Project: **REViSITE**

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

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

Executive summary:

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

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

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

Authors:

Matti Hannus (VTT)
matti.hannus@vtt.fi

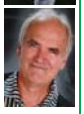
Keith Ellis (Intel Labs)
keith.a.ellis@intel.com

Bruno Fies (CSTB)
bruno.fies@cstb.fr

Farid Fouchal (LOU)
f.fouchal@lboro.ac.uk

Tarek Hassan (LOU)
t.hassan@lboro.ac.uk

Daniel Kuhn (FHG)



Veijo Lappalainen (VTT)
veijo.lappalainen@vtt.fi

Kai Lindow (FHG)
kai.lindow@ipk.fraunhofer.de

Hans Pille (KEMA)
hans.pille@kema.com

Eino Tetri (AALTO)
eino.tetri@aalto.fi

Nico Vlug (KEMA)
nico.vlug@kema.com

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

Acknowledgement:

Project co-financed by the European Commission under the contract no: 248705

SEVENTH FRAMEWORK PROGRAMME

1. Specification & design ICTs

RTD topic	State of the art	Short term *~3yrs*	Medium term *~6yrs*	Long term *~9yrs*	Vision
Design concept-ualisation	Limited tools for requirements capture and engineering, energy analysis and concept visualisation.	Methods for early stage decision support. Templates for requirements and user profiles.	Tools for concept development. Reference models for LC requirements and usage scenarios. Simulation based systems for refining requirements for highly interdependent complex systems.	Generation of requirements from related system models. Context aware visualisation based EE criteria, with context specific content suggestion, all rendered based on device capability & user preferences.	Integrated ICTs for holistic design, modelling and assessment covering energy interaction between the different subsystems, technical, commercial, sustainability and regulatory factors. Interoperability of design ICTs in model based information sharing. Libraries of re-usable design solutions with rich search capabilities. Standardised data models covering energy related aspects. Standardised energy performance indicators. Models of stakeholder profiles, requirements, energy consumption, market dynamics etc. Certified software for compliance assessment. Evidence-based knowledge about the impacts of ICTs on energy efficiency.
Detailed design	Scanning of existing facilities for retrofitting design. General purpose tools like CAD, PDM, PLM and visualisation. Proprietary and domain specific applications. Web based product catalogues.	CAD tools with design templates and interoperable component libraries. Support for designing service oriented systems.	Parametric design using templates and design rules. Parametric product libraries.	Configuration design based on reference solutions, adaptation rules and intelligent component objects.	
Modelling	Evolving model based tools for mostly isolated design & analysis applications, file based data exchange, reverse engineering, digital/hybrid prototyping, rapid manufacturing, visualisation etc.	Domain specific application tools enhanced with energy related attributes. Tools for modelling existing products/systems.	Model based tools (design, performance estimation, state prediction, optimization, simulation, etc.) and object libraries.	Functional (beyond data) product/system objects enabling new object oriented applications.	
Performance estimation	Tools (LCA) for assessing costs, environmental impacts, comfort etc. (e.g. CFD).	Metrics and validation methods for holistic static performance: technical, economic and environmental. Quality of Service and Service Level Agreements.	Metrics for dynamic performance. Simulation based validation methods.	Metrics and validation methods for real time performance.	
Simulation	Tools for simulating energy consumption, generation, markets. CFD. Some interfaces from CAD/design tools to simulation. 2D/3D/4D visualisations.	Simulation methods for design & validation. Dynamic/4D visualisation.	What-if analysis using simulation, interfaced with models. Integrated cross-domain simulation of interactions within complex systems such as major infrastructures.	Live virtual models enabled by simulators and models. Live virtual models capturing each system parameter & user experience / perception.	
Specification & product/ component selection	Limited sector specific specification methods and tools, e-procurement.	Specification templates. Catalogues of materials, products & suppliers. E-market tools.	Specification models. Model based product libraries. Selection tools.	Optimally automated component selection & procurement.	

Holistic design of the interactions between different subsystems. Interoperability between CAD tools, applications for design, performance analysis, simulation, visualisation, libraries etc.

2. Materialisation ICTs

RTD topic	State of the art	Short term *~3yrs*	Medium term *~6yrs*	Long term *~9yrs*	Vision
Decision support & visualisation	Manufacturing / process simulation tools. 4D visualisation / animation of processes e.g. in construction. Life Cycle Assessment of different construction / manufacturing options.	Tools to visualise real time progress to plan for energy sourcing options regarding cost & CO2 Impact (including CO2 certificates). Energy related aspects included into decision support to select production strategies e.g. offsite / onsite production and materials. Tools and e-commerce platforms for waste re-use.	Tools & interfaces using data from multiple ICT systems (e.g. BIM/PLM/ERP) to analyse and visualize (e.g. in 3D/4D/VR) current state, energy related information, environmental impacts etc. Location based services to decide on optimum materials suppliers. Visualisation of trade-offs between environmental and economic concerns.	Automated alerts to persons in charge on deviations in the production process. ICT for proactive decision making (instead of support only). Decision recommenddation to solve trade-offs between environmental and economic concerns.	ICTs to optimise / select production / materialisation / procurement methods based on optimum energy consumption. ICTs to rationalise materialisation processes (in terms of planning and control) for energy efficiency (e.g. logistics, sequence, etc.). Real-time communication in materialisation phase. Tracking and visualisation of materialisation process in virtual planning models.
Management & control	Generic project planning tools (Gant charts, cost estimation etc.). ERP, BIM & PLM systems.	Energy related aspects integrated into planning tools (finance, logistic, scheduling) to define energy targets for production.	Whole life cycle costing. Automated tools for testing energy performance & validation of compliance to energy related requirements. Automatic calculation of energy consumed during production.	Simulation based real-time production management. Real time target/actual performance comparison.	
Real-time communi-cation	Syndication tools (e.g. RSS). Collaboration tools from video conferences to CAD collaboration used in project management.	Using RFID/ NFC tags or similar to track transport & status of components, enabling near real time manufacturing.	Pervasive Context related multimedia content provided to workers on portable devices & back office.	Direct feedback of changes into planning models / simulations.	

3. Automation & operational decision support ICTs

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

4. Resource & process management ICTs

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

5. Technical integration ICTs

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

6. Trading / transactional management ICTs

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