Roadmap Enabling Vision and Strategy for ICT-enabled Energy Efficiency

D2.1 - ICT4EE Data Taxonomy

‘A Common Methodology to assess the impact of ICT developments’

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Disclaimer

Contents

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. ICT's ability to organise and innovate is a key factor".*[1]

The EU Commission has identified 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".*[2]

The main objective of the REViSITE Coordination Action is to produce a common cross-sectoral ICT4EE roadmap to address this call. As allude to above there is no agreed 'level playing field' when it comes to measuring energy performance or indeed the impact of ICT on energy performance.

The document that follows firstly profiles the current state of play within the EU27 with regard sector specific energy consumption across the four identified sectors, namely Smart Grids, Buildings, Manufacturing and Lighting. The approach of other organisations focused on developing methods to assess ICT impact on energy efficiency is then reviewed. Subsequently, the main aim of the deliverable is addressed as the REViSITE common methodology and taxonomy is presented.

Given the scope, resources and challenges posed in accurately measuring the impact of ICT on energy efficiency a qualitative approach which leverages the heuristics of domain experts was deemed appropriate and the methodology developed is based on 'life cycle thinking' coupled with elements of the Capability Maturity Model.

The SMARTT taxonomy is posited as a useful means for common categorisation across sectors. SMARTT stands for Specification and design, Materialisation, Automation and operations decision support', Resource and process management, Technical integration and Trading/transactional management.

The methodology and SMARTT taxonomy were utilised throughout the project research to guide the common assessment of ICTs in highlighting that which was homogenous, heterogeneous and synergetic.

In short the REViSITE consortium deemed the approach to be a feasible and useful common methodology and taxonomy for guiding research and roadmap development in the area of ICT for Energy efficiency and is one that is open to use and adaptation by the wider community.

Acronyms and terms

BAU………………….	Business as Usual
BIM………………....	Building Information Modelling
BMS……….…….....	Building Management Systems
CAD………………....	Computer Aided Design
CEP…………………..	Complex Event Processing
CFD………………....	Computational Fluid Dynamics
CMM..................	Capability Maturity Model
DEFRA……….	Department of Environment, Food and Rural Affairs (UK)
DMS ………………..	Distribution Management Systems
EC ………………....	European Commission
ECTP………………..	European Construction Technology Platform
ECTP FAPICT	ECTP Focus Area Processes and ICTs
EE…………………....	Energy Efficiency
EEA…………………..	European Environmental Agency
EEB.....................	Energy Efficiency in Buildings
EMS………………..	Energy Management Systems
ERP ………………....	Enterprise Resource Planning
ETP.....................	European Technology Platform
EuP…………………..	Energy using Products
GeSI ………………	Global e-sustainability Initiative
GHG………………..	greenhouse gas
HVAC…………….....	heating, ventilation, air conditioning
ICT......................	Information and Communication technologies
ICT4EEB.............	Information and Communications Technologies for Energy Efficient Buildings
ICT4EE...............	ICT for energy efficiency
IEA……………………	International Energy Agency
LCA.....................	Life cycle analysis
LEDs………………..	Light emitting diodes
MFG…………………	Manufacturing
MMS ……………....	Market Management Systems
PLC ………………..	programmable logic controllers
REG………………….	REViSITE Expert Group
RES……………………	Renewable energy sources
RFID……………......	Radio Frequency Identification
ROI……………….....	return on investment
RTD………………….	Research and Technology Development
SETAC	Society of Environmental Toxicology and Chemistry
SME....................	Small and medium enterprises
SOA....................	Service-oriented architecture
SOTA	State of the Art
Taxonomy………..	Division into ordered groups or categories
WAM…………………	With additional measures
WEM…………………	With existing measures
ZigBee…………….....	Communication protocols designed to use small, low power wireless networks

1 REViSITE project 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 and complementary application sectors: Smart Grids, Smart Buildings, Smart Manufacturing and Smart Lighting. The REViSITE work package structure is outlined in figure 1 below:

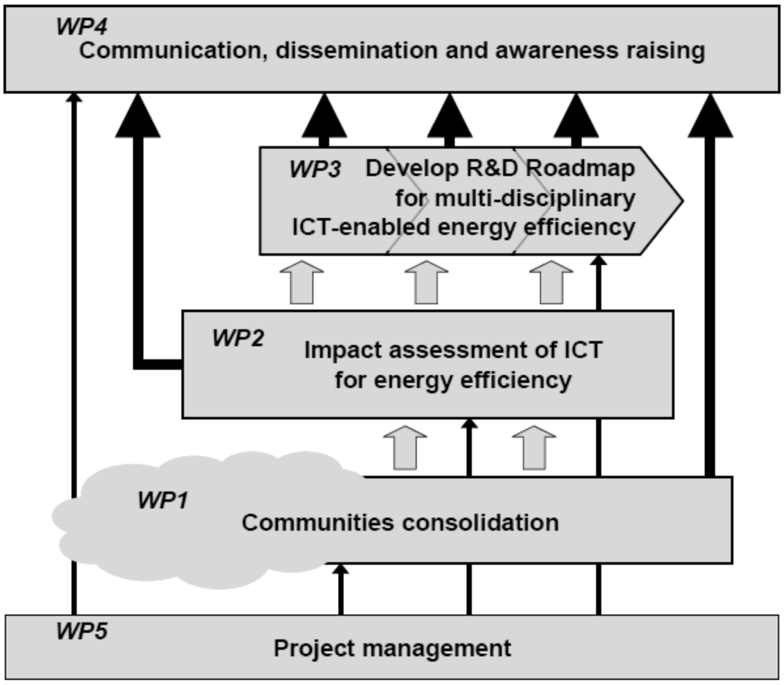


Figure 1. REViSITE Work Package structure.

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 a causal model of how ICT can 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 the 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.

1.1 Deliverable - Purpose and target audience

While the methodology was developed for internal use the report is a public document and it is envisaged the generic taxonomy and methodology posited may offer value to those seeking to categorise and assess the impact of ICT adoption in their chosen sector.

The ultimate goal of WP2 is to identify key ICT RTD topics for roadmap development. In reaching this goal the consortium must identify that which is homogenous, heterogeneous and synergetic amongst the sectors highlighting interdependencies and gaps while identifying best practices. Any proposed methodology therefore needed to support the following activities:

- Classification of issues in the four sectors in a unified way so that findings can be compared and common ICT-related RTD priorities can be identified.
- Identification of causal relationships between ICT and other factors that together influence the overall energy efficiency.
- Assessing potential impacts.

Developing such a methodology is the purpose of this deliverable, which is essentially the output of Task 2.1 - a common methodology to assess the impact of ICT developments on energy efficiency. However, it was deemed necessary to incorporate elements of Task 2.6 'Impact assessment model of ICT on energy efficiency' given the obvious connection between model development and the methodology adopted within the research.

Although the deliverable is a public document, the primary audience was that of the REViSITE consortium. The aim to provide a common approach in preparation of deliverables:

- D2.2 ICT4EE – Knowledge and Current Practices review, (T2.2-2.5), and
- D2.3 ICT4EE – Impact Assessment Model (T2.6)

The approach in developing the T2.1 (D2.1) was to:

- Identify existing methods that could potentially be applicable for REViSITE.
- Give preference to methods which were familiar to the involved participants.
- Select a promising combination of methods.
- Prepare instructions to the rest of the consortium how to apply the methodology.
- Present the methodology to the consortium and to external experts and use their feedback and suggestions to consolidate the methodology (workshop report D4.3-1a, held in June 2010, project month 6).
- Maintain consistency of the methodology as part of the WP2 management.

1.1 Project scope

The ICT energy paradox suggests that, while the ICT industry accounts for approx 2% of global CO_2 emissions, it can have a significant enabling effect on reducing the emissions of the remaining 98%. The focus of REVISITE is on the enabling impact of ICTs in four target sectors - namely smart buildings, grids, manufacturing and lighting.

It should be flagged that this focus in itself is a limitation in that the important sector of 'transport' is outside the direct scope of REViSITE and, while there are other initiatives focused on the transport sector, it is important to note that it would be impossible to holistically consider the enabling impact of ICT without considering effects across the full sectorial spectrum.

That said, REViSITE will centre on examining the enabling impact of ICTs on energy efficiency, in and across the above identified sectors, resulting from augmentation or replacement of existing business-as-usual (BAU) products, services or systems. In trying to understand the net impact, REViSITE must also consider the direct consumption impact on energy by such ICTs.

Estimating the impact of such ICTs is a challenge, not least because assessing and proportioning the impact of ICT’s must be done amidst sector specific non-ICT technology advancement. For example, what level of improvement is attributable to solid state lighting technology versus intelligent ICT control of that lighting? One needs to be careful about how any potential abatement is communicated and whether it is estimated from an original or an adjusted baseline.

One potentially fruitful means of examining the net impact of ICT4EE is to assess the respective life cycles of the systems (sectors) in which they are deployed. The intent within REViSITE is to utilise such an approach. However, the REViSITE methodology also seeks to bound any ‘system of interest’ by excluding certain life cycle phases or rather by excluding the assessment of ICT4EE in those phases as part of the current system assessment (see Figure 2).

The reason for doing so, within REViSITE, is context dependant and is somewhat conceptual in that these peripheral phases often represent a different system to the system of interest. For example the ‘design’, ‘construction’ and ‘usage’ phases of the building life cycle sit within the remit of ‘buildings’ while the preceding ‘products (materials) manufacture’ phase of the building life cycle sits within the ‘manufacturing’ life cycle. Ones perspective needs to be understood - is it a multi-sectorial or mono-sectorial view?

To explain further, and staying with the building example, energy abatements achieved in the production of building materials positively impact on the building life cycle in terms of the embodied energy of those products. However, if considering multiple sectors, the direct energy abatement will have been accounted for in the operational phase of the manufacturing process life cycle. When taking a multi-sectorial view one must ensure not to double count improvements.

The REViSITE approach is designed to be multi-sectorial, but, is however, flexible. Again, in the case of buildings, if one takes a mono-sectorial view, the REViSITE approach will allow for upstream embedded or downstream energy to be considered as part of material specification and dispose/recycle type decisions, without having to assess energy impact on ‘manufacturing’ or ‘waste/recycle’ industries processes as part of the building life cycle assessment.

In summary, REViSITE will focus on ‘design’ ‘materialisation’ and ‘usage’ phases of the typical life cycle of a grid, a building, a production system or lighting infrastructure in order to understand and estimate the impact of ICT on energy efficiency across the four sectors.

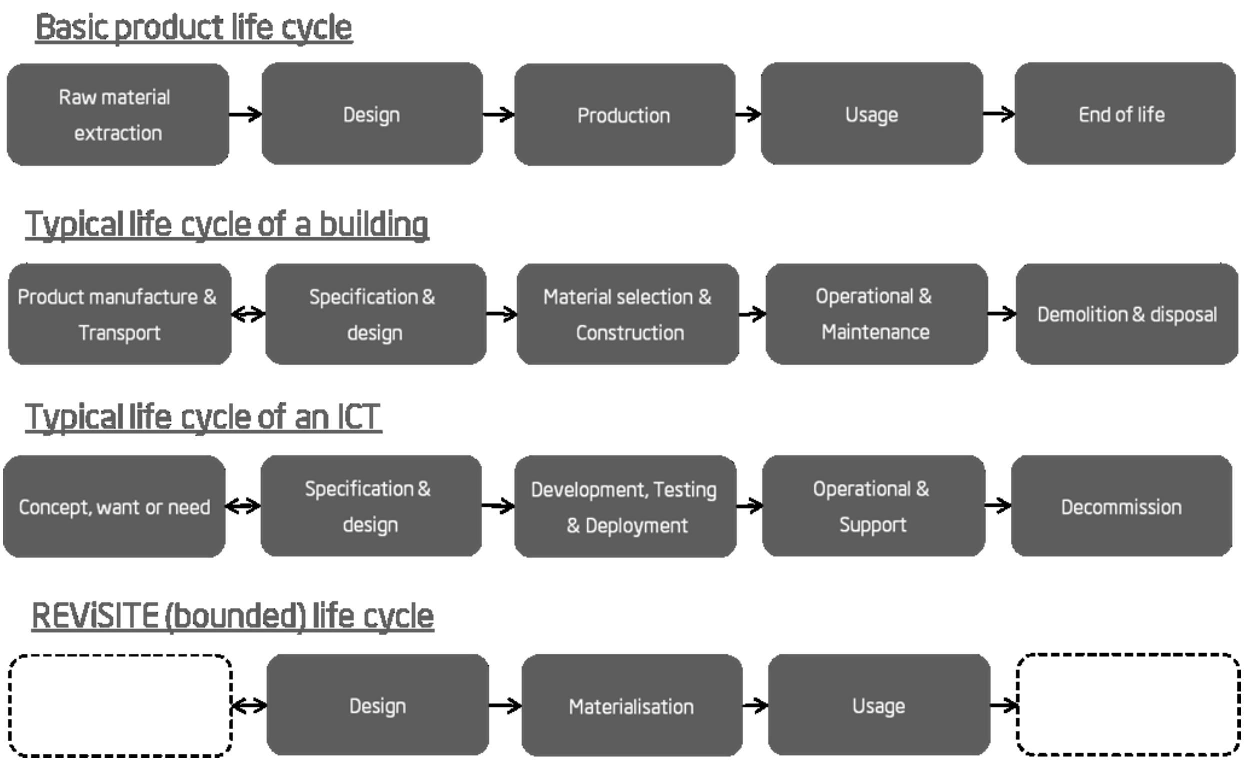


Figure2. Bounding of Life cycle

Note *'Materialisation' is a neutral term used within REViSITE to delineate the 'Production' 'Construction' and 'Development' terminology of the specific sectors.*

1.2 Scenarios, Assumptions & Definitions

The need for a systems approach is well understood and the REViSITE consortium is cognisant of the part 'interconnectedness', 'emergence' and 'unintended consequence' play in accurately understanding and predicting change within any system. It is worth noting again therefore those variables and sectors outside the scope of this project that hold immense implications for energy consumption and efficiency within the EU27.

Transport, both of people and cargo, is extremely pertinent to the discussion on energy consumption and efficiency. In fact, the energy impact of many of the ICTs utilised in the REViSITE target sectors are realised within the transport sector. So, while not directly the focus here, transport needs to be inherently considered.

The REViSITE research is about identifying those ICTs best positioned to deliver EE gains in the identified sectors. But it is recognised that ICT4EE is but one pillar in achieving energy and emission targets. Solid state lighting, engine and aerodynamic improvements in transport, energy efficient manufacturing techniques and building material advancements are all examples of technological enablers that are in the main outside the scope of a review on ICT4EE.

Renewable energy and dematerialisation are others, while the role of social, economic and behavioural elements cannot be over emphasised. In fact it could be argued that economics, and, by association 'markets', has been and will continue to be the primary driver of energy consumption and efficiency decisions.

The path to success will encompass thousands, perhaps millions, of trade-off decisions and those decisions will often come down to economics. Decision makers must be influenced.

Making the case for ICT and renewable energy investment, as well as offering incentives and informing consumption behaviour, will all play a part in the holistic effort required to influence citizens and commerce in achieving target reductions. The role of policy is obvious and paramount. That said, the reality for REViSITE is that the consortium must focus on estimating the impact of ICT4EE in the identified sectors but will do so inherently mindful of the above considerations.

Within many disciplines it is appropriate to model future systems in order to gain some understanding and inform choice. When dealing with future events one must make decisions about how to model that future. In terms of scenario setting REViSITE will reference three reports, namely the 'Greenhouse gas emission trends and projections in Europe 2009' report[3], the 'European Energy and Transport Trends to 2030'[4] 2007 report and the 2009 update of the same[5].

The 'Greenhouse gas emission trends and projections in Europe 2009' report identifies two scenarios 'with existing measures' (WEM) and 'with additional measures' (WAM). These scenarios are, in the main, consistent with the 'Baseline' and 'Reference' scenarios of the 2007/2009 DG 'European Energy and Transport Trends to 2030' reports. Essentially both documents estimate the effects implementation of current and additional identified policies might have on energy within the EU.

Apart from some additional policy inclusions in the 2009 documents, the assumptions that underpin the reports are consistent. However, the recent economic downturn has necessitated the updating of projected consumption and CO_2e values. The 2009 baseline scenario, which assumes existing measures, is now anticipated to account for a 14% reduction in CO_2e levels within the EU27 by 2020, as opposed to 6.4% identified in the 2007 report. While the 'Reference' scenario, which assumes the implementation of identified additional measures, is now forecast to account for a 20% reduction on 1990 levels. The Eurostat monthly gross consumption figures would suggest the 2009 reductions will be in the order of 5-6%, a fact supported by the EU report 'Europe's Energy Position – markets and supply' report[6]. This means that, as a result of the economic downturn, and assuming implementation of 'Reference' scenario conditions, the EU 2020 targets would be exceeded.

The REViSITE research is set in the context of this shifting landscape. However, the REViSITE objective is normative in the sense that specific targets, embodied in the Commission '20 20 by 2020 -Europe's climate change opportunity'[7] and the GeSI Smart 2020 report[8], are set and the objective is in assessing the impact ICT can have on such targets. To a degree the REVISITE research need not dwell on the overall predicted consumption figures because the objective is more about identifying the impact of ICT in terms of an order of magnitude and identifying those ICTs with the highest potential for impact. Nevertheless, REViSITE aims to be both systemic and rigorous in its approach and it is paramount therefore that REViSITE be explicit regarding the assumptions, terminology, data and resources used. What follows outlines the main assumptions that underpin the REViSITE approach.

- The geographical frame of reference for the studies is the EU-27.
- The time frame in terms of impact assessment is 1990 to 2020.
- The overarching target is a 20% cut in emissions with respect to 1990 CO_2e levels by 2020. Note - EU27 does not have a commitment under the Kyoto protocol.
- The prime units of reference will be 'watt hours' or 'toe' (tonnes oil equivalent) and 'carbon dioxide equivalent'
- The EuP EcoReport used emission factor of 0.4582 kg CO_2e / kWh for electricity consumption will be assumed where direct data is unavailable and calculation/estimation is required. 1toe = 11.63 MWh

- REViSITE is focused on ICT4EE. Energy efficiency within REViSITE is defined as 'a process that uses less energy per unit of service'.
- It must be stressed that energy efficiency and energy conservation are not the same. Conservation is about refraining from use in maintaining or reducing current levels. Efficiency is about maintaining the same level or increased levels of commerce while using less and this may result in a net reduction in CO_2e.
- ICTs have the capacity to reduce the energy and carbon intensity in predominately three ways:
  - Reduced direct energy consumption. Less oil, gas, electricity etc
  - Indirect energy savings due to reduced or eliminated travel (people/goods).
  - Indirect energy savings due to reduced or eliminated materials and space
- REViSITE research will focus on the impact ICT can make with respect to direct prime energy and electrical consumption within grids, buildings, manufacturing facilities and lighting infrastructure. That is lighting both internal and external to buildings.
- Lighting – is treated as a separate sector to buildings as it includes external street lights and on-street signage. The separation is also testament to importance and potential existing lighting technology has in meeting medium term EU emission targets.
- Indirect energy consumption savings in the external transport network due to reduced or eliminated travel of people/goods will be referenced as long as the ICT is directly employed within one of the target sectors.
- Reductions in prime energy or electrical power due to reduced movement of people/goods within manufacturing facilities or buildings should be the focus for REViSITE i.e. intra-logistics, however, improvements realised above in the transport sector, as a result of ICT deployment in the target sectors, can be included. A manufacturing intra-logistics example might be - where Enterprise Resource Planning leads to improvements in the energy efficiency of manufacturing equipment and internal transfer processes through better shop-floor scheduling.
- Dematerialization in terms of products is out of scope. The reason for this exclusion is that this project focuses on manufacturing processes as opposed to products. However, it is recognized that dematerialization of product offerings is a burgeoning and important element in addressing energy consumption / efficiency. An example for inclusion within REViSITE might be - 'digital mock-ups' reducing energy intensity in terms of physical prototyping in the manufacturing design phase.
- The limitations in bounding or taking a partial/simplified life cycle view (Fig 2) are understood but deemed appropriate, a position validated by the REViSITE Expert group (REG) as being 'sound'.
- The production of building materials, as per Eurostat, will be addressed within 'industry' figures. As discussed in section 1.1 the approach still allows for embodied energy considerations that feed into the bounded life cycle if taking a mono-sectorial view.
- REViSITE will only address the consumption behaviour of users within the target sectors in line with the bounded system.
- The assumption throughout REViSITE is that, once given the information, users will make choices that reduce their energy intensity. This is of course a leap assumption and the economic factors touched upon will, for one, play a paramount role in this regard.
- First order, primary or direct effects refer to the immediate impact of ICTs on energy intensity and carbon emissions i.e. its own footprint or consumption.
- Second order, secondary or indirect effects refer to the impact on other sectors or sometimes 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.

- The 'Shifting of burdens', i.e. savings in one phase at the expense of another will be considered throughout.
- 'Rebound effects' are akin to the system concept of 'unintended consequence'. 'Rebound effects' in an energy context describe the situation whereby users negate savings made by energy efficient investment through increased consumption. As an example '…the introduction of telecommuting in a facility delivers a net decrease in emissions but the savings from reduced travel and building emissions are somewhat negated by changes in home consumption'. A possible indirect third order effect in this case might be an increase in urban sprawl. The extent to which 'rebound effects' negate emission reductions is the subject of much debate and is beyond the scope of REViSITE. However all effects will be included where there is justification to do so and where the effect is in terms of energy consumption. That said, any policy maker would need to consider such effects.

A note on two themes central to REViSITE research:

Causality is a key topic, with the model of T2.6 (deliverable D2.3) being a causal model. Understanding the emission footprint i.e. the direct effect of ICTs on their environment is part of the process but understanding the indirect enabling effects of those ICTs is where the research is essentially targeted. Understanding the 'knock-on' direct and indirect causal effects a particular ICT has is an arduous process but needs to be considered and captured throughout. REVISITE will rely on partner research and expertise to identify relationships to inform the T2.6 model

Interoperability will be paramount to the REVISITE research. The identification of 'integration technologies' within the taxonomy is part of the equation. However, knowledge about the information itself is crucial to achieving interoperability among processes, people, and organizations that goes beyond ICT system and application integration. Context and semantic interoperability is as important and, where specific to the sectors, will be considered by REVISITE as they investigate integration technologies

In summary, REViSITE will, in line with the EU 'Impact of information and communication technologies on Energy Efficiency –final report'[9] and the GeSI Smart 2020 report, focus on the extent to which energy efficiency and hence CO_2e abatements/reductions can be achieved/enabled through ICT investment/adoption. The research will focus on the four target sectors and on identifying the types of ICT technologies that will have the greatest impact on energy efficiency. The ultimate aim is to develop a roadmap that informs strategy, investment and policy in this space.

1.3 Reading the rest of this document

Section 2 that follows is essentially background information that influenced the REViSITE approach. A high level (EU27) assessment of the energy profile of the sectors together with an estimate as to the energy abatement potential of ICTs at a macro level are given in Section 2.1 & 2.2 . Existing methods and best practice covering what other organisations are doing in this space of ICT impact assessment is covered in sections 2.3 2.4. A description for the consortia on how one might represent 'causality' internally is also introduced.

If the general reader wishes to understand the REViSITE approach specifically without reading through section 2 background information then they can move to section 3 which gives an overview of the REViSITE approach together with section 4 which furthers discusses the approach with the aid of an example. Any general reader should understand the approach was essentially developed with the internal Partners of the REViSITE consortium in-mind however it does represent an approach the consortium deem useful in the context of the wider community.

2 Assessing Impact - Background & existing practice

2.1 Energy Profile of EU-27

The GeSI Smart 2020 report projects global emissions will be 51.9 $GtCO_2e$ in 2020 under a business as usual scenario. The ICT sector footprint for 2020 is estimated to be 1.43 $GtCO_2e$ or 2.7% of total emissions. This is taken to be the assumed World baseline scenario for the ICT industry by REViSITE and is consistent with cross-referenced values calculated under the WEM (baseline) and WAM (Reference) scenarios see Annex 1.

Total ICT enabled reductions within the GeSI report is estimated to be 7.8 $GtCO_2e$. This figure is equivalent to the entire potential saving identified for Europe in the 2006 Commission report 'Action Plan for Energy Efficiency: Realising the Potential'[10] and highlights the potential pervasive impact ICT can have. However both reports include logistic/transport abatements and within the Smart 2020 report dematerialisation abatements are also included. Logistics, transport and dematerialisation are not the focus of the REViSITE study.

Indicator	2007 World	2007 EU27	2007 EU27 as % of world
	Mtoe		%
Gross inland prime energy production	11,939	849	7.11%
Gross inland prime energy consumption	12,029	1,808	15.03%
Final energy consumption	8,286	1,165	14.06%
	MtCO2e		%
Total emissions	41,413	5,039	12.17%
	TWh		%
Gross Electrical generation	19,771	3,368	17.04%
Final Electrical consumption (1414Mtoe)	16,445	2,844	17.29%

Source: IEA 2009 key indicators + Eurostat
(based on IEA 2009 CO2 value representing 77% of GhG + 20% for deforestation, decay & biomass)

Figure 3. Comparing World & EU27

Use of ICT products and services represents about 7.8% of electricity consumption in the EU and may grow to 10.5% by 2020[11]. From Figure 2, in 2007 the EU-27 accounted for 7% of world prime energy generation and 17% of world electrical generation. Prime energy consumption was 15% of world values with final energy consumption at 14%.

Total 2007 (GhG) emissions stood at 5.039 $GtCO_2e$, approximately 12% of world CO_2e values. However this excludes net CO_2 removals from land use, land use change and forestry

(LULUCF). If including global emissions from deforestation the share would be 11%. Figure 4 shows the breakdown of CO_2e within the EU27 by sector and by gas for 2007. Figure 5 shows the % consumption of prime energy by sector within the EU27 for 2007.

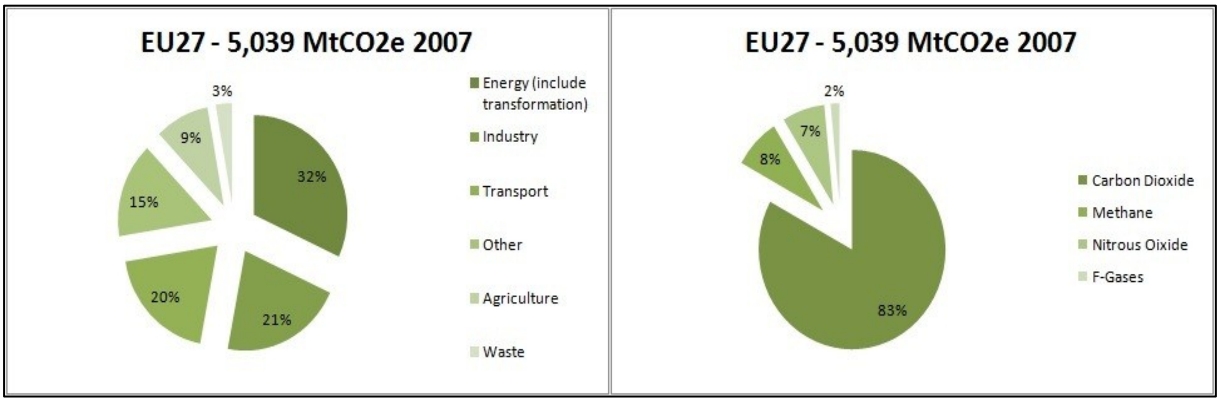


Figure 4. CO_2e breakdown EU27 (2007) (source Eurostat)

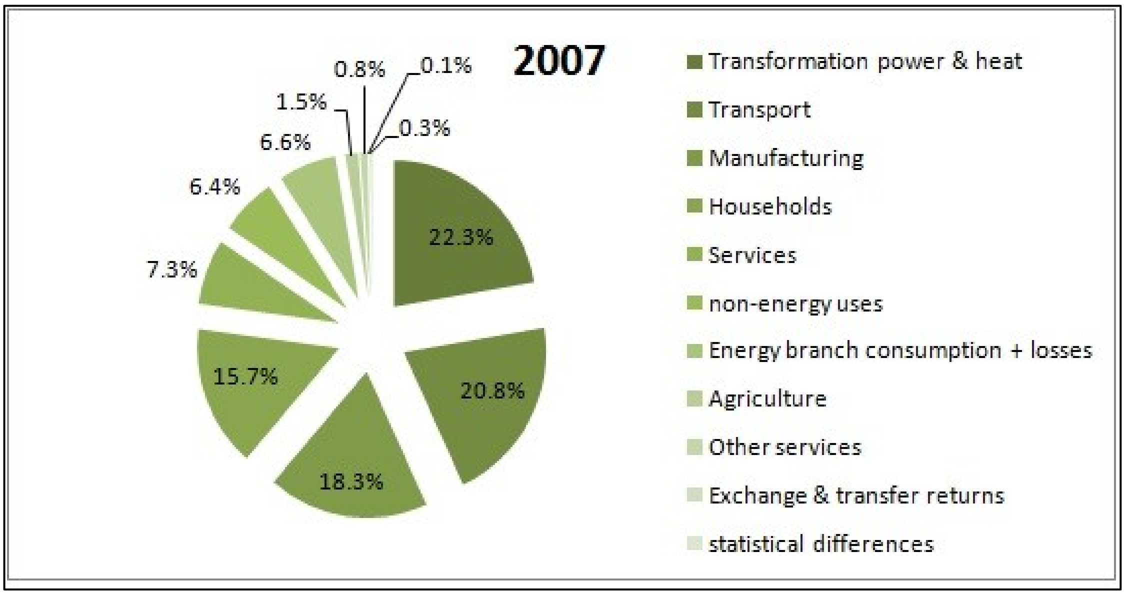


Figure 5. EU27 energy consumption (source Eurostat)

According to IEA and EEA sources energy intensity was originally assumed to increase by 0.8% per year in EU27 and 1.9% globally from 2010 to 2020. However the recent economic downturn has had significant impact on energy consumption trends.

Figure 6a presents projected trends from 2007-2020. The 1990 base levels on which 20% targets are calculated are referenced. The graph is consistent with the 'EU Trends to 2030' 2007 report and also illustrates its 2009 update.

In the original 2007 report the 'baseline scenario' consistent with the 'WEM scenario' of the EEA 2009 GhG report projected CO_2e savings of 6.4% on 1990 levels. However, as per the 2009 update to the EU Energy trends report, the changing landscape means the baseline scenario is more likely to see savings in the order of 14.3% and with additional measures (WEM) the 'reference' scenario should achieve ~ 20.9% savings on 1990 levels.

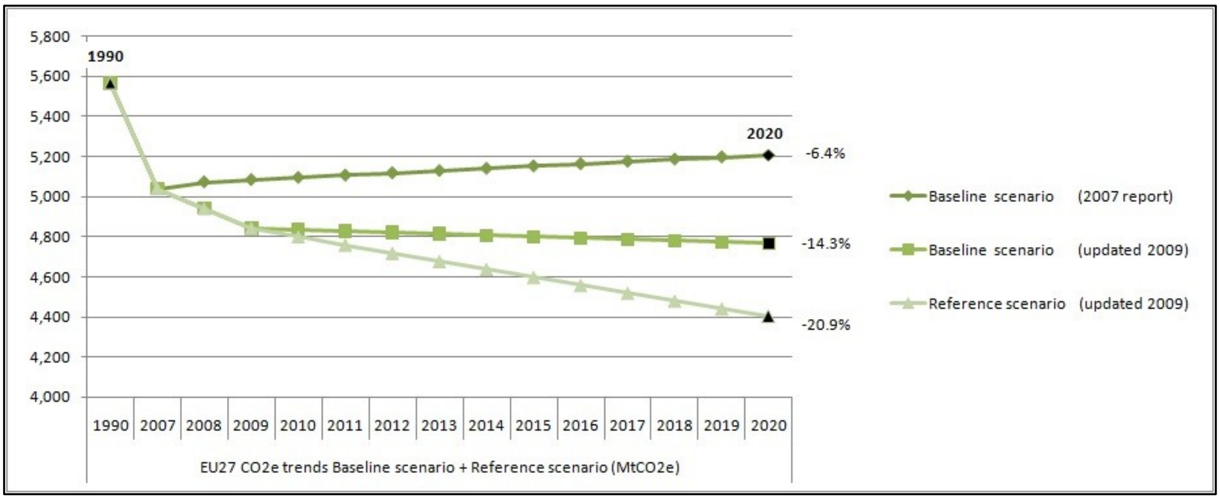


Figure 6a. EU27 CO_2e emission projections EU27 (2007 & 2009 reports)

However consumption figures for 2009 were not fully complete when these projections were made and the Eurostat monthly consumption figures for 2009 would suggest that there has been a more significant downturn in energy consumption for '09 than previously thought. Figure 6b outlines the effect this may have for *CO_2e* percentage savings.

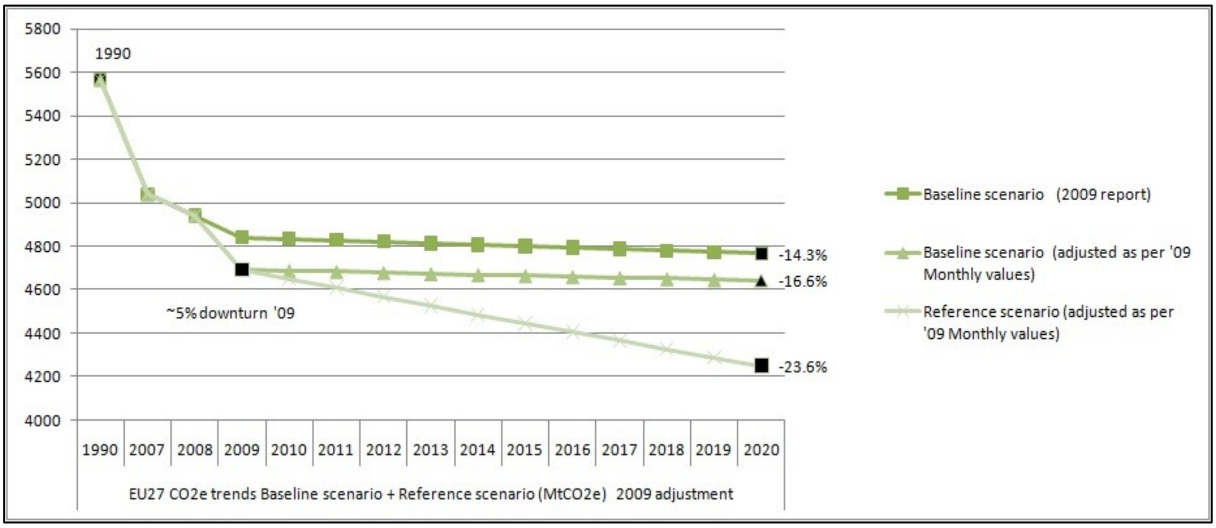


Figure 6b. EU27 CO_2e emission projections EU27 (2009 downturn adjusted)

The link and effect economic activity has for energy consumption and associated CO_2e is apparent. However there seems to be an increased decoupling of energy consumption and economic output. It is somewhat arduous to predict exact abatements however it now seems likely that baseline scenario will result in ~ 7-10% lower CO_2e values by 2020 than originally envisaged in 2007.

Trend's apart the question here is 'to what degree does ICT impact on consumption abatements?' REViSITE will endeavour to estimate that impact of ICT and more importantly highlight favourable actions to enable such abatements.

From Figure 5a, total EU27 CO_2e would under the 2009 Reference scenario equate to ~ 4,451 $MtCO_2e$, a 1,113 $MtCO_2e$ (20.9%) saving/abatement on 1990 levels. The following section therefore estimates to what degree the four identified sectors might contribute to those abatements via ICT enabled initiatives. In doing so it references estimated 2020 values based on the original 2007 baseline trends. The reason for this is in part because sector specific references have not typically been updated to reflect reduced economic activity.

2.2 Energy Profile of Target Sectors

Global figures for the four sectors reference the 2008 GeSI Smart2020 and the IEA 2009 reports. All EU27 figures reference Eurostat and other commission sources. Figure 7 below identifies the projected prime energy of each of the sectors in 2020 and is taken from Annex 2 which is a REViSITE synthesis of sources including Eurostat tables and the 2007 'European Energy and transport trends to 2030' report.

Total prime energy consumption in each sector is identified in million tonnes equivalent. The total potential saving based on the literature is presented and the total CO_2e saving attributable to ICTs is calculated from total savings based on world % as per 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%		
Energy branch consumption	95	252	less user	-30	5.0%	**257**	73.5%
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 7. Potential 2020 sectorial breakdown- (REViSITE summarised synthesis from Annex 2)

If assumptions made in the GeSI report hold ICT enabled changes could account for ~ 56% of the four identified sector specific abatements. If ICT enabled abatements alone were implemented the projected 2020 CO_2e values would be ~ 15% below 1990 levels as opposed to 6.4%.

Estimated abatements identified in the 2006 'Action Plan for Energy Efficiency' for buildings and manufacturing are indicative of much of the literature relating to these sectors (27% & 25%) and were used here to calculate sector specific abatements. Smart grid projections are taken from various ETP sources and Eurostat data regarding transformation efficiencies, integration of renewable, energy branch consumption and losses projections. Lighting here represents ~13% of the building figure and is stripped out and presented separately. It is estimated that changes to lighting technologies like LED could save as much as 50%.

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.

2.2.1 Grids

- Total power sector (global baseline) emissions in 2020 are estimated to be 14.26 $GtCO_2e$ of 51.9 $GtCO_2e$ (27.48% of total). Figure 3 shows this is in the order of 32% within the EU27 for 2007
- Total predicted ICT enabled abatements in the sector is estimated to be 2.03 $GtCO_2e$, 14.24% of 2020 total Global power sector emissions.
- 280 $MtCO_2e$ (13.8%) of that 2.03 $GtCO_2e$ figure is attributable to 'reduced consumption through user information'.
- From figure 7 projections 2020 prime energy consumption would equate to ~576 Mtoe. With emissions equating to approx. 1,537 $MtCO_2e$.
- Assuming the 14.26% savings in above Figure 7 scenario holds true for EU27 total projected ICT EU27 smart grid abatements (WEM) would equate to 1,537*14.3% = 220 $MtCO_2e$ however 13.8% of this is demand side reductions and is accounted for in other sector calculations. Therefore **projected ICT enabled Smart Grid saving within the EU27 = 189 $MtCO_2e$.**

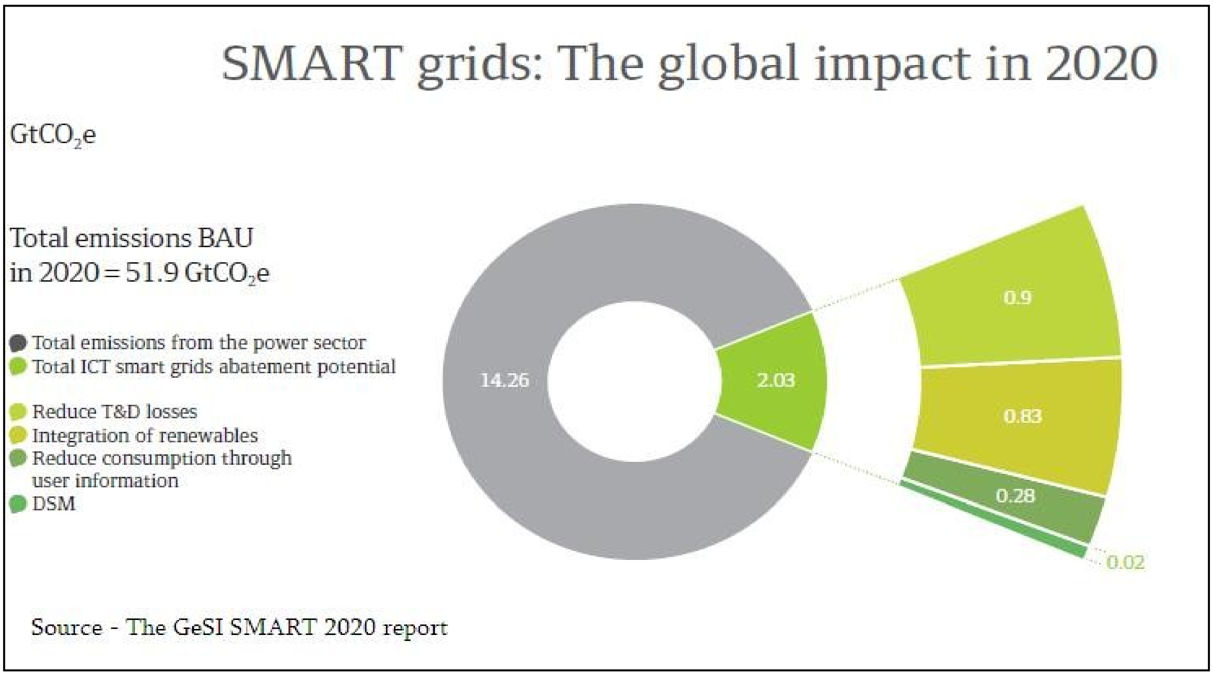


Figure 8. Smart Grids: The Global Impact in 2020

2.2.2 Buildings

- From Figure 9 Total world building emissions (BAU) in 2020 is 11.70 $GtCO_2e$.
- From Figure 9 Total globally predicted ICT enabled abatements in sector equals 1.68 $GtCO_2e$ however this includes 0.12 $GtCO_2e$ for lighting automation which falls within the SMART Lighting remit. Therefore world total is 1.56 $GtCO_2e$ or 13.33%.
- From Figure 7 - buildings having adjusted for the removal of lighting equates to a projected 437 Mtoe prime energy consumption or 1,160 $MtCO_2e$

- **Potential total savings equate to 27% of this ~313 $MtCO_2e$ with ICT enabled savings being 13.3% or 154 $MtCO_2e$**

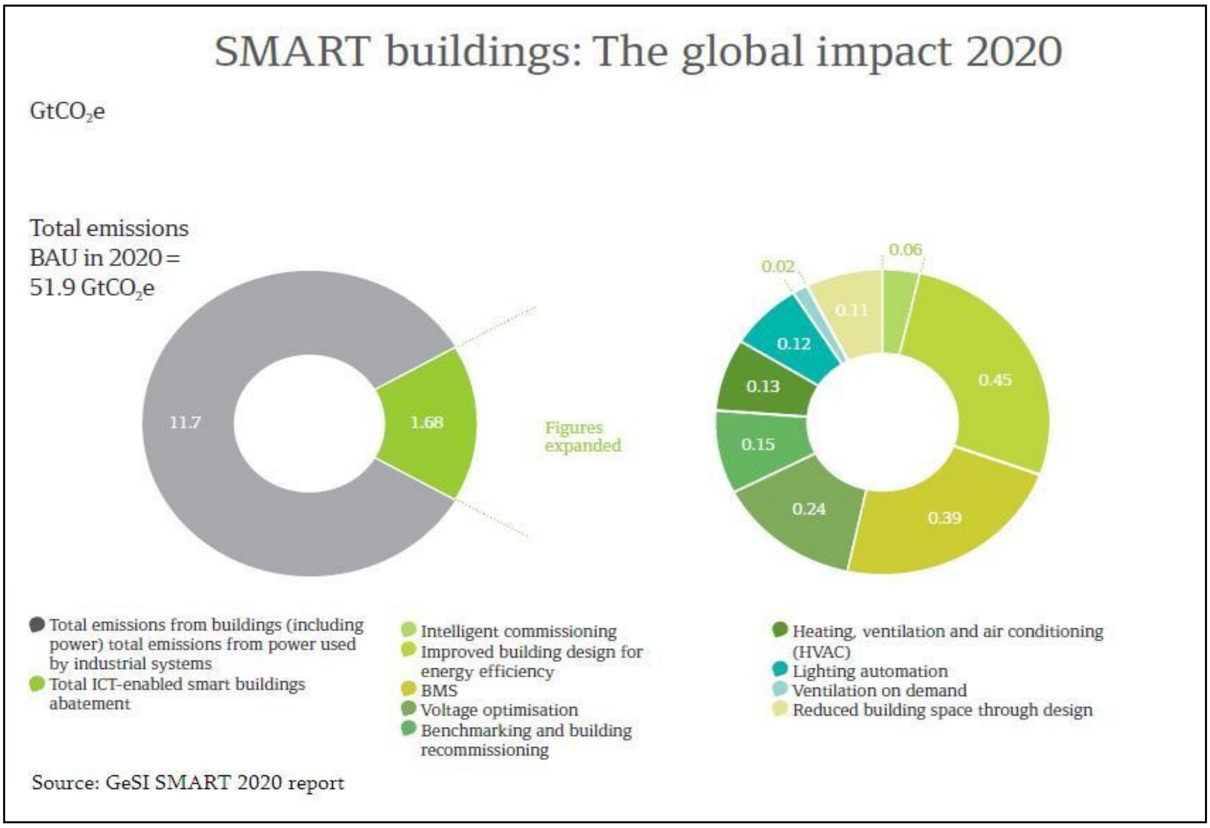


Figure 9. Smart Buildings: The Global Impact in 2020

2.2.3 Manufacturing

'Manufacturing includes all industrial activities from customer to the factory and back to the customer, the term production may be used for the process of making the goods. Manufacturing processes also involve supply chains that span the globe as well as lifecycle of a product.'[12]

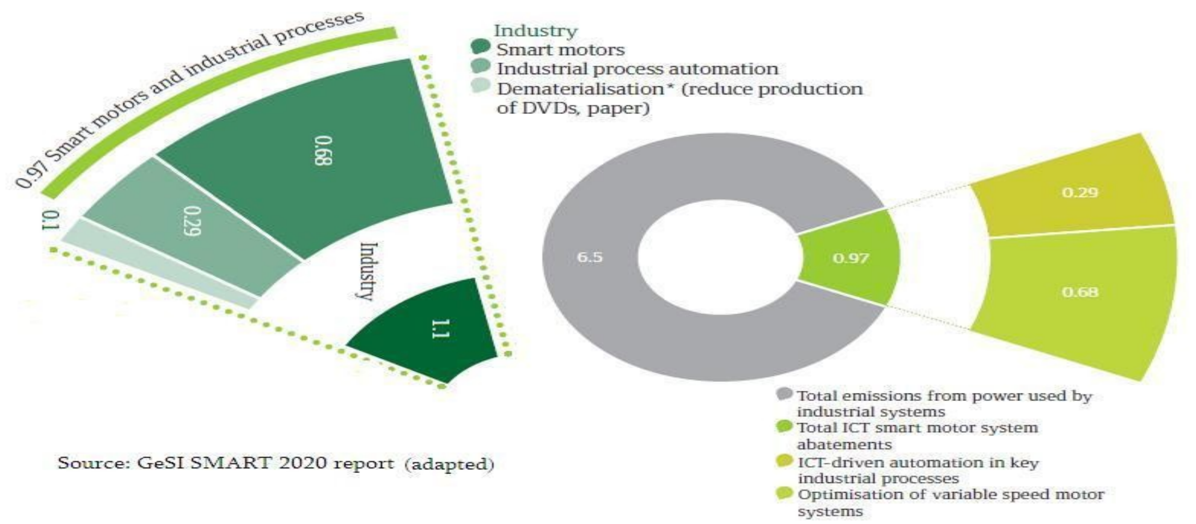
However within REViSITE the focus will be on the production-system as per section 1.3 and the focus is bounded within the physical production plant the machinery and processes required to produce product and the energy intensity of such facilities. 'Industry' as defined within Eurostat is consistent with this definition. Figures reported here as 'industry' equate to 'manufacturing'.

'Industry' is defined by Eurostat as all industrial sectors, e.g. iron and steel industry, chemical industry, food, drink and tobacco industry, textile, leather and clothing industry, paper and printing industry, etc., with the exception of transformation (energy sector) and/or own use of the energy producing industries. Small-scale craft industry is reported by Eurostat under household and services, with external logistics reported under transport.

In addressing potential abatements in manufacturing the GeSI Smart 2020 report refers to 'smart motor systems' however the abatements outlined actually cover 'smart motors' and 'industrial process automation' this aligns with the REViSITE ICT production-system focus. In total 1.1 $GtCO_2e$ are listed as being the potential global abatements for industry but this includes 0.1 $GtCO_2e$ due to dematerialisation. In short 0.97 $GtCO_2e$ can be taken to be reflective of possible world abatements.

The 297 Mtoe value in Figure 10 is approx 16-17% of the 2005 EU-25 primary energy consumption. From Figure 7 this is projected to be ~ 346 Mtoe or 919 $MtCO_2e$ by 2020.

From EU27 Eurostat figures, industry consumption as a percentage of gross energy consumption averaged 18.62% for the period 1997-2008 (See Annex 2). This percentage is consistent with Figure 10 sources, 'ICT and Energy Efficiency - The case for manufacturing' and 'action plan for Energy efficiency: Realising the potential', with respect to total prime energy consumption of industry. Average electrical consumption equated to 39% for the same period.



Source: GeSI SMART 2020 report (adapted)

Sector	Energy consumption (Mtoe) 2005	Energy Consumption (Mtoe) 2020 (Business as usual)	Energy Saving Potential 2020 (Mtoe)	Full Energy Saving Potential 2020 (%)
Manufacturing Industry	297	382	95	25%

Source: EU Commission 'Action plan for Energy efficiency: Realising the Potential' (adapted)

Figure 10. Smart MFG: The Global Impact in 2020

From Figure 7 total projected savings are estimated at 230 $MtCO_2e$ or ~ 87 Mtoe which is comparable with the 95 Mtoe of Figure 10 when adjusted to remove logistical savings. **ICT enabled abatements are therefore projected to account for ~ 137 $MtCO_2e$.** This saving aligns to the GeSI estimates of 14.61% abatements. EU27 2007 industry consumption represents 14.55% of world industry consumption see IEA + Eurostat compare (Figure 11) and 14.61% of 970 $MtCO_2e$ (i.e. the estimate global impact of ICT on industry) is 141 $MtCO_2e$.

	2007		
	World	EU-27	EU-27 as % of
	Mtoe		
Total Final Energy consumption (industry)	2,275	331	14.55%

Source IEA 2009 report + Eurostat 2007

Figure 11. EU27 MFG as a % of World MFG

2.2.4 Lighting

Lighting is a large and rapidly growing source of energy demand and greenhouse gas emissions. In 2005 grid-based electric lighting consumed was 2 650 TWh worldwide, about 19 % of the total global electricity consumption. [13] Global lighting electricity use is distributed as approximately 28 % to the residential sector, 48 % to the service sector, 16 % to the industrial sector, and 8 % to street and other lighting. For the industrialized countries national lighting electricity use ranges from 5 % to 15 %, while in developing countries the value can be more than 86 % of the total electricity use.[14] The percentage of the electricity used for lighting in European buildings is 50 % in offices, 20-30 % in hospitals, 15 % in factories, 10-15 % in schools and 10 % in residential buildings.[15]

Directive 2005/32/EC of the European Parliament and of the Council of July 6th 2005 establishes a framework for the setting of ecodesign requirements for energy-using products (EC 2005). A recast of the directive was adopted on 21 October 2009 (Ecodesign Directive 2009/125/EC). The implementing measures have been published in form of Commission Regulations (Commission Regulation (EC) No 244/2009 and 245/2009). Regulations will gradually phase out incandescent bulbs starting in 2009 and finishing at the end of 2012, give limits for the efficiency of ballasts and stand-by losses and set limits for the efficacy of discharge lamps.

In different studies lighting has been found to be a cost-effective way to reduce CO_2 emissions. The Intergovernmental Panel on Climate Change for non-residential buildings concluded that energy efficient lighting is one of the measures with the largest potential and also providing the cheapest mitigation options. Among all the measures that have potential for CO_2 reduction in buildings, energy efficient lighting comes first largest in developing countries, second largest in countries with their economies in transition, and third largest in the industrialized countries.[16]

The 2006 'Action Plan for Energy Efficiency: Realising the Potential' suggests "20% of global electrical energy production today is used for lighting. According to studies, the adoption of high efficiency Light Emitting Diode (LED) technology, already available on the market, could by 2015 save 30% of today's consumption for general lighting and 50% by 2025".

Table 97: Saving potential for lighting according to ELC 2008[203]

	Savings potential (per year) *			
	CO2 (Million tonnes)	Savings potential (KWh) = 0.37 kg CO2/kWh (**)	Savings potential in Euro (***)	Euro/kWh (***)
Domestic Lighting	23	62.2	€ 9.3 billion	€ 0.15
Office Lighting	8	21.6	€ 2.2 billion	€ 0.10
Industrial Lighting	8	21.6	€ 2.2 billion	€ 0.10
Street Lighting	3.5	9.5	€ 0.9 billion	€ 0.10
Total	**42.5**	**114.9**	**€ 14.6 billion**	**N/A**

* This figure is based on the latest (conservative) industry estimates for the a total switch to energy efficient street, office, industry and domestic lighting in the EU (27). Detailed savings potential figures from each EU member states are in the process of being calculated by the ROMS programme.
** Figure courtesy of the International Energy Agency - 0.37kg CO2/kWh - CO2 EMISSIONS FROM FUEL COMBUSTION (2006 Edition) - II. 61
*** Figure courtesy of Philips Lighting B.V

Fig 12 - Saving Potential of Lighting

The GeSI Smart 2020 report suggests lighting automation within buildings equates to 0.12 $GtCO_2e$.

The ELC federation suggests the saving potential of lighting to be 42.5 $MtCO_2$ a year (see figure 12 above). However again the changing of lamp type is not the focus of REViSITE but rather ICT enabled savings. The GeSI figure of 0.12 $GtCO_2e$ is taken to be realistic for lighting automation.

From Figure 7 the total lighting consumption in buildings equates to ~60 Mtoe. Therefore the **ICT smart lighting potential abatements for the EU27 equate to 12 $MtCO_2e$.**

2.3 Existing Sector specific taxonomies and points of reference

2.3.1 The need for a common approach and taxonomy

It is apparent that the task of assessing the energy profile of the various sectors at the Eu27 level is a considerable task. Even more arduous is the task of estimating the impact of ICTs on the energy efficiency and consumption of those sectors. When dealing with four different sectors with their own units of measurement, language, practices and terminology it is important to offer a means of common assessment. A common methodology and taxonomy for categorising technologies is required. As such REViSITE set about researching existing methodologies and taxonomies that needed to be considered, utilised or adapted in offering a common means of assessment to all four sectors.

2.3.2 Existing taxonomies

Our research suggests that there exists no commonly known taxonomy for the categorisation of ICTs relevant to a specific sector or sector specific life cycle nor is there a general taxonomy that could be applied. The most relevant taxonomy in this regard was that developed by the REEB consortium[17]. What follows is a description of that taxonomy which related to the smart building sector only.

REEB:

A common taxonomy in the REEB project has been defined in order to ensure broad coverage of the scope of the ICT4EEB domain, to harmonise work between different WPs within the project and to present the project results in a consistent way. All reports of REEB apply a similar structure with some variations depending on the specific contents.

The taxonomy has 3 levels: categories (<u>underlined</u>), sub-categories (*italic*) and RTD topics (normal). The categories and sub-categories have proven to cover the scope well and are quite stable, while an almost endless number of RTD topics can be identified. The below RTD topics are common examples.

<u>1. Tools for EE design and production management</u>

- ***Design:*** CAD, configuration management, visualisation of design solutions
- ***Production management:*** contract & supply network management, procurement, logistics, on-site and off-site production management.
- ***Modelling:*** building & district modelling, ontology's, semantic mapping.
- ***Performance estimation:*** simulation, whole-life costing, life cycle assessment.

<u>2. Intelligent control</u>

- ***Automation & control:*** system concepts, intelligent HVAC, smart lighting, ICT for micro generation & storage systems, predictive control.
- ***Monitoring:*** instrumentation: smart metering.

- *Quality of service:* improved diagnostics, secure communications.
- *Wireless sensor networks:* hardware, operating systems, network design.

3. User awareness and decision support

- *Performance management:* Understanding ICT impacts, performance specification, performance metrics, performance analysis and evaluation, conformance validation, commissioning, audits, labelling.
- *Visualisation of energy use*.
- *Behavioural change* by real-time pricing.

4. Energy management and trading

- *Building energy management:* building management systems, metering infrastructure, on-demand energy management and optimisation, load and distributed energy resources forecast algorithms, smart appliances.
- *District energy management:* demand response capabilities, real-time self-assessment, load balancing techniques, energy network design and integration, secure, ubiquitous and low-latency communications, interfaces with smart grids.

5. Integration technologies

- *Process integration:* collaboration support, groupware tools, electronic conferencing, distributed systems, business work flows.
- *System integration:* plug & play, connections, service oriented architectures, integration and service platforms, cabling, gateways, middleware, development methods and tools.
- *Interoperability & standards:* BIM standardisation, simulation and interoperability, protocols for real time operation, energy trading protocols.
- *Knowledge sharing:* access to knowledge, knowledge management, knowledge repositories, knowledge mining and semantic search, long-term data archival and recovery.

- *Virtualisation of the built environment:* Replacing physical assets with services and ICT, teleconferencing, remote learning.

ECTP SRA+IAP

The ECTP SRA + IAP are currently under revision. The draft version v.1.02 (3 Nov 2009) includes 59 “items” organised into 9 “priorities”:

A Technologies for healthy, safe, accessible and stimulating urban and indoor environments for all.

B Innovative use of underground space.

C Energy efficient buildings – This priority is being implemented by E2B PPP.

D Reduce environmental and man-made impacts of built environment and cities.

E Sustainable management of transports and utilities networks.

F A living cultural heritage for an attractive Europe.

G Improve safety and security within the construction sector.

H New integrated processes for the construction sector – This priority is being addressed by FP7 Coordination and Support Actions REEB, REViSITE and ICT4E2B Forum, and a number of projects in FP7 and CIP ICTPSP.

I High added value construction materials.

Due to application-orientation, many of these categories address similar or same technologies (e.g. ICT). In order identify potentially common RTD topics, the ECTP FA Processes and ICTs has regrouped the “items” e.g. as shown in Figure 13. This exercise is quite similar to REViSITE: construction sector consists of several segments, in this case shown as four. The challenge is to identify common RTD topics between them.

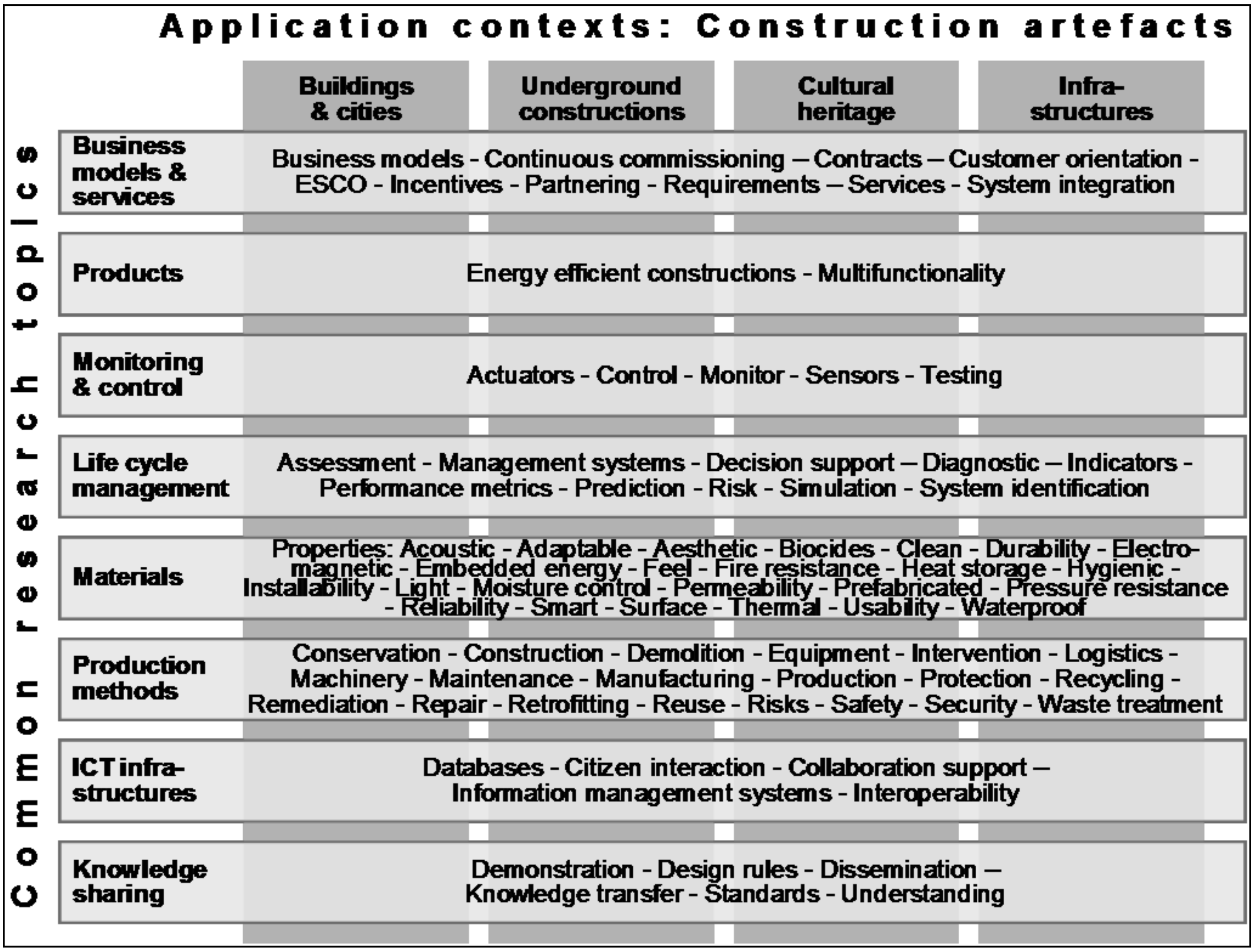


Figure 13. Tentative consolidation of the topics of the ECTP SRA+IAP.

2.4 “Quantifying” potential impact

2.4.1 Existing assessment methods

Existing Standards / Guidelines

The ISO 14040 series, PAS 2050 (proposed Publically Available Specification) and GHG Product Protocol are widely referenced. Commission, DEFRA, EEA and IEA resources are extensively referenced within the literature.

LCA

The only internationally recognised standard for LCA is the ISO 14040 series see illustration below. ISO define LCA as "the compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle."[18]

SETAC definition - "Life Cycle Assessment is an objective process to evaluate the environmental burdens associated with a product, process, or activity by identifying energy and materials used and wastes released to the environment, and to evaluate and implement opportunities to affect environmental improvements."

The commissions LCA Info Hub website states "LCA, is a methodological tool that applies life cycle thinking in a quantitative way on environmental analysis of activities related to processes or products (goods and services). A central characteristic of life cycle assessment is the holistic focus on products or processes and their functions, considering upstream and downstream activities"

The word 'objective' in the SETAC and 'potential' in the ISO definitions should be noted, as LCA is not a measurement system but rather a type of 'quantitative' modelling approach and any assumptions therein need to be understood.

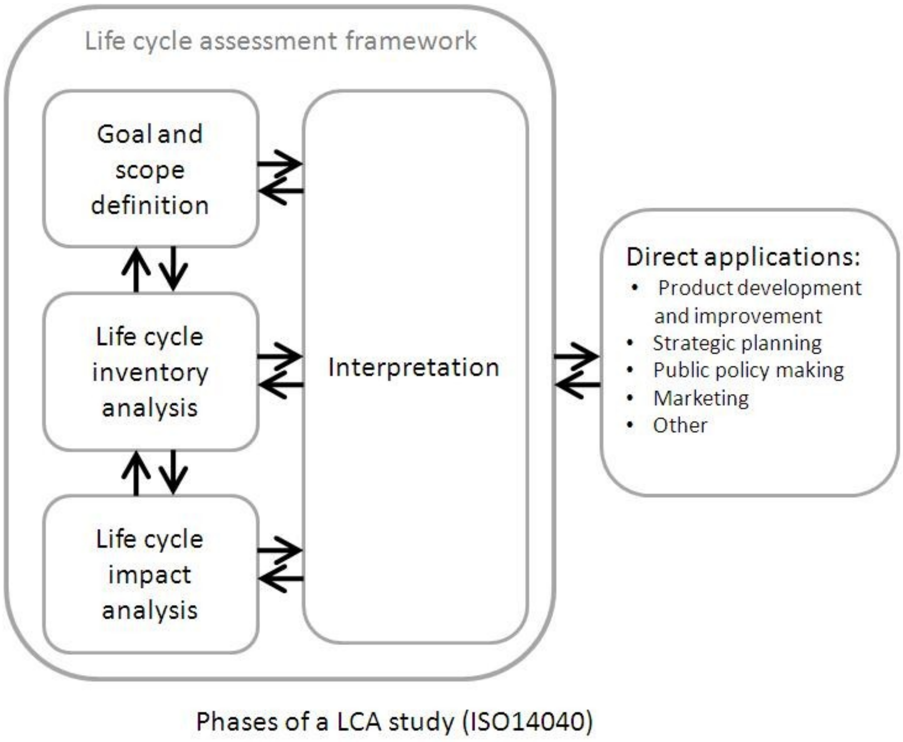


Figure 14. ISO LCA Structure

The EU-Commission LCA hub website is an excellent resource with a LCA introduction section, a resource/services directory as well as guidelines and the ELCD database http://lca.jrc.ec.europa.eu/lcainfohub/index.vm

EIO

Economic Input-Output (EIO) LCA is based on the input-output analysis technique, developed by the Noble winning Wassily Leontief for capturing economic interdependencies.

EIO LCA involves the use of economic sector-level data to determine the level of impact that can be attributed to each sector. This approach alleviates to some degree the scoping issue of process-sum LCAs, however using information at the macro level has its disadvantages as translating the economic to environmental an arduous and assumption dependant task.

TCO & account based methods

Full (true) Cost accounting, Environmental accounting and total cost of ownership are economic based techniques that are evolving to incorporate the sustainable and energy efficient aspects of capital purchases and operations and can be useful with regard to trade-off decisions and EE awareness.

Modelling

There are many different types of model, causal, mathematical, conceptual, diagrams, maps etc many types of computer based modelling techniques are used in many different fields of study including energy efficiency. But all depend on the ability to accurately make assumptions, to set affective boundary conditions and to describe the system rules that govern that which one is attempting to simulate. An example would be Agent-based modelling (ABM), within ABM a system is modelled as a collection of autonomous decision-making entities called agents. Each agent individually assesses its environment and makes decisions on the basis of a set of defined rules. Agents may execute various behaviours appropriate for the system they represent, for example, purchasing, consuming or conserving. Computational techniques such as 'Monte Carlo' analysis are run to determine likely scenarios.

2.4.2 Other Bodies examining ICT impact

Below (figure 15) are some of the main bodies developing ICT impact assessment frameworks. All suggest some form of 'life cycle thinking'.

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

Figure 15. What others are doing in terms of impact assessment

2.4.3 An introduction to Causality

Causality & causal relationships (Definition)

Causality is - A relationship between one phenomenon or event (A) and another (B) in which A precedes and causes B. The direction of influence and the nature of the effect are predictable and reproducible and may be empirically observed.

A causal relationship - is an information connection between events or happenings whereby one state of affairs (the effect) is brought about by another (the cause). Sometimes this causal relationship is also referred as the cause-effect relationship.

Causal relationship modelling (definition & techniques)

Causal relationship modelling is - an approach or methodology that clearly indicates the information understanding of related entities involved in the causal relationship (e.g. interdependency matrix, sign graphs, cause & effective diagrams, etc,.) The investigation and the understanding of the direction of the causality between enabling ICT and energy efficiency are of great value due to their policy implications. The existence of any causal relationships running from enabling ICT to energy efficiency would indicate the dependence of the economy on energy efficiency with the latter being a stimulus to combat the climate change challenge. In the presence of such causal relationships any structural policies aiming at the reduction of energy use like the policies following the Kyoto protocol or the recent surge in the fuel prices might possibly inspire the development of a large leading-edge market for ICT enabled energy-efficiency technologies and solutions that will foster the competitiveness of energy service industry and create new business opportunities without slowing economic growth. What follow are a number of means to express causal relationships.

Interdependency matrix

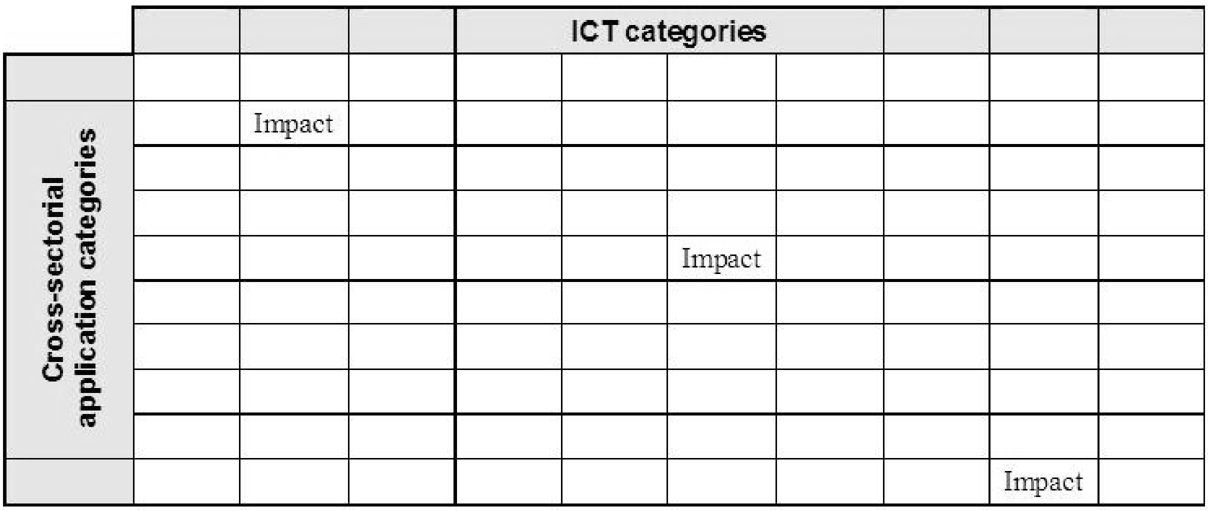


Figure 16. Principle of linking ICTs with EE impacts.
A given ICT may have been used in different applications with different impacts.

Sign graphs & Causal loops

A sign graph, an annotated number line, is a powerful easy-to-use mathematical tool. A sign graph contains the following information for an expression or function:

- The real zeros (the real values that make the expression or function equal to zero)
- The intervals over which the expression or function is of constant sign
- The constant sign for each of these intervals (“+” or “-“)

In causal relationship modelling, using sign graph tool to determine behaviour and intervals of constant sign for products and quotients of functions.

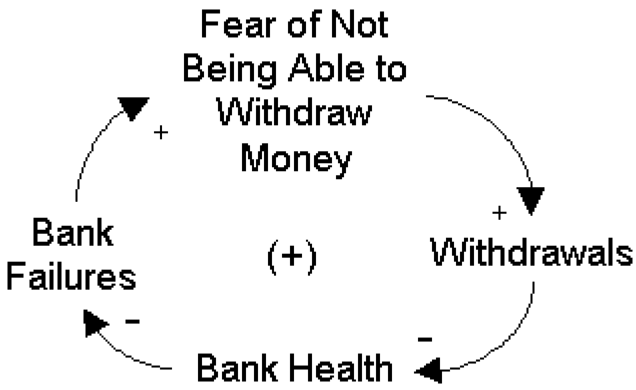


Figure 17. Example of a Reinforcing causal loop

Cause & effect diagrams

This method[19] is useful for identifying the likely causes of problems or any particular effect. The related variants are Fish or Fishbone Diagrams, and Ishikawa Diagrams. Cause and Effect Diagrams help you to think through causes of a problem or any effect thoroughly. Their major benefit is that they push you to consider all possible causes, rather than just the ones that are most obvious. The approach combines brainstorming with use of a type of concept map. Cause and Effect Diagrams are also known as Fishbone Diagrams because a completed diagram can look like the skeleton of a fish.

As an example quality problems are typically not simple. They often involve the complex interaction of several causes. A cause-and-effect diagram will help to: (1) define and display the major causes, sub-causes and root causes that influence a process or a characteristic. (2) Provide a focus for discussion and consensus. (3) Visualise the possible relationships between causes which may be creating problems or defects.

Cause-and-effect diagrams are also particularly useful in the measure and improve phases of Lean Six Sigma methodology.

How to do it?

1. Decide which quality characteristic, outcome or effect you want to examine. You might consider Pareto analysis to help you focus on the most important issue.
2. Write your chosen effect on the right side of a paper, board or flipchart and draw a box around it. If you think of this as a fishbone diagram, this is the fish head.
3. Draw a straight line to the left, the fish backbone.
4. For each primary cause or category of causes, draw a diagonal line slanting from left to the centreline. Alternate these ribs on the top and bottom of the backbone. Label the end of each rib and draw a box around the label.
5. Draw a horizontal line intersecting the appropriate diagonal line and label it to describe each secondary cause that influences a primary cause. Alternate these medium sized bones to the left and right of each rib.
6. In a similar way, draw and label diagonal lines for third level or root causes, small bones, intersecting the secondary cause lines, medium sized bones.
7. Examine the diagram. If certain causes seem to have a significant effect on the characteristic you are examining, mark them in a special way.

Variation 1: Cause Enumeration

Sometime it may be very difficult to determine the primary causes to be included in the diagram. If that is the case, after determining the characteristic or effect being examined, follow these steps:

1. Use brainstorming to create a list of all the possible causes. The list will contain a mixture of primary, secondary and tertiary (or big bone, middle sized bone and small bone) causes.
2. Sort the list by grouping causes that are related.
3. Identify or name each major grouping and make your cause-and-effect diagram.

Machine, Manpower, Material, Measurement, Method and Mother-earth (Environment) are frequently used major causes that can apply to many processes.

The advantage of the cause enumeration technique is that you stand a much better chance that all causes will be listed, especially hidden ones, and the diagram will be a complete and useful picture. The disadvantage is that it may be difficult to relate all the causes clearly to the result, making the diagram hard to draw.

Variation 2: Process Classification

Sometimes it is more helpful to look at causes in the sequence in which they occur instead of considering overreaching logical categories. With this approach, the centre line or backbone follows the sequence of the process.

Instead of primary causes as the ribs, show the major process steps from left to right. Construct your cause-and-effect diagram as before.

The advantage of this technique is that, since it follows the sequence of the process, it will be easy for everyone to understand. The disadvantages are that similar causes will appear again and again, and causes due to a combination of factors will be difficult to show.

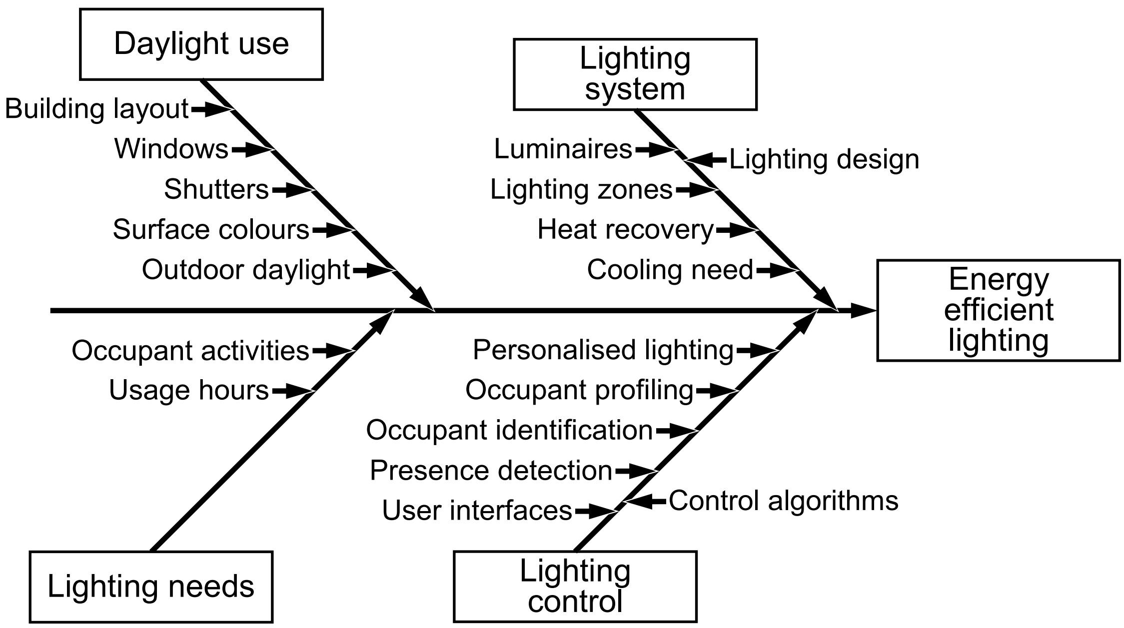


Figure 18. Example of Cause & Effect diagram

Sankey diagrams

Sankey diagrams are commonly used for visualisation of energy conversions and flows in a system.

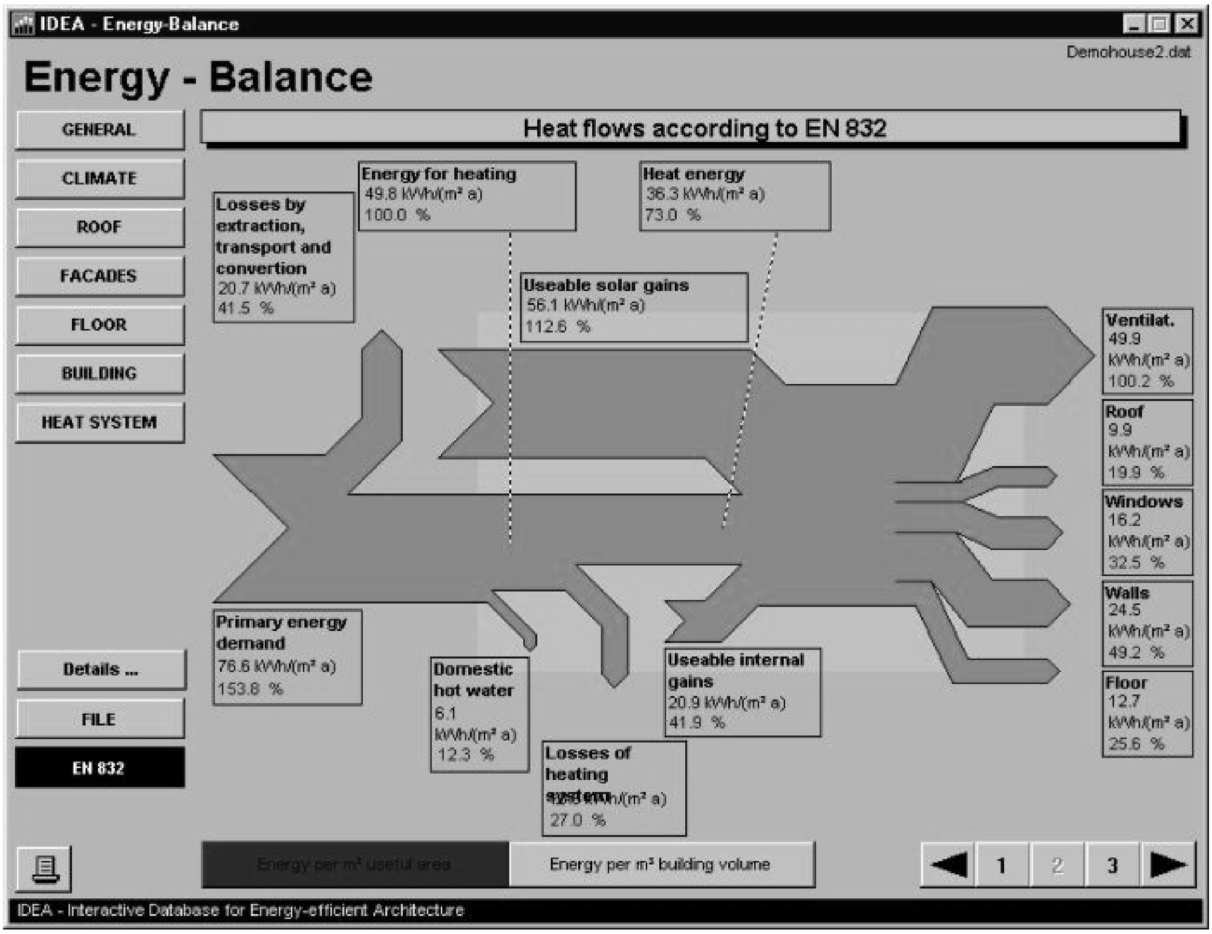


Figure 19. Example of a Sankey diagram

9 Windows

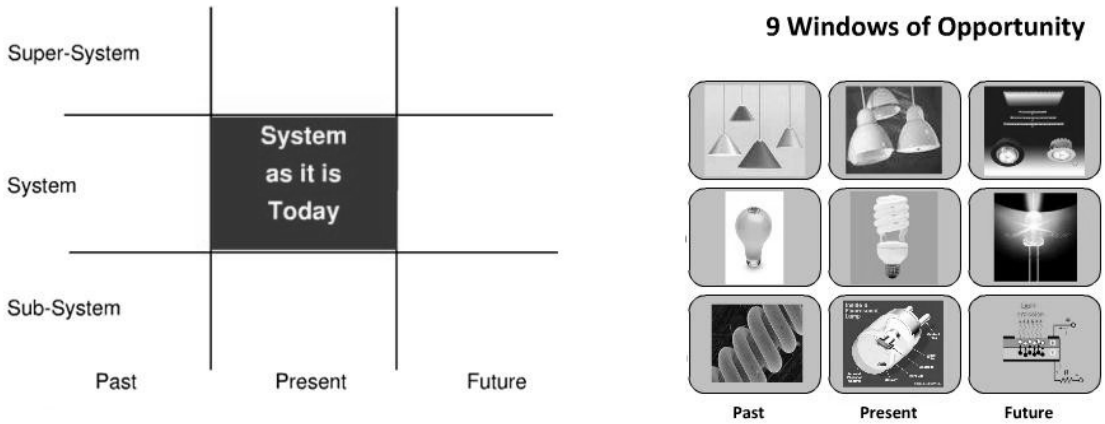


Figure 20. Nine windows technique.

3 The REViSITE approach

3.1 REViSITE Methodology overview / introduction

Considering the existing information, methodologies and taxonomies (of which REEB was the only relevant taxonomy), we concluded that no one existing methodology was appropriate for REViSITE in assessing the impact of ICT on energy efficiency in the target sectors. As such we prepared the criteria, listed below, in order to guide methodology and taxonomy development.

Any common methodology should:

- Be generically applicable to any identified sector but specific enough to be of value in analysing the impact of ICTs on EE and by association CO_2e in specific sectors. Particularly the four identified:
  - Smart Grids
  - Smart Buildings
  - Smart Manufacturing
  - Smart Lighting
- Be applicable to identified stakeholders.
- Consider current 'Best Practice' in capturing both the consumption and enabling impact of ICT.
- Assess impact of ICT where it makes sense to do so in 'life cycle'.
- Assist in understanding causal relationships.
- If possible utilise a single taxonomy for categorising RTD / technologies in order to make cross-sector comparison more feasible.

What follows is an overview of the approach developed internally for REViSITE partners to utilise as part of their research within the project. The general reader should note it was written with the REViSITE consortium partner's in-mind. As stated previously it is envisaged that the methodology may prove useful to a wider community.

It is apparent that emerging 'best practice' in assessing the impact of ICT4EE utilises some form of 'life cycle assessment' (LCA) or 'life cycle thinking' approach. It is also clear that LCA's, in the main, focus 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 –v- product. This is fine from a product/service or company perspective; however, gaining a regional or system (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. What is required is a means of evaluating the ICT types best positioned to drive energy and CO_2e reductions while also highlighting gaps that require future ICT investment.

The REViSITE methodology is a hybrid that seeks to combine simplified 'Life cycle assessment' or rather 'life cycle thinking' and an adapted 'Capability Maturity Model' (CMM). By combining existing LCA data, secondary sources, sector specific standards and heuristics, it is believed REViSITE can build an 'informed view' (see Figure 21) regarding those ICTs best positioned to impact on energy efficiency.

Full LCA's are heavily data dependant and specific in nature. However, REViSITE partners may deem it appropriate in using LCA methods in completing 'simplified' LCA's for inclusion in their research. Partners should note that the posited approach is more in keeping with the 'holistic spirit' or 'Life cycle thinking' of LCA, as opposed to detailed assessment. The approach cannot, and is not, intended to replace a more detailed, expansive LCA. Such

LCA's 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 approach here is focus on the systems life cycle processes and the energy intensity of those processes in order to build an informed view that can assist roadmap development.

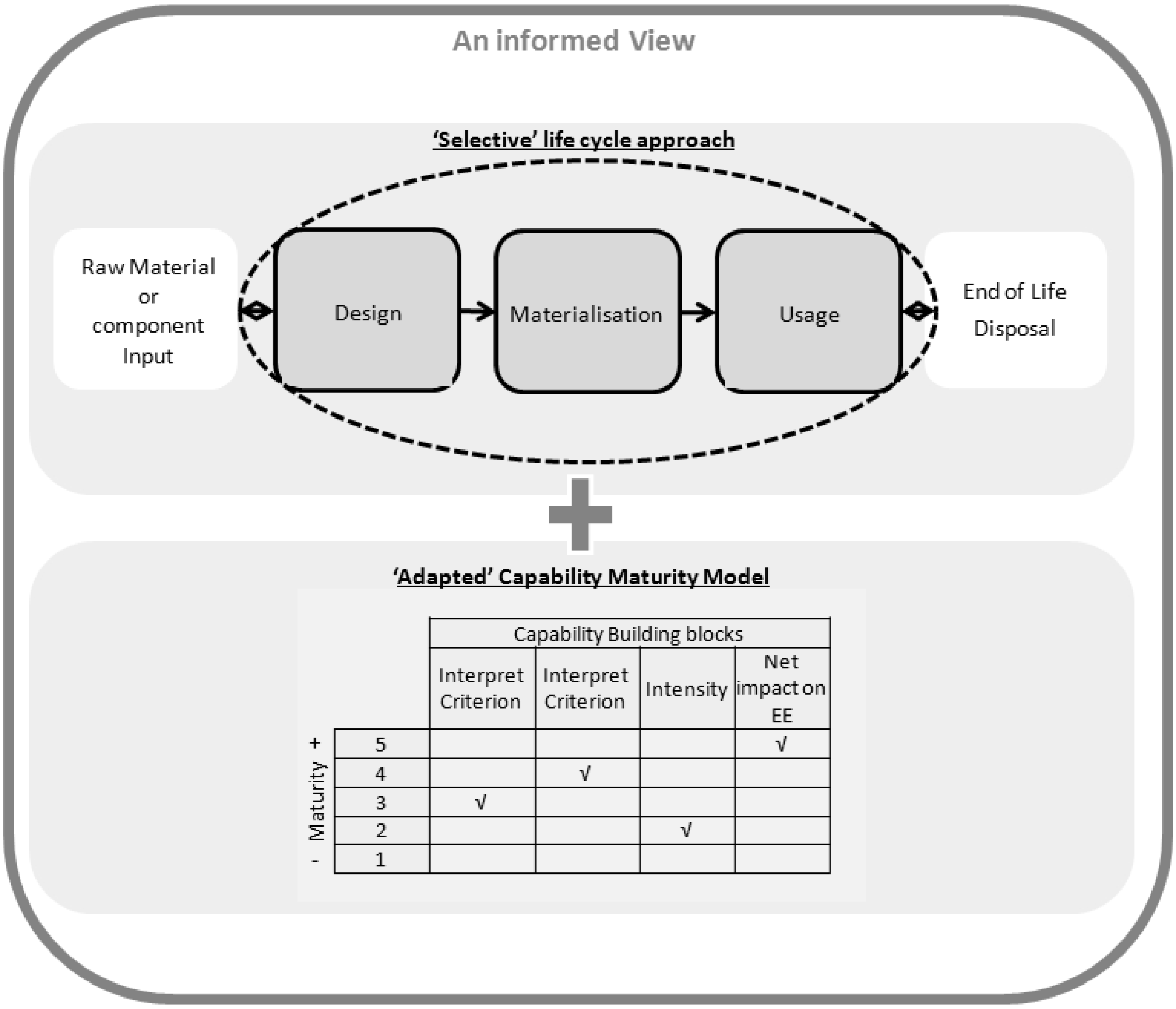


Figure 21. The REViSITE approach, an informed view

In short, where there are gaps in available primary data and analysis, individual partners will make an assessment of the impact of ICTs based on heuristics and expertise within their defined sectors. This is where the simplified CMM maturity analysis comes into play. By understanding the respective 'maturity level' of specific ICTs, one can begin to identify those ICTs best placed to deliver meaningful impact. Section 3.2 that follows will give some insight into the choice of CMM as a framework. This is followed by Section 3.3 which details the REViSITE developed SMARTT taxonomy which is posited as a useful means of ICT/RTD categorisation.

3.2 Why CMM – some background

The capability maturity model or framework (CMM or CMF) was originally developed by researchers at the Software Engineering Institute (SEI) at Carnegie Mellon University. The framework was developed as part of their overall thinking and approach to improving the software development process.

The Software CMM has had an enormous impact within the ICT industry, spurring significant investment and restructuring. It was, for example, one of the drivers in the development of the ISO/IEC 15504 – 'Process Assessment' standard, also known as SPICE (Software Process

Improvement and Capability Determination), and while the first versions of the standard focused exclusively on software development processes it has since expanded to cover all related processes in a software business, for example, project management, configuration management, quality assurance etc.

In fact, stripped of its software content, the CMM provides a framework for understanding the maturity of almost any process. It is also worth noting that CMM actual harks back to Quality/TQM principles and is influenced by the concepts of luminaries such as Crosby (1979), Deming (1986) and Juran (1988). Specifically, Crosby describes five evolutionary stages in adopting quality practices. The five stages are:

- Uncertainty: Management is confused and uncommitted regarding quality as a management tool.
- Awakening: Management is beginning to recognize that quality management can help.
- Enlightenment: The decision is made to really conduct a formal quality improvement program.
- Wisdom: The company has the chance to make changes permanent (things are basically quiet and people wonder why they used to have problems).
- Certainty: Quality management is considered an absolutely vital part of company management.

Quality based methodologies and sustainability have a highly complementary intolerance of waste, and methodologies such as TQM, Lean and Lean six sigma are increasingly used in an environmental improvement capacity.

The application of CMM in a sustainable context is not entirely unique either. The UNEP (United Nations Environmental Programme) and SETAC (The Society of Environmental Toxicology and Chemistry) produced publication on Life Cycle Management also references CMM as being a *"tool that can support companies in moving towards a next level of evolution in business management. Acting as a framework, this tool provides five levels of maturity. As the organization moves from a compliant strategy toward sustainability, higher levels of maturity or capability are required for successful execution"*

Maturity Level	Description	Span of control
1 Ad hoc	Chaotic, success depends on heroic effort of individual.	Individual
2 Managed	Requirements managed, measured and repeatable results on a project basis.	Project
3 Defined	Standard processes, consistent across organization, measures of process and work products.	Organization
4 Quantified process control, quantified objectives, special causes of variation corrected.	Value chain	Value chain
5 Optimizing	Process improvement objectives continually revised to reflect changing business objectives: agile and innovative workforce.	Society

Figure 22. CMM maturity levels (source UNEP & SETAC)

Within REViSITE, CMM, together with 'Life Cycle Thinking', is employed to frame the thinking, heuristics and estimates of partners with regard to the ICT types with the greatest impact potential. Within REViSITE, the five level framework above is replaced with that of Figure 23 below.

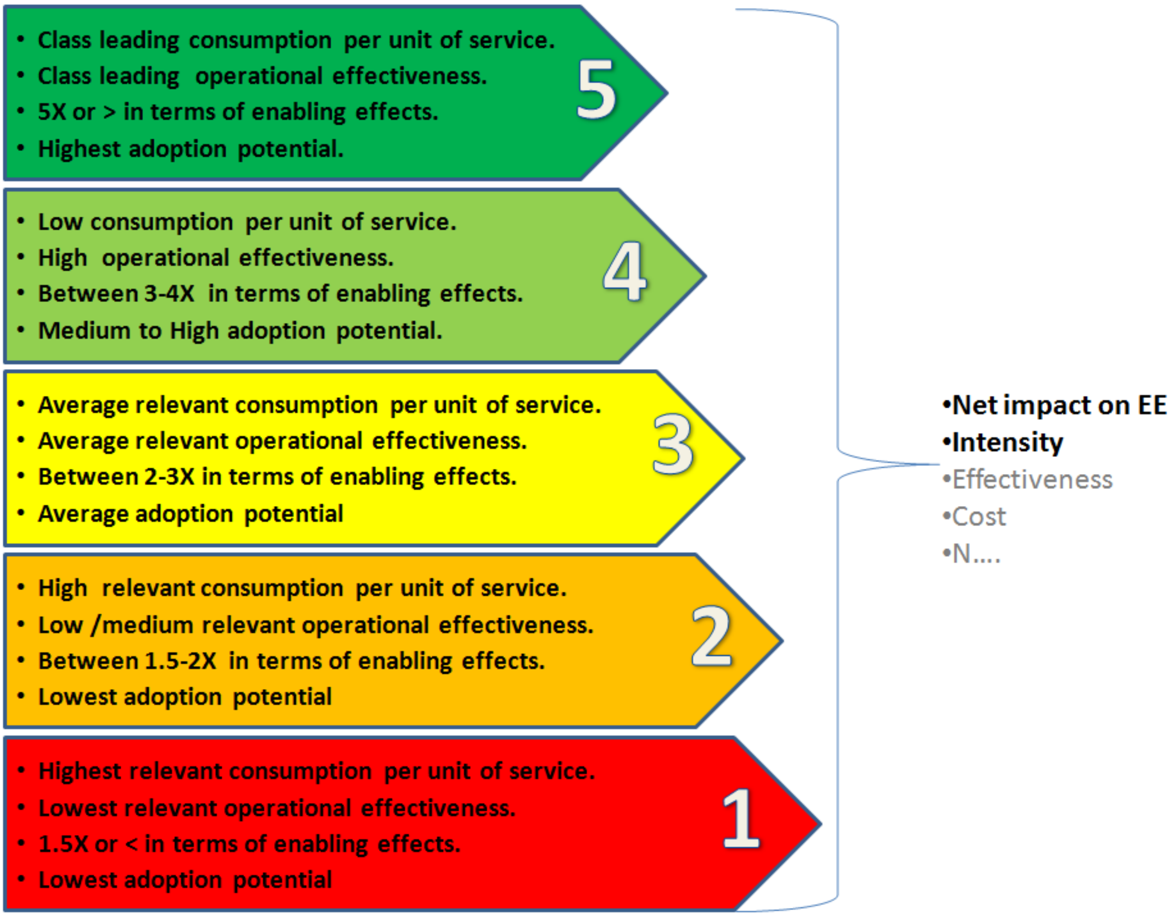


Figure 23. REViSITE Maturity scale for assessing ICT4EE maturity

REViSITE Partner Intel through its co-founding involvement in the Innovation Value Institute[20] has built considerable competence in applying CMM (called CMF capability Maturity Framework within IVI) to varied contexts including sustainability. The use of CMM in REViSITE is simplified to the extent that it involves a template with a uncomplicated cause and effect type matrix. REViSITE focus is on two identified 'critical building blocks' or 'fixed criterion'. ICT/RTDs are scored on these criterion - namely 'intensity' (potential versus actual) and 'net impact on EE'. Additional 'interpretive criterion' 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 examples that follow in section 4 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.

Utilising elements of the CMM, 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 the contextual richness of the qualitative research, augmented by a quantitative estimate of the 'potential intensity' and 'potential net EE impact' of ICTs, should reliably inform the causal model and roadmap development. That, in essence, is the power of a CMM, in that it allows partners to quantitatively illustrate and analyse what is essentially inductive qualitative research based on heuristics.

As partners document that research throughout D2.2 'Knowledge and current practice report', they should utilise methods and tools such as Sankey diagrams, Cause and Effect diagrams, sign-graphs and matrices as outlined in section 2 to effectively illustrate and explain causal relationships and non-interdependencies. The level of capability maturity will undoubtedly vary between sectors and ICTs. It is envisaged that sectors with high levels of capability in individual elements will offer potential progression paths for other sectors.

It is worth noting that model development as part of D2.3 is high level and causal in nature. In fact, it is more closely aligned to a framework development than a model in any quantitative sense. Nevertheless, low level data will be included where available and appropriate. The aim is to build on the qualitative assessment of partners in each sector as outlined in T2.2-2.5 (D2.2) and, as part of that process, partners should utilise the taxonomy of section 3.3 to categorising their research in a consistent fashion, allowing for effective cross sectorial comparison.

3.3 REViSITE SMARTT Taxonomy

The REViSITE taxonomy utilises six high level categories and is a variation on the SMARTT acronym. There are 20 less abstract sub-categories nested within the 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 & 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. (see figure 24 below)

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 exemplars

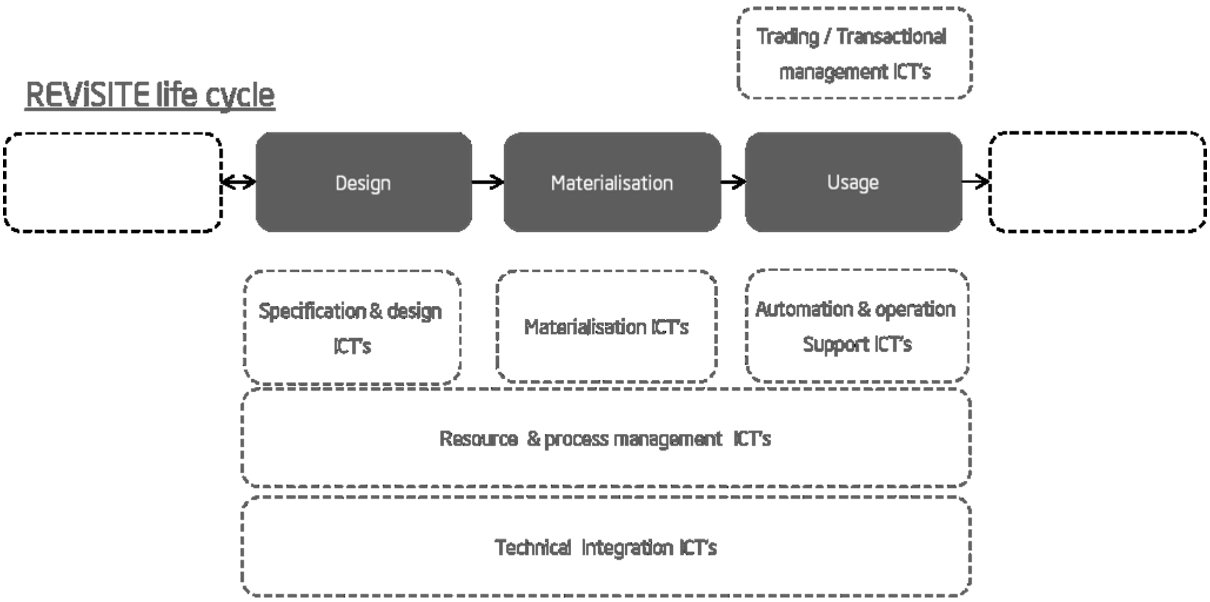


Figure 24. The SMARTT Taxonomy mapped to Life Cycle Phases

As above, partners identified ICT/RTDs that represent the lowest level of granularity. By fixing higher levels of the taxonomy we allow for cross-sectorial comparison and discussion. REViSITE developed the taxonomy for use within the four target sectors. However, it is posited as a generic and useful taxonomy for any sector, including transport. In the example of transport it may well be the case that those categories and sub-categories which align to the materialisation life cycle phase would not be particularly applicable. Nevertheless, those that apply to the design and usage phases would be pertinent. What follows details the taxonomy, main categories and sub-categories:

1. **Specification & design ICTs**
   a. ***Design conceptualisation:*** requirement engineering/mgmt 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.
    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

4. **Resource & process management ICTs**
    a. ***Inter-enterprise coordination***: contract & supply network management, process planning & scheduling, procurement, Intra-logistics, elements of Enterprise Resource Planning systems etc
    b. ***Process integration:*** collaboration support, groupware tools, electronic conferencing, distributed systems, social-media, business work flows, ERP (front end) systems
    c. ***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.

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.

6. **Trading / transactional management ICTs**
   a) ***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
   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 refueling). However we may want to include interaction of various agents within a district, those agents could be Buildings, Citizens, vehicles etc.

A note on GPT's 'General Purpose Technologies' – GPT's are radical new ideas or techniques that have the potential to have an important impact on many industries in an economy. Their key characteristics are: pervasiveness (used as inputs by many downstream industries); technological dynamism (inherent potential for technical improvements) and innovation complementarities with other forms of advancement (meaning that the productivity of R&D in downstream industries increases as a consequence of innovation in the GPT).[1]

Some ICTs e.g. broadband internet can easily be described as GPTs and, as such, would considerable exceed a 5X enabling impact. It could be argued that a 5 point scale does not effectively differentiate the enormous potential of such technologies and it would undoubtedly be an arduous task to neatly categorise (bucket) such ICTs. Nevertheless, while simplistic the 5 point scale has been successfully applied in other domains and is deemed by REViSITE to be appropriate and workable. In terms of categorisation a judgement call will be required by partners with respect to context of application.

4 Instructions for use

4.1 Approach Introduction

At a high level partners approach their research in a systemic fashion consistent with the REViSITE ethos and life cycle thinking. Partners adhere to REViSITE assumptions as set out in sections 1.2. At a more granular level, partners use the REViSITE SMARTT taxonomy of section 3.3 to guide and categorise their research. As outlined SMARTT categories and sub-categories are 'set' in order to provide for common cross sectoral analysis. As partners identify key RTD topics they <u>include specific ICTs</u> that are exemplars of that RTD theme and use the below template to illustrate their thinking and assessment. The various scored ICT's will be updated into a unified matrix for comparison.

By estimating current versus potential 'intensity' of an ICT, in combination with interpretive criterion such as 'effectiveness' and 'cost', one begins to understand adoption decisions set against the context of potential impact. For example, one may well uncover barriers to choosing energy efficient offerings because of cost barriers. Another benefit is that, by looking across industries, one might identify an EE killer application that can be used in another.

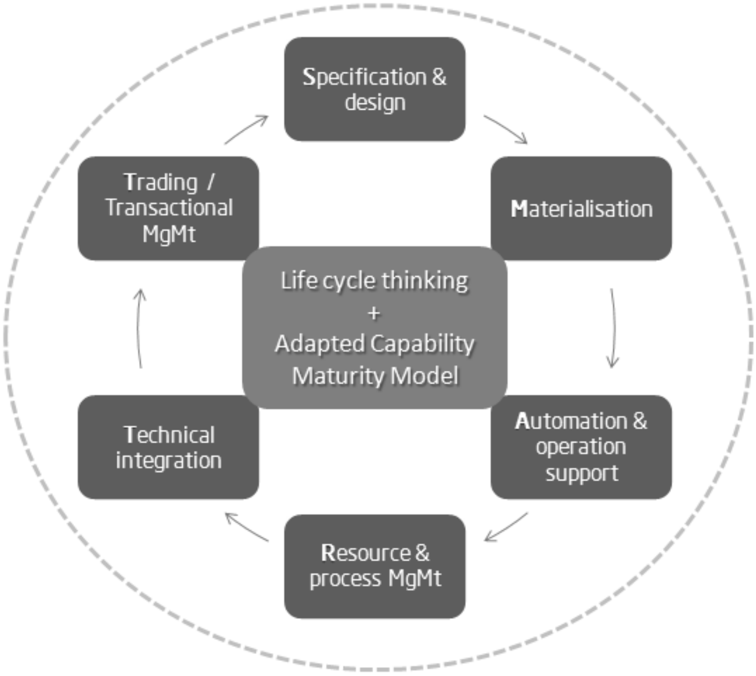


Figure 25. The REViSITE – Methodology & SMARTT Taxonomy

To understand the 'net impact on EE' one must make an informed decision as to direct effects, i.e. the energy increase in utilising the offering, and the indirect enabling effects that result in energy consumption improvements in the wider system. Having a better understanding of the actual energy intensity of an offering that considers its life cycle phases is necessary if one is to make claims regarding enabling effect. Quantitatively assessing where one can directly measure is a relatively easy task, however one inevitably crosses into the realm of the qualitative when making a retrospective assessment or when making an assessment at a more macro level.

Assessing ICT functional effectiveness helps to answer the question 'how well does the ICT perform its design purpose?' The thought of assessing this is less to do with energy efficiency and more to do with interpreting the factors that come to bear on trade-off decisions that may affect energy efficiency. One might have a highly energy efficient technology but with average functional performance and this may or may not have a relationship with intensity/adoption of that ICT. The premise in assessing the two fixed criterion together with the user-defined interpretive criterion is that it provides for an 'energy efficiency' focus while also providing for tailored adaptation.

In terms of an output the idea is to develop a type of energy efficiency matrix (a coefficient of performance type indication) for ICTs that is based on data and domain expertise. This will help build an inventory of possible synergistic ICTs. These ICTs will be differentiated on a 'less energy per unit of service' basis but where there is an expansion of what constitutes 'service' because of a recognition of the indirect enabling effects of such technologies. The suggestion here is that this approach will be useful in accurately understanding and interpreting a given context and in informing roadmap development.

4.2 Using the methodology –examples

The following examples are designed to illustrate how the REViSITE methodology can be used to estimate the impact of an ICT on energy usage and efficiency in a particular sector. The scenarios, assumptions and definitions as per section 1.2 are assumed to be understood. The examples are detailed for illustration purposes. However it captures a decision that might be made quite rapidly using tacit domain knowledge, it is assumed those utilising the approach are domain experts.

The process has three steps:

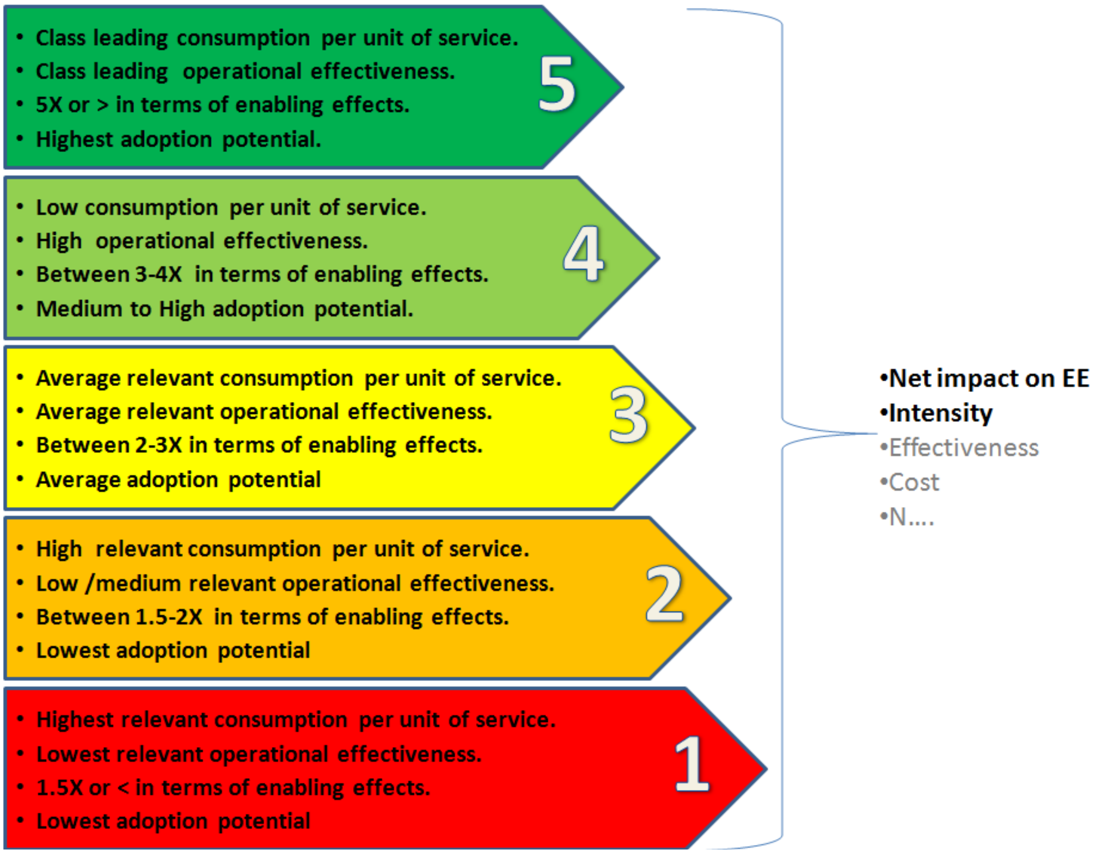
1. Define & categorise
2. Refine
3. Assess & Estimate

One begins by defining the ICT/RTD to be assessed, the relevant life cycle phase(s) of the relevant system life cycle and the relevant phase(s) of the product life cycle of the 'to be' ICT offering.

One utilises the SMARTT taxonomy to categorise the ICT/RTD in order to aid the task of cross-sectorial comparison. One then refines ones focus regarding relevant life cycle phases both within the offering being introduced and within the relevant system life cycle whether that be Grid, Build etc

One then utilises heuristics, qualitative and quantitative data to assess and estimate the impact of the ICT/RTD based on Fig 23 scale. 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. As stated there are two fixed criterion scored together with a user defined number of interpretive criterion.

Fig 23 Repeated



Example 1 – Home Energy Management system (HEMs)

Define & categorise	
Intended audience	Home owners, utility providers, policy makers
ICT / RTD to be assessed	Home Energy Management System (HEMS) or rather the augmented system required to implement the offering. Including wireless hub, meter clamp, sensors and plugs etc From here in HEMS will signify the augmented system
Relevant SMARTT sub-category	Operational decision support & visualisation
Relevant SMARTT main-category	[A] Automation & operational decision support ICTs
'Smart' 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 energy consumption required to implement the HEMS offering.
Second order effects (indirect)	The enabling impact of the ICT on the energy consumption / efficiency of the building. Electrical/Gas / oil metering not linked back to HEMS in the case study.
third order effects	Shifting of peak demand or load balancing effects etc within the 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.

This stage is essentially about defining and framing the ICT/RTD to be considered in a consistent way that allows for cross-sectorial comparison.

It prompts the assessors to begin the process of thinking about the life cycle of the offering and the system in which it will be deployed.

Refine
From an energy perspective the HEMS focuses on the 'usage' phase of the building Life Cycle. The 'Design' & 'Materialisation/construction' phases can be considered insignificant & therefore excluded.
Assumption was the HEMS product life cycle was insignificant in comparison to its enabling effects. Secondary sources were obtained from LCA databases & 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 & the energy consumption of the HEMS product life cycle.

This stage is all 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 & the phase of the host system which need to be assessed from an enabling impact perspective.

Assess & 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 info was gauge from manufacturing data and LCA databases for specific or similar products. Combined 'usage' + 'manufacture' phase of Product system = 141 kWh
Second order (Enabling effects)
Average measured electrical power saving in case study was 426 kWh per household
At the EU27 level an avg saving of ~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 EU27 level that equates to ~ 120 Twh saving in electrical consumption.
601/141= 4X enabling effect. However the case study did not include Gas/Oil usage which accounts for ~ 70% of household energy within the EU27. 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
The ICT is scored as per fig 22 scale this is of course open to interpretation but the assumption is that industry practitioners are scoring the ICT & are in a position to make estimates based on available data & heuristics. Net impact is estimated from above 1st & 2nd order effects

Assess & estimate is about leveraging heuristics and secondary data to understand & estimate the most likely impact of the technology in question.

It is about comparing the gap between the direct and indirect (enabling) effects to understand if a detailed assessment of the embodied energy of the offering would be required to make an adoption decision, or is it a case that the enabling impact is multiple that would suggest a qualitative estimate will suffice. It is important to work through the template before trying to score any RTD/ICT because any assessment is not easily quantified. For example an ICT with a 20X enabling impact will score the same as a 5X enabling impact, looking solely at the scoring would not identify this but this would be identified within the text of the template.

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	0 = Low 25 = High	0 = Not scalable 1 = Highly scalable
Sub cat.	Operational decision support & Visualisation:	1 = low cost 5 = highest cost					Impact Score	Sector scalability
ICT/RTD's	HEMS	3	3	1	5	5	25	0.80
	ICT 2	3	2	3	4	5	20	0.25
	ICT 3	4	5	2	5	5	25	0.60
	ICT 4	1	5	1	4	4	16	0.75
	ICT 5	2	4	5	5	5	25	0.00

Used to interpret (Cost, Effectiveness) Used to score (Intensity, EE Net Impact)

The value in scoring the technologies means partners can understand/assess quickly those ICTs that offer the best potential for improvement. 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 & taxonomy offers because partners can then look and share across sectors and quickly identify technologies they can possible leverage within their own context.

Example 2

Define & categorise	-
Intended audience	IT data center & facilities managers
ICT / RTD to be assessed	Virtualisation' specific ICT is hypervisor X to be run on a Dell PowerEdge R710 with an Intel Xeon x5670 2.9 GHz processor
Relevant SMARTT sub-category	Automated monitoring & control
Relevant SMARTT main-category	[A] Automation & operational support ICTs
'Smart' sector / system impacted	Building [here Data centers are thought of as ICT factories housed within buildings]
Most relevant 'sector life cycle' phase - 'Function'	Usage
Most relevant 'sector life cycle' phase - 'Impact'	Usage
First order effects	kWh of the server with hypervisor in the usage phase, manufacturing phase of new & existing cancel out.
Second order effects	The enabling impact offered in terms of the consolidation ration of existing servers.
Third order effects & Possible rebound effects	The knock on decrease in the cooling and power infrastructure required to support the reduced server footprint.
	Reduction in the # of licences & service contracts, increase in power density of the building which could cause issues with cooling. Possible increase in demand & hence consumption due to green credentials of the offering

Refine (Effects brought forward for impact assessment)

The comparison of the usage phase of the new product offering and the existing system is justified in this case as the energy intensity of the manufacturing phase of the new server versus one of the existing servers would be comparable perhaps even lower. Design, shipping and recycling of the two would also be comparable I terms of energy impact

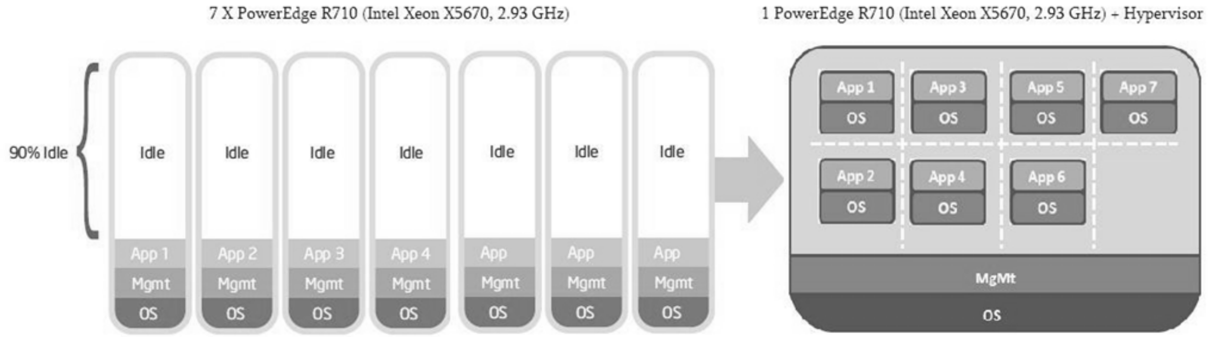
Assess -

First order effects (Own consumption)

The power consumed by the server in delivering the defined service utilising the hypervisor consumes 194W at 80% utilisation. This can be calculated from online application provided by manufacture or from independent sources such as SPECpower - SPECpower_ssj2008* The direct annual energy impact of the deployment of option 2 the single server with the hypervisor is ~194W*24*365 / 1000 = 1,699 kWh per year. The energy intensity of manufacture the newly deployed server with hypervisor ~ 1,400 kWh however this would be comparable to one of the existing servers in the existing scenario & therefore can be cancelled out. Allowing us to compare usage phases & effects on building infrastructure

Second order (Enabling effects)

From Figure 1 we see that 1 server without the addition of a hypervisor will run at 10% utilisation at an average power consumption of 106 W. This utilisation represents the average utilisation of the individual dedicated server in providing the required service. The seven dedicated servers required to meet service demand under option 1 would consume 742W. The power consumed in delivering that same level of service utilising the hypervisor is 194W. This equates to a ~ 4X saving.



Third order effects

We see that a 4X saving is delivered through use of the hypervisor however the added value is the reduction in terms of building cooling infrastructure required to support the servers see Figure above. In the case below which is typical of the industry for every 1 watt delivered to the IT load another 1 watt is required to support it which equates to a PUE of 2. The order of impact remains at 4 however the actual kWh saving is double

Server no.	Actual load	total ssj-ops	Total IT power in Watts	Total power Watts @ PUE=2
7	10%	641,207	742	1484
1	80%	730,542	194	388
			548	**1096**

One should note that in a more likely scenario the physical servers to be consolidated would be an older model/rev of server with higher consumption rates up through the utilisation range. In such cases the order of savings would exceed above and for 4/5 year old model could be in the region of 15-20X. Also for certain application type's virtualisation ratios of ~ 100:1 are possible.

The reduced server footprint 7 versus 1 (some cases have much higher ratios), the reduced demand in power and cooling (a factor of 4 here) together with reduced maintenance and licensing mean the deployment of such Hypervisor technologies coupled with the latest processor/server capabilities could feasibly offset the need for future data centre construction.

One possible rebound effect is an increase in ICT based services as the 'green' credentials of hypervisor technologies take hold. However the general trend is for an increase in ICT based service offerings and it is very hard to say if any increase could be attributed to the deployment of the technology. However a more likely effect is a required change in support infrastructure due to high increasing rack densities as a result of hypervisor deployment.

Sys LC phase	'Usage' / 'Operational' Phase [Buildings]							
Main Cat.	Automation & operational decision support ICT's	Cost	Effectiveness Operational	Intensity Actual | Potential		EE Net Impact Potential	0 = Low 25 = High	0 = Not scalable 1 = Highly scalable
Sub cat.	Automated monitoring & Control:	1 = low cost 5 = highest cost					Impact Score	Sector scalability
ICT/RTD's	**Hypervisor**	3	**4**	**2**	**5**	**5**	**25**	**0.60**
	ICT 2	3	2	3	4	5	20	0.25
	ICT 3	5	4	2	5	5	25	0.60
	ICT 4	1	3	2	3	4	12	0.33
	ICT 5	2	4	5	5	5	25	0.00

5 Conclusions

Given our research it is safe to say that attempting to assess the impact of ICTs on Energy Efficiency is an onerous task made more complex when bridging varied domains. The process is not helped by a lack of agreed metrics or approach. The following are some general conclusions:

- There is no one agreed methodology for assessing the impact of ICT on another variable in our case energy efficiency.
- Organisations that are assessing this topic in the main advocate some form of Life Cycle Thinking or Assessment.
- Easily re-applicable quantitative methods are effectively non-existent.
- Qualitative methods that utilise domain heuristics are considered useful.
- There was no readily available taxonomy available that could be commonly applied and utilised across all sectors.
- REViSITE produced the SMARTT taxonomy which proved a useful means of common categorisation across sectors within the project

The REViSITE project also developed a qualitative approach to ICT impact assessment based on 'life cycle thinking' and the 'Capability Maturity Model'. That methodology and SMARTT taxonomy guided partners in researching D2.2 'knowledge and current practise' report and will be the guiding approach for D2.3 in developing the impact causal model/framework. In conclusion the REViSITE consortium deem the taxonomy and methodology outlined to be a useful and feasible means of qualitative common assessment which provides for an informed view on the impact of ICTs on energy efficiency and is a framework in which more detailed quantitative measures can be positioned.

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7 Appendix

Annex 1

Comparing World & EU27 values 1990,2007,2008 + 2020 projected trends WEM

		1990	2007	2,008	2009	2,010	2011	2,012	2013	2,014	2015	2,016	2017	2,018	2019	2,020
Gross inland prime energy consumption(world)	Mtoe	8753	11788	11,733	11,709	11,932	12,158	12,389	12,625	12,865	13,109	13,358	13,612	13,871	14,134	14,403
Gross inland prime energy consumption EU27	Mtoe	1,650	1,808	1,799	1,796	1,810	1,825	1,839	1,854	1,869	1,884	1,899	1,914	1,929	1,945	1,960
Final prime energy consumption EU27	Mtoe	1,068	1,165	1,169	1,166	1,176	1,185	1,195	1,204	1,214	1,223	1,233	1,243	1,253	1,263	1,273
World MtCO2 emissions	MtCO2	20,822	28,960	28,815	28,758	29,361	29,978	30,608	31,250	31,907	32,577	33,261	33,959	34,672	35,401	36,144
World MtCO2e emissions	MtCO2e	29,775	41,413	41,206	41,123	41,987	42,869	43,769	44,688	45,626	46,585	47,563	48,562	49,582	50,623	51,686
EU27 MtCO2e emissions	MtCO2e	5,564	5,039	4,938	4,928	4,953	4,978	5,002	5,027	5,053	5,078	5,103	5,129	5,154	5,180	5,206

		1990	2007	2,008	2009	2,010	2011	2,012	2013	2,014	2015	2,016	2017	2,018	2019	2,020
World electrical generation	TWh	12,000	19,771	20,133	20,501	20,877	21,259	21,648	22,044	22,448	22,859	23,278	23,704	24,138	24,580	25,030
EU27 electrical generation	TWh	2,600	3,368	3,373	3,420	3,468	3,517	3,545	3,595	3,645	3,696	3,748	3,800	3,853	3,907	3,962
Final electrical consumption EU27	TWh	2,141	2,844	2,856	2,896	2,936	2,977	3,001	3,043	3,086	3,129	3,173	3,217	3,262	3,308	3,354

Source : IEA Key Statistics Report 2009, Eurostat 2007/2008 Tables, DG European Energy & Transport - trends to 2030 Report

Annex 2 (note energy sector includes transformation of energy)

ANNEX 2 c (D2.1) Baseline scenario (2007) all figures ktoe unless stated

% change		0.49%		0.95%	-0.71%	0.80%	2.23%	-0.20%	2.49%	1.20%	0.04%	0.03%	-0.98%	-0.47%
1,000 toe	% of Gross	AVG	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Gross energy consumption		1,772,618	1,706,489	1,722,731	1,710,521	1,724,241	1,762,726	1,759,137	1,802,902	1,824,589	1,825,237	1,825,756	1,807,794	1,799,294
Energy used in Transformation for power & heat	22.76%	-403,412								-407,066	-401925	-407,772	-403,475	-396,824
Energy branch consumption + losses	6.76%	-119,878								-120,110	-122080	-119,469	-119,142	-118,588
non-energy uses	6.27%	-111,084								-103,336	-109598	-112,785	-115,751	-113,949
Exchange & transfer returns	0.12%	2,076								3,842	3026	424	918	2,169
statistical differences	0.15%	-2,622								1,601	-1620	-4,113	-5,510	-3,468
Final energy consumption			1,106,503	1,115,544	1,113,377	1,117,232	1,142,972	1,128,875	1,165,853	1,181,198	1,182,403	1,186,125	1,164,833	1,168,635
Transport	19.86%	352,007	319,458	330,237	338,971	341,003	344,196	347,636	352,457	362,131	364,711	372,191	376,826	374,269
Manufacturing	18.62%	330,100	332,530	329,407	322,250	332,420	333,434	328,238	337,134	336,687	332,262	328,340	330,616	317,887
Households	16.67%	295,506	291,470	291,242	287,726	285,418	299,038	291,622	302,724	305,418	306,602	303,658	284,516	296,632
Services	7.14%	126,586	118,576	121,089	122,048	116,503	124,272	120,665	128,103	130,779	131,703	135,816	131,354	138,122
Agriculture	1.66%	29,512	30,975	30,246	29,805	29,897	29,611	28,938	30,438	31,125	30,931	28,952	26,935	26,286
Other services	0.79%	14,074	13,493	13,320	12,575	11,990	12,419	11,776	14,987	15,035	16,172	17,144	14,563	15,412
1,000 tCO2e		5,099,142	5,217,139	5,169,055	5,060,167	5,062,303	5,116,970	5,071,816	5,148,740	5,148,450	5,116,735	5,099,814	5,038,775	4,939,738

	% Change													
	2009	2010-20	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Gross energy consumption	100.5%	100.7%	1,808,171	1,821,551	1,835,030	1,848,610	1,862,289	1,876,070	1,889,953	1,903,939	1,918,028	1,932,221	1,946,520	1,960,924
Energy used in Transformation for power & heat	100.7%	101.2%	-399,602	-404,477	-409,412	-414,406	-419,462	-424,580	-429,759	-435,002	-440,310	-445,681	-451,119	-456,622
Energy branch consumption + losses	100.3%	100.2%	-118,944	-119,182	-119,420	-119,659	-119,898	-120,138	-120,378	-120,619	-120,860	-121,102	-121,344	-121,587
non-energy uses	100.5%	100.8%	-114,496	-115,412	-116,335	-117,266	-118,204	-119,150	-120,103	-121,064	-122,032	-123,008	-123,993	-124,984
Exchange & transfer returns														
statistical differences			-231	-3,397	-6,655	-10,003	-13,445	-16,982	-20,614	-24,343	-28,171	-32,100	-36,130	-40,264
Final energy consumption	100.5%	100.7%	1,175,360	1,185,878	1,196,518	1,207,282	1,218,170	1,229,185	1,240,327	1,251,597	1,262,998	1,274,530	1,286,195	1,297,994
Transport	101.5%	101.2%	379,733	384,290	388,902	393,568	398,291	403,071	407,908	412,802	417,756	422,769	427,842	432,977
Manufacturing	99.6%	100.8%	316,647	319,180	321,734	324,308	326,902	329,517	332,154	334,811	337,489	340,189	342,911	345,654
Households	100.2%	100.5%	297,255	298,741	300,235	301,736	303,245	304,761	306,285	307,816	309,355	310,902	312,457	314,019
Services	101.5%	101.5%	140,139	142,185	144,260	146,367	148,504	150,672	152,872	155,104	157,368	159,666	161,997	164,362
Agriculture	98.6%	98.6%	25,910	25,540	25,174	24,814	24,460	24,110	23,765	23,425	23,090	22,760	22,435	22,114
Other services	101.7%	101.7%	15,676	15,942	16,213	16,489	16,769	17,054	17,344	17,639	17,939	18,244	18,554	18,869
1,000 tCO2e	99.5%	100.5%	4,917,015	4,942,682	4,968,483	4,994,418	5,020,489	5,046,696	5,073,040	5,099,521	5,126,141	5,152,899	5,179,797	5,206,836

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