makers
ICT / RTD to be assessed	Home Energy Management System (HEMS)
Relevant SMARTT sub-category	Operational decision support and visualisation
Relevant SMARTT main-category	[A] Automation and operational decision support ICTs
Sector / system impacted	Buildings
Most relevant sector life cycle phase – Function	Usage
Most relevant sector life cycle phase – Impact	Usage
First order effects (direct impact)	Additional power envelope required to implement the HEMS offering
Second order effects (indirect impact)	Enabling impact of the ICT on the electrical energy consumption/efficiency of the building
Third order effects	Shifting of peak demand or load balancing effects within the power grid. Increased awareness and dissemination of sustainable thinking and behaviour
Possible rebound effects	Increased consumption due to additional devices or through increased use match existing cost point

The ‘define and categorise’ stage is essentially about defining and framing the ICTs/RTDs to be assessed using the SMARTT taxonomy in a consistent way that allows for cross-sectoral comparison.

Table 4: Impact assessment process: refine

Refine
• From an energy perspective the HEMS focuses on the ‘usage' phase of the building life cycle. The 'design' and 'materialisation/construction' phases of the system life cycle i.e. buildings can be considered insignificant and therefore excluded. • Assumption was the HEMS product life cycle was insignificant in comparison to its enabling effects. Secondary sources were obtained from LCA databases and manufactures on specific or similar devices. Phases of product life cycle to consider - 'usage' followed by 'materialisation/production'. • In essence the net impact will equal the delta between the energy saving in the 'usage' phase of the building life cycle and the energy consumption of the HEMS product life cycle phases of the manufacturing (materialisation) and usage phase.

The ‘refine’ stage is about focusing on what really matters from an energy perspective. It helps to identify the phases of the product offering that need to be assessed and the phase of the host system which need to be assessed from an enabling impact perspective.

Table 5: Impact assessment process: assess and estimate

Assess and estimate
First order effects (own consumption)
• The augmented HEMS is projected to utilise 101 kWh per annum in an always on scenario. The manufacture of the augmented system was estimated at 40 kWh. This information was gauge from manufacturing data and LCA databases for specific or similar products. Combined 'usage' + 'manufacture' phase of product system = 141 kWh.
Second order effects (enabling effects)
• Average measured electrical power saving in case study was 426 kWh per household. • At the EU level an average saving of about 601 kWh per household per year is feasible given a 15% saving due to behavioural change. Literature in this space suggest 19%±5%. At the macro EU level that equates to about 120 TWh saving in electrical consumption. • 601/141= 4X enabling effect. However the case study did not include gas/oil usage which accounts for about 70% of household energy within the EU. Average consumption of all energy sources calculated from Eurostat data is ~16,630 kWh per household (based on 285 Mtoe final energy consumption of households with a housing stock of ~ 200 Million) even a conservative 10% saving per household equates to 1663 which equates to a enable impact of >11X.
Third order effects
• Shifting of peak demand or load balancing effects etc within the grid. • Increased awareness and dissemination of sustainable thinking and behaviour. • Perhaps increased consumption in some cases as consumers negate savings as they increase usage to meet previous cost point for example or where they introduce new devices.
Scoring the matrix (see results in Figure 5)
• The ICT is scored as per Figure 4 scale this is of course open to interpretation but the assumption is that industry practitioners are scoring the ICT and are in a position to make estimates based on available data and heuristics. • Net impact is estimated from above 1st and 2nd order effects (601/141 = 4X). The European level data constituted a higher impact score based on potential savings regarding all energy as opposed to just electrical savings so net impact was scored a 5. • Potential intensity and current intensity in this case were estimated based on Eurostat data regarding the population and housing stock, the final energy consumption as per Eurostat main tables and heuristics regarding proliferation of HEMs devices. High potential based on the household stock and low proliferation meant potential intensity was scored a 5 with current score a 1. • The effectiveness and cost of the offering seemed to be on a pair with other offerings so effectiveness was scored as 3.

During the 'assess and estimate' stage, assessors use heuristics, qualitative and quantitative data to assess and estimate the impact of the ICT/RTD based on the scale defined in Figure 4. The benefit of this is that one can build an informed view as to the ICTs/RTDs that have the best potential in positively impacting on energy consumption and efficiency. There are two fixed criterion scored together with a user defined number of interpretive criterion used in this example.

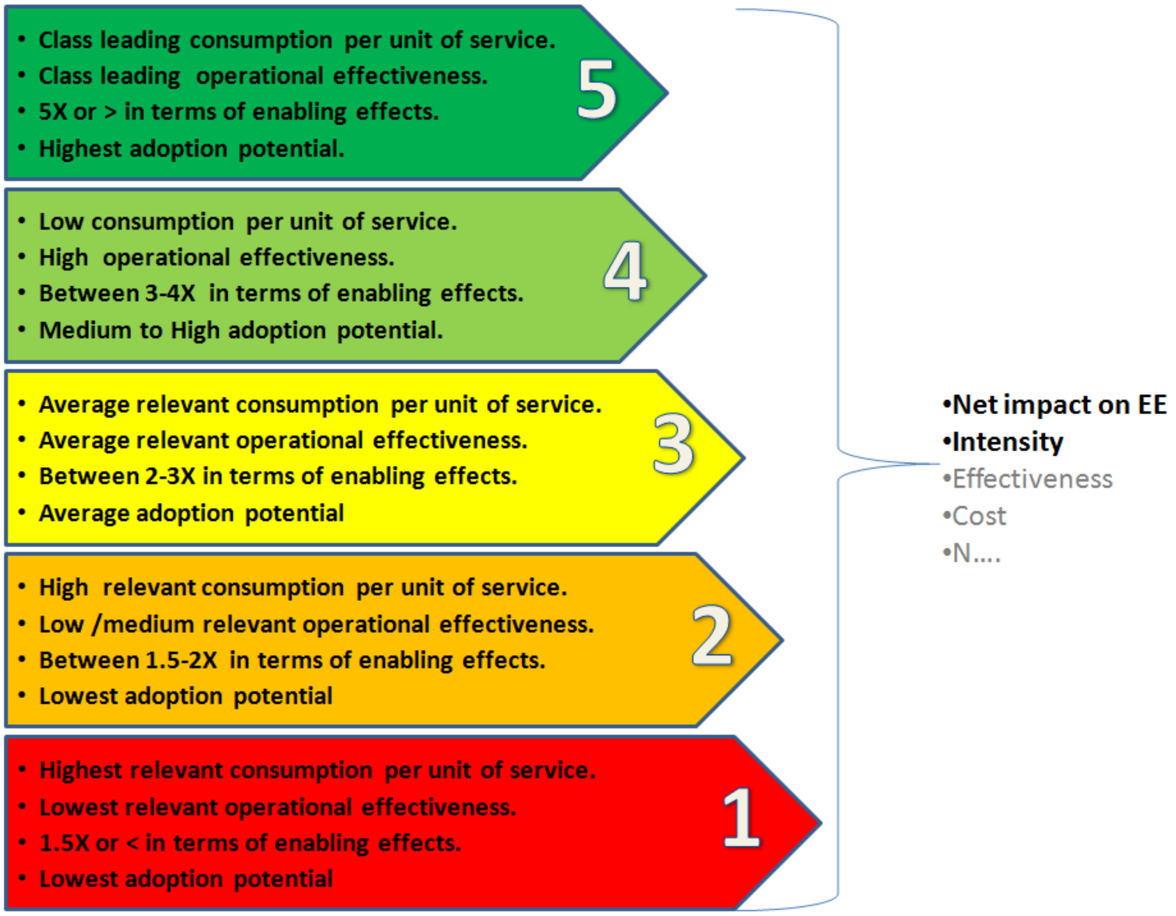

Figure 4: REViSITE maturity scale for assessing ICT4EE maturity

Sys LC phase	Usage' / 'Operational' Phase [Buildings]								
Main Cat.	Automation & operational decision support ICT's	Cost	Effectiveness Operational	Intensity Actual	Intensity Potential	EE Net Impact Potential			
Sub cat.	Operational decision support & Visualisation:	1 = low cost 5 = highest cost					Impact Score	Intensity factor	Overall Score
ICT/RTD's	**HEMS**	3	**3**	**1**	**5**	**5**	**25**	**1.80**	**45.0**
	ICT 2	3	2	3	4	5	20	1.25	25.0
	ICT 3	4	5	2	5	5	25	1.60	40.0
	ICT 4	1	5	1	4	4	16	1.75	28.0
	ICT 5	2	4	5	5	5	25	1.00	25.0

Figure 5: Impact assessment score value

The value in scoring the technologies means partners can understand/assess quickly those ICTs that offer the best potential for improvement (as shown in Figure 5 for example). They can also use the interpret factors to assess why they think there is a current gap between potential versus actual adoption. The real value however comes from the common language and approach the methodology and taxonomy offers because this offers the user a 'lens' into the research, technologies and practises of other sectors, thus quickly identify technologies they can possible leverage within their own specific context.

6 CONCLUSIONS

In this paper, a qualitative approach to impact assessment of ICTs on energy efficiency has been introduced. The approach leverages the heuristics of domain experts based on life cycle thinking coupled with an adapted capability maturity model/framework. As part of the overall approach for common assessment of ICT4EE, the SMARTT taxonomy (which consists of six high level categories and further twenty sub-categories) has proved useful in mapping user-defined ICTs/RTDs within and across the four sectors of smart buildings, manufacturing, grids and lighting. An example was also provided to demonstrate the developed methodology and SMARTT taxonomy. Within REViSITE this common approach has proved to be a useful means of qualitatively assessing the impact of ICTs on energy efficiency and is posited as a framework in which more detailed quantitative measures can be positioned. The approach will be used to guide further research and subsequent roadmap development in the REViSITE project and is open to use and adaptation by the wider community.

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