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Smart city

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SMART CITY INTRO AND CONCEPTS

SMART CITY GOVERNANCE

SMART CITY INTELLIGENT BUILDINGS AND URBAN SPACES

SMART CITY DISTRIBUTED ENERGY

Smart City: local but networked, distributed but integrated

The concept **smart city** pops up frequently in the context of urban development. The concept definitely has a positive flavour, but what does it actually mean?

There is no unique definition for a smart city. The interpretations and definitions used by different interest groups, stakeholders and regions vary. The impression is often that a smart city is the same as a digital city, and sometimes its meaning is close to that of a sustainable city. It is a challenging term, because who wants his contribution to the development not to be called smart. While most human activities take place in cities, almost anything can be included within the smart city concept. So, why should we use a special term if it includes everything in a city?

The basis of developing systems has always been to move towards an optimum defined by multiple criteria. Economic aspects are often among the core criteria. Traditionally, an optimum has been reached with centralized solutions. Economy of scale has been achieved by systems with a distinctive point of control. For example, power grids have been built around large power plants. Public transport systems have been based on somebody deciding the schedules and routes on behalf of others. Retail shopping has moved to large shopping centres. Even governance in society has meant a powerful central administration making decisions on behalf of the citizens.

The development of information and communication technology (ICT) has enabled the search for new kinds of optima. The outcome of the implementation processes in various systems is often called ‘smart’.

As regards energy, for example, distributed local production is feasible to the extreme that every building may become a power source, but a system of distributed production is better than the old centralized system only if the energy network is managed properly. The transition to smart grids has only been possible thanks to advanced ICT.

New on-demand service concepts are emerging in public transport, which is still based largely on predetermined schedules and routes. As in the case of energy, if more is produced than is needed, the capacity can be offered for use by others. Without advanced ICT linking, service providers and users would not be possible.

In retail, rapidly growing shopping over the Internet has created a need to rethink local urban logistics. The role of shopping centres and department stores is undergoing significant change. At the same time, the end delivery to individual customers is seeking new forms. Increased efficiency and better response to customer needs is possible only with the use of advanced ICT.

In order to make use of public services, it is necessary to go to the city centre or at least the local centre in the suburb. Due to the changes in the relative costs of operations in the societies, the development has unfortunately meant that the distances to the service points have gradually increased. Owing to ICT, it is now increasingly possible to use the services at home or even when travelling. The saving for the service provider is evident.

ICT also enables citizens to participate in decision-making much more than before. While tools now exist to enable information to be received, it is much more difficult for the authorities to keep their work behind closed doors. Citizens are able to interact with the officials and the elected representatives more than ever before. Despite the challenge of the digital divide, the development of ICT has altogether meant a huge increase in the power of citizens.

All the examples above have meant that the meaning of geographical location has changed. You can act locally but at the same time use resources in places you do not even know. Administrative borders can no longer be optimal borders for operations at the same time.

In the traditional systems, data were gathered in a central location where they were then analysed, often after a significant delay. The conclusions drawn were then transmitted back to users as instructions. In the current distributed systems, data can be gathered and analysed anywhere. This allows a much larger set of input data and much wider resources for assessment and conclusions. The central decision-maker is not always needed. Open data – just let the data be available and somebody will analyse the data for his own interest – are essential in this process.

The essence of being smart in modern society lies in acting locally but being networked outside one's own geographical location. The technological systems can only be managed if they are properly integrated. ICT is the enabler that, when properly used for networking and integration, provides social, environmental and economic benefits for all. Cities all over the world see this as an opportunity for better quality of life. Therefore, the smart city agendas will have a central place in urban development projects. While those projects are always huge investments, they also provide lucrative business opportunities for technology providers. No wonder that practically all of the biggest technology providers also have their own smart city agendas.

VTT for Smart City

As a multidisciplinary application-oriented research organization, VTT serves the innovation activities that support the development of smarter cities in many different ways. At VTT, we work with the public sector as well as technology providers. We work from the early phases of concept or ecosystem development to the practical implementation of research outcomes. We are active participants in European and global research and industry networks.

The research and innovation activities at VTT cover all the core technology areas relevant to smart city development. The key technologies and application domains are ICT, energy, transport and the built environment.

This publication

This publication is a collection of extended abstracts on recent and ongoing public research at VTT. The topics broadly cover the topical spectrum of smart city-related activities. Topics have been included largely on the basis of the interests of individual researchers and research teams. We have not even tried to be systematic on what is and is not included, but the interpretation has been left largely to the researchers themselves.

In order to make it easier to find interesting contributions, we have organized the abstracts under different topics. However, many of the papers could have been under several headings as smart city research is inherently multi-technological and cross-disciplinary.

The primary readership of the document is expected to be the research community, i.e. those who are actively connected to research either as researchers or users of the research results. However, we believe the topics are also of interest to practitioners in industry and the public sector.

February 2015

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Smart City

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All around the world, urbanization is a growing trend. As more and more people get together, smart systems and their integration need to be developed, not only to provide the services that people need but also to do so efficiently with minimum impact on the environment. It can be said that efficient ICT, one part of which is the Internet of Things, is a common dominator: tying together services, residency, mobility, infrastructure and energy.

It is a global challenge to reduce environmental impact and the carbon footprint. At the same time, societal development needs to be addressed and the focus put on people's well-being. Pressure is growing to reduce our environmental impact, and there is a parallel compelling need for business to remain globally competitive. The need for investment and expenditure to improve energy efficiency, modernize infrastructure and create high quality living environments is enormous. At the same time, cities have limited access to financial resources. Sustainable transformation of cities is only possible when it is done in a smart way.

Smart cities can be seen as systems with flows of energy, materials, services, people and financing. Moreover, urban planning is closely related to the economic and social metabolism of communities, i.e. technology is seen as an enabler of good life. Identification, integration and optimization of different energy, transport and data flows in city planning and city management are crucial to creating sustainable smart environments. Since the renewal of the urban environment is slow, the implementation of any new technologies must fit with the existing structures.

Holistically operating resource-efficient cities are better able to react to changes. Multifunctioning systems not only create cost savings but also increase safety and reliability through better utilization of intelligent, integrated and optimized networks. Smart management is the key to maintaining people's well-being under the pressure of resource efficiency.

This novel integrating approach by different sectors would make use of the synergistic opportunities provided by advanced ICT. It comprises citizens and business-based services and solutions. It also requires higher-level cooperation with the city administration and its agencies.

Figure 1. Connection of VTT's programmes to major areas of smart city development.

More information:
VTT Pro-IoT spearhead program. http://www.vtt.fi/research/spearhead_iot.jsp.
VTT Ingrid Innovation program. http://www.vtt.fi/research/innovation_intelligent_energygrids.jsp
VTT TransSmart spearhead program http://www.vtt.fi/research/spearhead_transsmart.jsp

The integration should be based on a real PPPP (public, private and people partnership) model in which all actors are committed to development and innovation together.

Smart city design, operation and management need to be done at system level. Sub-optimization of individual components will not lead to optimal performance of the system. Multi-target optimization is not an easy task, but it becomes necessary as different components and systems are interlinked and interconnected – irrespective of where they are physically located. Traditional sector-based industries and value chains are also changing, and completely new business models are starting to emerge. Radical innovations and paradigm shifts are changing our whole city systems

VTT is focusing its research on this systemic change in three programmes that work together, namely Ingrid (Intelligent Energy Systems and Cities), TransSmart (Smart Mobility Integrated with Low Carbon Energy) and pro-IoT (Productivity Leap with Internet of Things).

City monitoring and operation systems

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Introduction

Innovative and smart solutions are available in some cities while in others the uptake is low because the impacts of these solutions have not been objectively verified and there is a lack of confidence that the solutions can also be applied in other contexts and cities. This transition can be speeded up by enabling a progress monitor by means of a common performance measurement framework and real-time monitoring technologies. The aim of a city operating system is to combine city level operation with co-operation between local sub-systems in order to monitor performance.

City systems help to monitor progress and optimize processes

The aim of a city system is to combine city level operation with co-operation between different local systems in order to monitor performance and optimize processes. Intelligence and interoperable interfaces are added between separate systems, e.g. lighting systems, the energy grid and mobility systems, in order to input information from these into the city decision-making services. Available solutions are often off-line and ad-hoc, not replicable or suitable for comparisons between cities. The new developments on fused sensing, data monitoring technologies and the Internet of Things (IoT) are key to efficient and real-time collection of "raw" information from various sources that are then enriched into information through KPI calculations and further into decision-making services.

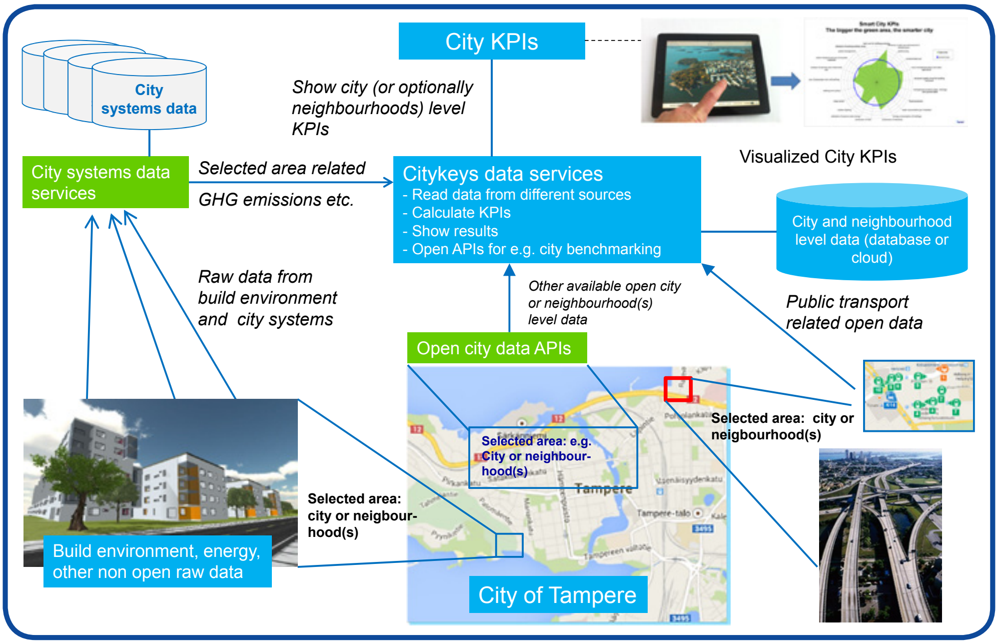
The performance measurement system meta-data model and calculation methodologies are based on:

- Defining the required data sets to be collected based on the specified indicators
- Identifying available data sources, their reliability, accessibility and data models
- Specifying the collection system and calculation methodologies for the performance measurements
- Integration into the system of intelligence and interoperability interfaces between separate systems, input specifications and calculation methodology
- Development of user-friendly interface and information visualization.

Figure 1 shows a schematic presentation of the performance measurement system based on an example of a collection of specific data sets, the information processing, integration into key performance indicators (KPIs) and finally an example of a visualization interface [2,3].

Discussion

The development and implementation of city operating systems will impact on the transition to low-carbon, resource-efficient cities by cre-



ating the necessary framework for performance assessment of the deployment of smart city technologies. It will enable progress monitoring by means of a common performance measurement framework and real-time monitoring technologies. This will allow cities to move towards a sustainable transformation while spending less public resources and improving services offered to their citizens. Furthermore, it will support planning and procurement processes, allowing the stakeholders to access and compare different solutions and planning scenarios and thus impacting on the deployment of the most suitable ones.

Acknowledgements

The research is under development within the VTT spearhead programme "Pro IoT, Productivity leap with Internet of Things (IoT)" and VTT Innovation programme "INGRID, Intelligent energy grids and districts". (http://www.vtt.fi/research/spearhead_and_innovation_programmes.jsp)

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Vision of an open smart city interoperability environment

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Introduction

The application of ICT in a city environment can bring about a significant increase in productivity and well-being. However, smart city solutions seem to be fragmented across cities and sectors, which subsequently leads to a situation in which innovations do not diffuse widely and reach their full potential. To address this problem, we envision an open and modular interoperability environment across cities and smart city sectors. Here, we elaborate on the basic concepts around this vision, namely, innovative practices for public actors, a multi-actor multi-vendor business environment and a modular ICT architecture that leverages synergies across different smart city sectors and enables the creation and better diffusion of existing and new services across cities.

Background

Cities are increasingly being empowered with ICT. As the city core infrastructure and systems become instrumented with sensors and as these systems are interconnected to other systems, new levels of intelligence and services can be reached [1]. ICT has the potential, not only to help address the problems that we see in our cities today – like congestion and wasted energy – but also to offer new consumer experiences and convenience and help to stimulate much needed economic growth and job creation [2]. Although the smart city concept has received much positive attention, if we look at the current reality and the landscape around smart city solutions, an observation can be made that they are heavily fragmented. Artificial silos exist between sectors (e.g. mobility, built environment and energy) and there is very limited co-operation across cities. Furthermore, a city often partners with a company that then operates and manages the smart city services on the city's behalf. This often leads to the city planner becoming a rather passive entity and in turn to a vendor lock-in situation. Overall, in this kind of market structure, innovations do not diffuse and redundant isolated solutions are repeatedly built for the same problems and needs.

Key themes for enabling interoperability

Thus, it seems clear that there is a need for an open and modular interoperability environment for smart city solutions that spans across cities and sectors. In such a model, cities would be able to define a modular architecture together with infrastructure vendors and service providers, which in turn would form a basis for multi-vendor solutions, continual innovation and progress. To address fragmentation across sectors and

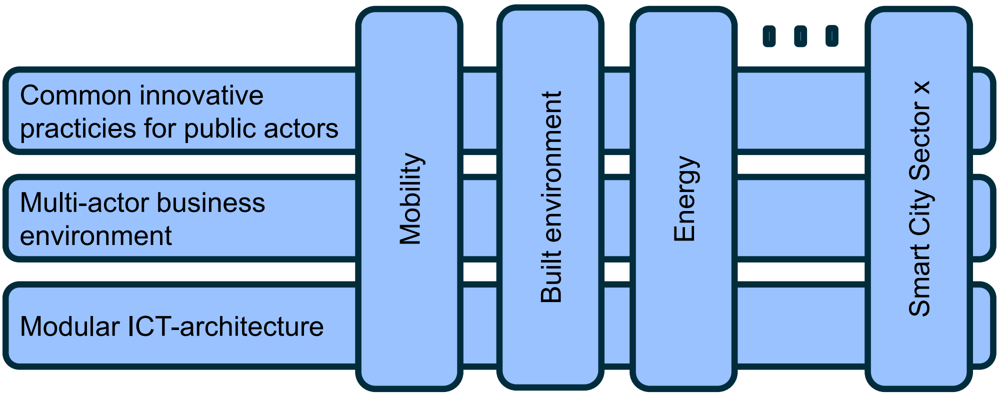

Figure 1. Key horizontal themes enabling interoperability.

cities we see three important horizontal layers in which modular and open processes need to be planned (Figure 1):

1. Common innovative practices for public actors related to, e.g., innovative procurement, regulation and opening of common resources (e.g. data) for the citizens' use.
2. Multi-actor business ecosystems with multiple buyers and multiple vendors and service providers all delivering their solutions over the same modular ICT architecture.
3. Modular ICT architectures with commonly agreed open interfaces, standards and an established interoperability certification mechanism for vendor products.

When planning these processes, important lessons can be leveraged from other fields where, e.g., the open interoperability environments around GSM-based mobile communications and the Internet can be used as examples [3].

Discussion

Overall, such a modular and open interoperability environment for smart city solutions could potentially connect demand and supply in a more effective way, increase the size of the existing markets and even create completely new markets. On the demand side, entities procuring systems could potentially remain better in control of the systems and more easily combine and switch between providers, thus inducing competition and diffusion of the best ideas. Furthermore, when there are many entities in the market buying standardized solutions, vendors and service providers can leverage economies of scale and do not need to tailor solutions to each customer. Nonetheless, the environment would need to remain modular so that barriers to market entry by smaller actors would be low, and novel innovations combining functionalities from the different smart city sectors would be possible

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Road maps for research and innovation policy

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Introduction

Road map building allows knowledge exchange between world experts and domain stakeholders and building of consensus on future technologies and research priorities, putting VTT one step ahead. The following introduces three of these road maps built by VTT, its partners and several international experts. Figure 1 summarizes the main scope of the developed road maps.
European Innovation Partnership (EIP) on Smart

Cities and Communities

This partnership, with private and public stakeholders, has been set up by the European Commission. It aims to help cities and communities, business and civil society to implement smart city solutions on a much greater scale and speed by connecting local initiatives. There is focus across the areas of energy, transport and ICT. The EIP's High Level Group developed recommendations for policy at EU, national, regional and local levels for actions by the private sector and for civil society. These are presented in the Strategic Implementation Plan. VTT experts participate in the formulation of the EIP Strategic implementation plan, through EERA, in the High Level Group and in the "Sherpa Group" assisting the High Level Group.

CIB Smart Cities road map

The CIB (International Council for Research and Innovation in Building and Construction) task group on smart cities is currently developing a road map for the building and construction-related research on future smart city solutions. The contents have been created in collaborative contributions from 17 member organizations. The task group identified the needs/problems of smart cities. These main challenges were prioritized into topics: Energy, Buildings, Infrastructure & Asset management, Resources & Waste, Land Use, Transport & Mobility, and Communities & Users.

Strategic research agenda for ICTs supporting energy systems in smart cities

The Ready4SmartCities project provides a road map for research and technical development and innovation activities for holistic design, planning and operation of energy systems in smart cities. In addition, synergies with other ICT systems for smart cities are considered. It is funded by the European Commission's 7th Framework Programme (2013-2015). The R4SC vision predicts future scenarios and development for smart energy systems based on identified links between different energy systems and interconnection needs and possibilities of broader smart energy networks. The road map is structured in four main domain areas: citizens, building sector, energy sector and municipality level.

IREEN: ICT road map for energy efficient neighbourhoods

The IREEN project produced a strategic research and technical development and innovation road map for future ICTs supporting energy efficient neighbourhoods. The project was funded by the European Commission's 7th Framework Programme (2011-2013). IREEN envisaged that smart energy management of a neighbourhood enables optimum energy distribution and balancing of all

	REEB	ICT 4 E2B Forum	REViSITE	IREEN	Ready4Smart-Cities
Scope	Buildings as stand-alone objects and end-users		Cross-sectorial synergies: grids, manufacturing, buildings and lighting	Neighbourhoods/ urban and rural communities: energy system and role of energy users	Energy systems; interconnections between misc. smart city systems; broad community engagement
Vision	Buildings meet EE requirements, optimized energy performance; new business models for prosumers	+ optimized energy use and production (RES) in buildings	Generic ICT4EE enabling wide markets and synergies across sectors	ICT4EE on design, operation and control of neighbourhood systems	Holistic integration of smart city systems for EE and beyond
Method-ology	Taxonomy of ICTs for: design and production mngt, user awareness and decision support, intelligent control, energy mngt and trading, and integration		Modified taxono-my "SMARTT" with sector-neutral termi-nology; impact assessment methodology (CMM)	Taxonomy enhan-ced to 2D matrix with application areas for: energy systems, buildings transport and people	2D-taxonomy en-hanced by other smart city systems beyond EE; impact assessment enhanced by REViSITE
Scena-rios	12 best practice-based scenarios focused on buildings	21 future scenarios, of which 2 at district level	(Summary and comparison of sector-specific visions)	18 future scenarios all addressing the neighbourhood scale	Updated scenarios + new scenarios on ho-listic integration of smart city systems
Road maps	5 sub-road maps based on the above taxonomy		6 sub-road maps based on the above taxonomy	Sub-road maps based on both ICT and application areas	ICT road map linked to anticipated evo-lution steps of related smart city systems
Imple-menta-tion plan	Recommenda-tions for innova-tion stages	Customized recommendations for different stakeholder groups			
Key stake-holders	ICT, construction and energy sectors		ICT, energy grids, manufacturing, construction and lighting sectors	ICT, cities, energy, and construction sec-tors and consumers	Cities, ICT and energy sectors, service providers and citizens

Figure 1. Summary of European ICT for energy efficiency road map projects

energy flows, resulting in maximized economic and environmental benefits. The energy system needs to be holistically coordinated and integrated, including buildings, infrastructure, transportation, energy distribution and production, as well as the involvement of citizens. The ICT development needs are proposal for: 1) planning, designing and operation, 2) decision support, 3) energy management, and 4) integration technologies.

Acknowledgements

CIB Smart Cities roadmap is being coordinated together with TNO (NL). IREEN and Ready4SmartCities roadmaps were developed within FP7 projects co-financed by the European Commission and developed together with the following partners: GreenITAmsterdam, Manchester City Council (UK), CSTB (FR), AATOS (SP), Acciona Infraestructuras (SP), D'Appolonia S.p.a (IT), AIT (AT); UPM (SP), CERTH (GR), INRIA (FR), AEC3, Politecnico de Torino (IT), Empirica (DE).

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Smart energy business concepts for EnergyHub districts

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Introduction

Much effort has recently been put into research and technical development for improving energy efficiency, increasing the use of renewable energy and improving districts' energy systems. Many of the technologies for these already exist, and we have experience of integrating them together into several pilot areas. However, the wide-scale roll-out of sustainable district level energy systems is yet to come. Here, the development of business models plays a key role in the wide-scale implementation of new neighbourhood energy systems.

Smart energy business for service providers and end-users

Energy hub systems optimize the use of renewable energy and required information exchange in a district. An Energy Hub is "a physical cross point, similar to an energy station, in which energy and information streams are coordinated, and where different forms of energy (heat, electricity, chemical, biological) are converted between each other or stored for later use" [1]. We have developed business and service concepts for Energy Hub systems targeted at end-users and energy service providers running practical actions in districts' energy business. An example of an energy brokering service model is shown in Figure 1.

A cookbook – collection of business concepts and elements

Business concepts are presented in a cookbook form – a collection of 13 business and service model recipes. Concepts describe the key idea, interactions between the seller and the buyer (Figure 1), key performance indicators measuring its success, and costs and benefits. Concepts are developed by modifying Osterwalder's business canvas method. They are based on stakeholders' interviews on the energy demand and supply needs [2]. Concepts are kept simple and focus on one stakeholder. Single business concept elements can be combined into broader and more specific business and service models and networks. [3]

Flexibility is one of the future energy commodities

Many of the business concepts (Figure 2) are

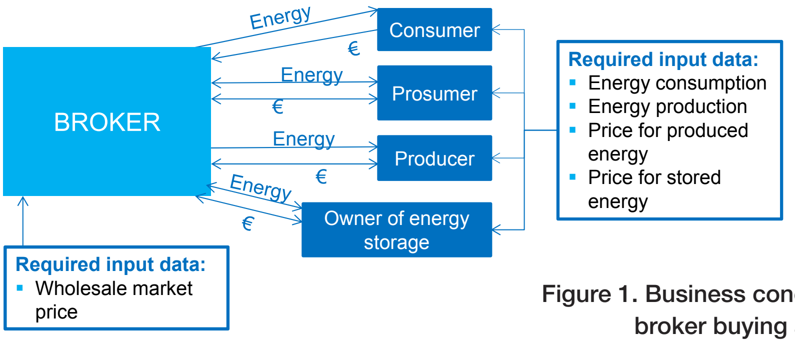

Figure 1. Business concept for an energy broker buying and selling energy

Business concepts for offering flexibility in energy demand and supply:
- Flexibility for energy retailer's portfolio management
- Flexibility enabling maximised utilisation of locally produced energy
- Flexibility for local network management enabling maximised renewable energy supply
- Flexibility for balancing services to the balancing responsible party and transmission system operator
- Flexibility for local balancing at district level

Business concepts for energy service providers:
- Energy broker buying and selling energy
- Flexible energy tariffs for (residential) consumers
- ESCO minimising customers' energy bills and optimising energy usage

Business models for new roles:
- Heat recovery of excess heat utilised in district heating and cooling
- Prosumer selling self-produced energy

Co-operative ownership of district heating network

Business concepts for energy producers and energy companies:
- Heat storage utilised in district heating and/or cooling
- Flexibility in electricity network by heat pump to avoid peak power

Figure 2. Business concept for an energy broker buying and selling energy

based on energy consumers and producers having a certain amount of flexibility available in their energy demand and supply. Flexibility is a new aspect of the energy market and a commodity that is used to create new business concepts. However, there are currently some barriers related to the legal framework and data privacy conservation, but these can be overcome. In general, parts of the proposed business concepts are easily feasible today, while others require new actors and roles that are not widely in existence in the energy business.

Demonstration and feasibility studies

The performance of the proposed business models is tested in feasibility studies: in a real district at Tweewaters in Belgium, as well as in four simulation case studies: Freiburg (Germany), Bergamo (Italy), Houthavens (the Netherlands) and Dalian (China).

Acknowledgements

The work is part of the project "E-Hub: Energy-Hub for residential and commercial districts and transport". The project is funded under the specific programme "Cooperation" in the FP7 framework initiative "Energy efficient Buildings (EeB, FP7-2010-NMP-ENV-ENERGY-ICT-EeB)". The following co-workers and partners are acknowledged: Mikko Virtanen (VTT), Frans Koene, Mieke Oostra and Cor Warmer (TNO); Kris Kessel (VITO); Reijo Kohonen (Global EcoSolutions Ltd.); Paola Laiolo (Intesa Sanpaolo Eurodesk), Mauro Alberti (CESTEC) and Bronia Jablonska (ECN), as well as other contributors via interviews and workshops.

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Identifying development trends in smart city technologies – VTT Trendgenerator

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Background

Trendgenerator is an analysis tool for identification and ranking of emerging and/or semantically related technologies based on patent, scientific and news wire information. Firms need information about emerging technologies in order to position their businesses on the market, allocate R&D investments and select partners.

With Trendgerator we aim to understand:

- What are the overall trends in research in this field over time, territory, application area?
- Which are the major companies and universities in this technology?
- How have their research and patenting strategies evolved over time compared with those of other industry key players?
- Which application areas are these technologies used for and by which companies?

Considerations

Firstly, while article and news wire data typically describe a technological development in a clear and informative manner, for patents this is not necessarily the case. The patent title, abstract and claims can be written in gibberish and hardly reveal what the patent really is all about.

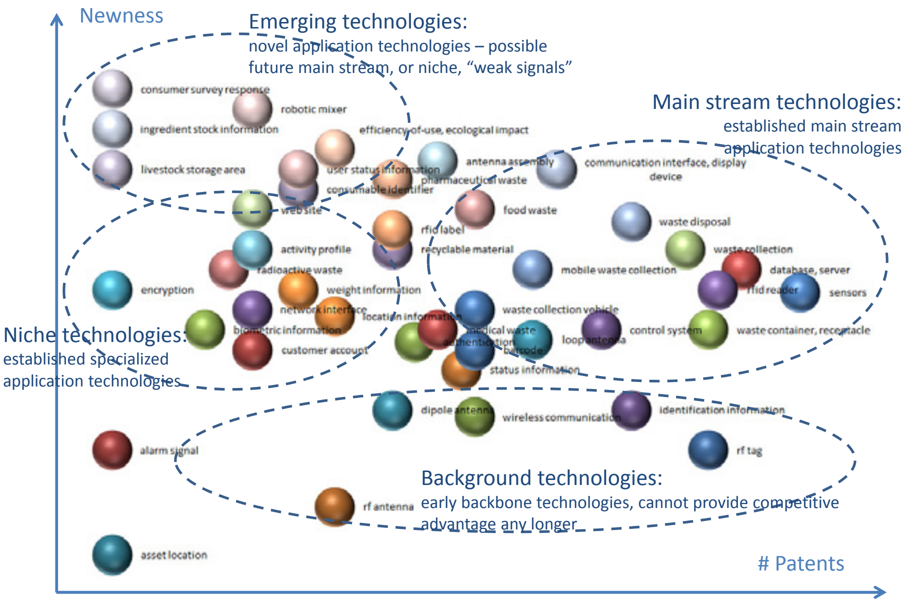
Secondly, IP Revenue is extremely skewed. For example, a distinction needs to be made between Big Corporation and Noname Ltd. In fact, while individual inventors, small businesses and universities hold approximately 60% of all US patents, large corporations generate 99% of the associated IP revenue. It follows that when studying emerging technology trends not all inventions and patent assignees can be considered equal.

Approach

We can tackle the content recognition problem by widening the scope of analysis from patent abstracts and claims to the inclusion of whole patent descriptions, including embodiments, and by using modern automatic term recognition techniques. This means that for a sentence "A new real time expert system is…" it would be optimal to find the term "real time expert system". Finding "real time" and "expert system" could be acceptable, but "time expert", "real time expert" and "time expert system" must be discarded automatically. Similarly, there are a number of approaches to detect the value of a patent. Patent applications and granted patents typically contain citations to earlier granted patents and other works that describe related art. Csárdi et al. (2007) extracted an attractiveness function that determines the likelihood of a patent attracting references from other patents.

Results

In the following example, we present a general picture of one particular technology area: RFID use in waste management. The x-axis shows the number of patents that mention a particular technology, while the y-axis depicts the "newness" of the patents – the higher the score, the more recent the respective patents. Here, we do not depict any company business strategies on the matter. It would be straightforward to do, however, and would imply the key players in each technology, how their strategies have developed over time and, most importantly, their current focus areas.



Identified technologies in RFID for waste management: their volume, recency and, hence, potential for being able to create distinctive competitive advantage.

We can depict four different clusters of technologies:

- Background technologies, that is, early backbone technologies that established the basis of the RFID use in waste management but are now "known" technology but can no longer provide any competitive advantage.
- Mainstream application technologies are relatively recent. "Big players" are typically active here – therefore this can be a tough environment for a Finnish SME to be competitive in.
- Niche technologies also include relatively recent technologies but with seemingly more specialized application areas. Examples include the treatment of certain types of waste (radioactive, recyclable) and data management solutions (biometric/weight/location/account information).
- Emerging technologies can be possible future mainstream technologies or can try to set up and secure small new business areas. Examples include more evolved data management (customer surveys, ingredient stock/user status information) and approaches towards a zero waste society (efficiency of use, ecological impact).

Discussion

Trendgenerator empowers inventors to innovate and collaborate by making it easy to monitor technology development trends within the entire technology landscape including patent portfolios, scientific articles and business news. This helps companies to harness their technologies' full potential as they decide on R&D investments, buy and sell assets, create alliances and open new markets.

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Public procurement of innovation for smart city solutions

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Introduction

The development and adoption of smart solutions in cities is largely dependent on procurement decisions made by city administrations and local governments. Public procurement plays a key role in creating demand for innovative and smart solutions to urban challenges. Conventional approaches to public procurement are not favourable for sourcing innovative products and solutions from technology supplier firms and service providers. This research has identified drivers and bottlenecks for public procurement of innovative solutions and reviewed available approaches to empowering local governments to become smart buyers.

Key findings

Based on a survey of supplier firms, public procurement can best advance innovation among companies when cities communicate early, in advance of their upcoming procurement needs. They should also engage in extensive dialogue with the markets. When specifying requirements, they should use functional and performance-based requirements instead of specifying particular technical designs. In addition, cities and local governments need to move towards procurement practices that enable interoperability across smart city solutions, enabling emergence of a modular market structure.

Application of research findings

The research was carried out by conducting two large-scale surveys, several case studies and engaging in extensive international collaboration. The findings have been applied to designing public procurement projects for intelligent transport services, smart water solutions and smart city governance. The results have also been communicated to policymakers at national and European levels.

Discussion

Through their great demand for power, procurement decisions made by cities and local governments play a significant role in shaping the emerging smart city markets. However, smart city markets are hybrid markets that constitute the demand from consumers, corporate buyers and public authorities. The challenge for city administrations is to shift their purchasing behaviour to support the emergence of open digital ecosystems for smart cities embracing interoperability. This approach holds great potential in creating lead markets for smart city products and services that are also scalable on the global marketplace.

Acknowledgements

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Real-time decision support systems for city management

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Introduction

The complexity of the current major societal challenges, in urban centres, demands the wide-scale deployment of solutions and services based on accurate and timely information. This will allow cities to move towards a sustainable transformation while spending less public resources and improving services offered to its citizens. The implementation of a common performance measurement framework based on a set of relevant indicators, open data applications and decision-support user-interfaces enables stakeholders to learn from each other, create trust in solutions, and monitor progress.

Smart city performance measurement framework

The European Commission has developed two parallel approaches to support the implementation of smart urban technologies: large scale demonstration of technology in cities and communities (‘lighthouse projects') and 'horizontal activities' to address specific challenges as in regulatory barriers, in standardisation, public procurement and performance monitoring. The CITYKEYS project, funded by the EC under the H2020 Programme, addresses these horizontal challenges. The goal is to provide a validated, holistic performance measurement framework for monitoring and comparing the implementation of Smart City solutions.

The CITYKEYS framework is defined as a smart city performance assessment system which includes city requirements, key performance indicators (KPI) ontology and calculation, and, data collection methodology (Figure 1). This development work is based on the following key pillars:

- Extensive collaboration and communication with European cities.
- Establish a baseline by analysis and integration of existing results from previous initiatives.
- Develop a set of KPIs evaluate the impacts of smart city projects/initiatives.
- Solutions for transparent and open data collection and processing.
- Validation based on real data during implementation testing in case cities.
- Identifying new business opportunities and build recommendations for the implementation of performance evaluation. These also include recommended paths for the future development of a 'smart city index'.

In order to achieve the objectives CITYKEYS is building on existing smart city and sustainable city assessment frameworks. The bases are the traditional sustainability categories People, Profit and Planet (Figure 2), but the performance measurement framework will also integrate specific smart city KPIs and assessment methodologies as the ITU I1440/1430.

Data collection and decision-support system

The work for the development of the performance measurement prototype system is based on the data sources needed to calculate the defined indicators, a transparent data collection methodology, the KPIs calculation procedures and visualization. The formulation of relevant KPIs will be based on harmonizing existing environmental, technological, economic and social indicators for Smart Cities and specifying missing ones. The Performance measurement system metadata model and calculation methodologies are based on:

- Defining the needed data sets to be collected, based on the specified indicators.
- Identifying available data sources, their reliability, accessibility and data models.
- Specifying the collection system and calculation methodologies for the performance measurements'.
- Developing a prototype of the performance measurement system integrating input specifications, calculation methodology and visualization.

The CITYKEYS framework will be tested in the 5 partner cities: Tampere, Rotterdam, Vienna, Zagreb and Zaragoza. The cities will be involved in defining the stakeholder needs and the performance system requirements (including usability requirements), in evaluating and testing the system prototype and in building recommendations for its implementation in planning and municipal decision-making processes.

Boosting the wide-scale deployment of smart city solutions

The results will impact on the transition to low-carbon, resource efficient cities by creating the necessary framework for performance assessment of the deployment of smart cities technologies. The performance measurement framework will include specific smart city KPIs that go beyond the traditional division into categories and will measure the integration level and openness of the technological solutions. This will support planning and procurement processes allowing the stakeholders to access and compare different solutions and planning scenarios and thus impacting on the deployment of the most suitable ones.

Acknowledgements

These results are under development within the H2020 project CITYKEYS, co-financed by the European Commission and developed together with the following partners: AIT Austrian Institute of Technology GmbH (AT), TNO Netherlands Organisation for Applied Scientific Research (NL), EUROCITIES ASBL (BE), City of Tampere (FI), city of Rotterdam (NL), City of Vienna (AT), City of Zaragoza (SP), City of Zagreb (HR). In addition the following cities had express interest to act as "contributing cities" for the validation of the performance system: Manchester (UK), Dresden (DE), Terrassa (SP), Birmingham (UK), Porto (PT), Utrecht (NL), Mannheim (DE), and, Burgas (BG).

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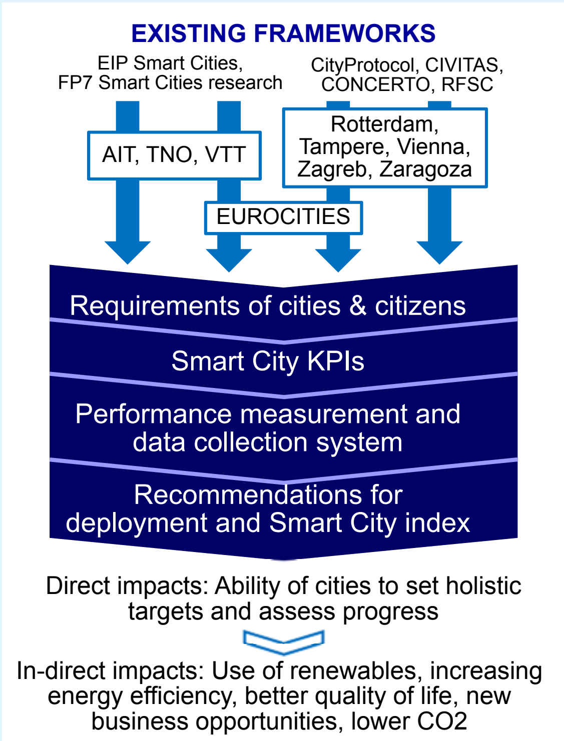

Figure 1: The concept of CITYKEYS project

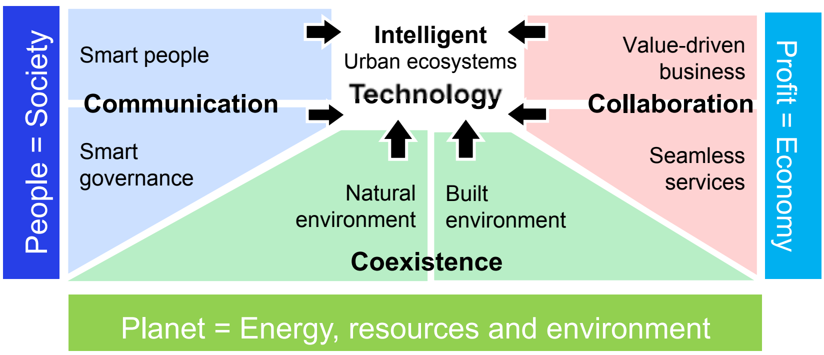

Figure 2: A typical classification scheme of Smart city assessment framework

Boosting collaborative planning with visualisation technology

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Introduction

Communication in large construction projects involves a great number of stakeholders, which is a special challenge for interaction. Many stakeholders view the process from different perspectives [1]. For collaborative planning, design visualisation offers a meaningful way to convey messages and reduce communication difficulties [2]. Immersive virtual environments are increasingly used in large projects to assist stakeholder interaction.

Majority of experts value virtual models

The benefits of visualisation in group-context include gains in productivity, quality and knowledge [3]. We collected feedback in VIREsmart project [4] from using virtual models as a presentation tool along traditional tools in nine expert meetings at two large construction projects in Finland. Results indicate that visually represented plans are introduced more rapidly to stakeholders, which leads to more balanced interaction between consults, experts and client. Altogether, 75% of experts felt that they understood the plan better with virtual model and as high as 90% wanted to use virtual models in the future.

90% of experts valued virtual models and wants to use those also in the future.

Visual working led to 2-4 times more comments

We have used activity theory [5] as a framework for observing and analysing the effects of virtual reality on interaction and related work practices. The amount of comments participants made during discussions was used as an indicator for participation. Especially client and experts appreciated the visual interaction, and plans were often reflected to opinions and regional comments. We also noticed that virtual models as a medium led to 2 to 4 times more comments in the discussions when compared to the traditional tools.

Efficient group work at VTT 'Creation Lab'

Active participation is essential in projects for successfully reaching the objectives. When a certain time is reserved for plan review, visual representation provides better opportunities for developing the plan. The empirical findings collected in this study underline that immersive virtual environments have potential to enhance collaboration [6], but must be facilitated carefully in sensitive meeting situations. During the work VTT also invested in a technology-assisted group workspace and built 'Creation Lab'. In the future, we aim at developing procedural meeting changes in order to turning those into more participatory.

Fig.1. Virtual model used in two meeting setup; a standard meeting room (left) and an immersive virtual environment (right).

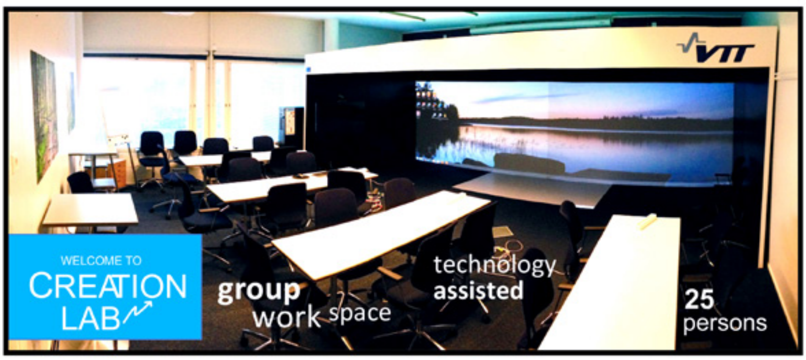

Fig.2. VTT's technology assisted group work space 'Creation Lab'.

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Virtual Model Facilitating Citizen Interaction

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Introduction

A continuous flow of public projects is required for the development and maintenance of built environment. Performance, achievements and decision-making in those projects are of public interest, and, thus easy access towards the relevant information is required in a growing manner. Interaction is one of the key elements in current design practice. The building act in Finland states that interaction with citizens is obligatory [1], and similar practices are present elsewhere. Still, communicative events between experts and citizens utilising interactive models have been studied in a very limited manner.

Presenting plans with virtual model to citizens

The focus of participation has during the past decades shifted from reducing consequences towards the identification of future opportunities [2]. Visualisation is seen as an efficient way to reduce communication difficulties [3, 4]. We have studied in VIREsmart project [5] citizen participation in one large construction project in Finland. Virtual model was adopted to three public hearing events (138 participants) together with design drawings and maps. Before the event, researchers participated to a planning meeting. Lengths of events ranged from 2 to 3 hours, each ending to a voluntary questionnaire.

80% of citizen's agreed that virtual model is suitable to examine plans.

Citizens understand plans better with virtual models

Virtual models are lucrative communication channel for experts to reach citizens. In two out of the three public hearings approximately 80% of respondents agreed with the statement virtual model was well suitable for examining plans. Interestingly, we found out that 10-25% of citizens did not fully understant design content from maps. About 70% of participants were also happy to use virtual models in the future. We also monitored attitude towards tablets. In last event, 70% of occupants whose average age was 62 years felt that tablet visualisation rousing. Based on observations, they experienced a wow-effect after they learning to navigate in the model.

Towards technology assisted small group discussions

Virtual models are a rather sensitive matter and their implementation must be prepared. For com-

Figure 1. Three studied public hearing events where plan was presented with virtual model (VIREsmart project [5]).

Figure 2. Virtual model studied from a tablet.

munication towards public, other supplementing communication channels need to be used to facilitate communication successfully. We also noticed that people have more courage to discuss in smaller groups, instead of a large audience. Thus, we suggest that group work should be the main working practice whenever possible in communicative events with citizens. Presenting virtual model from a suitable mobile device, such as a tablet, alongside paper drawings is a very potential way for enhancing interaction.

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Mobile Augmented Reality for City Planning

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Introduction

VTT has conducts leading research on Augmented Reality applications in the AEC sector (Architecture, Engineering and Construction). Beyond technical work, VTT has been the first to employ mobile AR in real land use cases, helping city officials and local residents to understand and comment the architectural plans in early design phases. User studies indicate good user acceptance and clear added value for the decision making process among different stakeholders.

Increasing understanding of architectural plans

Augmented Reality (AR) is a technology for superimposing digital information such as computer-generated graphics on the user's real time view of the physical real world. In land use planning, mobile AR can be used for visualizing planned 3D building models from arbitrary view points at actual locations. Increased situational awareness enabled by mobile AR allows allows for improved communication of plans between different interest groups.

Pilot cases

VTT's mobile Augmented Reality solutions [1] were used for mobile visualization of building plans in three real use cases: 1) hotel plans in Billnäs iron works site at Raseborg, 2) Kämp Tower plans in Jätkäsaari, Helsinki, and 3) wind generator farm in Pörtom, Närpes. The first two cases with city officers as users were performed in 2012, being the first times in the world when mobile AR have been applied for real decision making in land use planning. The third visualization was targeted further to serve local residents, farmers etc. who could thus evaluate the effect of new construction plans to their living environments. The first two pilot cases are shown in Figures 1 and 2; see also videos http://youtu.be/wvSPzG7AqLY (Billnäs) and http://youtu.be/c1DUkVhqVsM (Kämp Tower).

User acceptance

The participants in the example cases used the mobile AR system along with paper visualizations of the plans and evaluated the usefulness and overall strengths and weaknesses of the AR system. The results [2] indicate that AR was found to be a highly useful instrument to visualize building plans in a holistic and intuitive way from the first-person point of view. The system facilitated decision making and enriched the understanding of the plan, thus having a clear additional value over traditional visualizations. Each of the use cases lead to ordering of further mobile AR tours around the sites, as well as to employment of the system in further land use cases in Finland and abroad.

Discussion

In the future, we expect mobile AR to become a standard tool for city officials, residents and other stakeholders to evaluate and better understand new building plans and alternatives. Mobile AR enables people to view building plans in an easy and intuitive way, at any chosen viewpoint. Interaction with residents, land owners and other stakeholders is often a key issue in building and land use planning. Better understanding of the plans can lead not only to more democratic society, but can also have significant economic impact e.g. by means of reducing costly complaint times related to land use proposals.

Figure 1: Helsinki city planning council viewing augmented Kämp Tower plans on tablet.

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Co-creating future smart cities - Visual and participative urban planning services

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Introduction

Urban planning is traditionally perceived as a complex and time-consuming process. Unclear plans, possible misunderstandings and decision-making without stakeholder participation may cause complaints and delays even in long-prepared projects. New visual smart city planning solutions for illustrating urban projects are needed. Participatory design approach with advanced visualisation and open innovation tools enhance collaboration between stakeholders and facilitate discussion of new ideas and solutions.

Future urban planning services

VTT conducted research on participative urban planning and developed tools for illustrating design options and gathering user feedback. The aim of the visual and participatory urban planning study was to co-create, demonstrate and evaluate web-based service concepts, which utilise mixed reality technologies with user participation features. In the future, the development of urban living can be easily understandable, collaborative and transparent process engaging different stakeholders. The stakeholders in urban planning and the users of the new community planning services can be categorized into three main groups: 1) decision-makers 2) related companies, and 3) citizens. The research process involved interviews with visual software and urban planning related companies, local political decision-makers, municipal officials and citizens. In addition, 455 citizens have participated in the study via online questionnaire.

Participatory urban planning demonstrators

Different demonstrators related to real urban planning projects have been developed for concretizing the service concept [2,3]. Demos illustrate a sound barrier between a field and a highway in Pirkkala municipality, different options for a new office building in Lempäälä Church square and new buildings and rooftop gardening around Tampere Central Arena (Figure 1).

Technically, the demos are based on mixing panoramic imaging and 3D architectural drawings and they run on web browsers of different devices such as tablet devices and PCs. Advanced visualization approaches such as mobile on-site augmented reality solutions and table top interaction design tables (Figure 2) were also considered as possible participative urban planning concepts.

Stakeholders' views on the on the visual and participatory urban planning concepts and demos

According to the interviews, the new tools were expected to eliminate misunderstandings and

Figure 1. Rooftop gardening and Tampere Central Arena visualization. (Picture: VTT/NCC)

Figure 2. Visualization on an interactive design table.

Acknowledgements

The ILCO project has been funded by Tekes – the Finnish Funding Agency for Technology. The project has been supported by City of Tampere and the municipalities of Pirkkala and Lempäälä. Company partners participating in the project are JJ-Net Group Ltd, Sweco PM Ltd and Visura Ltd.

bring certainty in the decision-making processes [1]. The interviewed decision-makers wanted real team play and open discussions with different stakeholders. Illustrating and visualizing urban plans was thought to enhance the quality of the decision-making materials. The new web-based visualization services were seen as furthering the perception of entireties, dimensions and scales of new buildings, measures and impacts, which were seen as difficult to figure out at present. The new tools were expected to make it possible to illustrate and compare different options and their direct and indirect impacts on the environment. In addition, visualizations would offer users the option to give feedback and share their ideas at any time. This would be useful, especially in trying to target future users, e.g., the younger age groups, who rarely participate in public urban planning events organized by communities. In general, the new visual tools were seen as a possibility to enhance the most important and employing future urban planning projects.

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Citizen-driven co-design for a smarter city

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Introduction

Continuous innovation is in the core of the idea of smart city. Accordingly, the role of the citizen has evolved from a passive end user of technology to a source of ideas, a co-designer and a co-producer of technologies, services, activities and other facilities in the smart city. The citizens make a bountiful resource for the distributed innovation system. To benefit from this resource, the innovation system needs to efficiently utilise different tools, technologies and methods for efficient co-design. VTT has developed and investigated solutions to engage citizens to innovate for business and smart governance, decision making and urban planning. This chapter provides some highlights of the co-design research carried out at VTT. More detailed descriptions and results of some particular co-design studies are presented in the other chapters in this book.

VTT solutions and approaches for co-design

The Internet and social media make a powerful platform for co-design. Owela [1] is a web-based tool that enables co-design independent of time and place. Owela builds on social media features to attract consumers to participate co-innovation for the purposes of projects and companies. ICT is also taken advantage of in urban city planning with visual, augmented reality solutions (see [2] in this book). A web-based platform can show realistic images of a city area. The images are interactive and augmented with virtual objects and information to illustrate the development plans for the area. The images can be investigated and manipulated, and the application encourages user feedback through co-design elements (e.g. questionnaires) integrated in the display. Attaching these elements to specific spatial locations in 3D space in the image has been tested in the Visual IHME concept [3]. The concept has applications in cases when co-design is dependent on spatial referencing.

In the end, co-design is involvement of people to jointly develop something new or better. Living lab is an approach to co-design that is based on long-term participation and engagement of users as well as other stakeholders in the development process [4]. Living Lab provides an opportunity to apply a range of collaborative methods – whether ICT-based or not – during the process, resultings as deeper research knowledge and better ideas and raising feelings of togetherness and common purpose for the living lab community. On the other hand, collaborative design can also take place in an ephemeral manner. VTT has tested a concept of an open, public co-design showroom IHME [5] (Figure 1) that attracted consumers to visit the showroom and get involved in technology application design for a moment without commitment. The concept was very welcomed among the consumer visitors.

Figure 1. The public co-design showroom IHME attracted consumers to engage in co-designing smart applications.

Discussion

In the near future, engaging citizens in research and innovation is becoming ever more important. One notable thrust for this development is the initiative of Responsible Research and Innovation (RRI), recently launched by European Commission. RRI strongly emphasises citizen engagement in innovation in order to guide innovation towards the needs of the society, with prethought risks. The responsible innovation system starts in the school in science education and encourages both genders to participate making the future.

VTT faces the challenge set by RRI and societal needs by developing and implementing new co-design methods and tools to attract and facilitate citizens to participate in the continuous innovation.

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Social media for citizen participation

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Introduction

What opportunities and challenges do social media, openness and self-organising bring about for collaboration and communication between citizens and public organisations? Can social media be used as an effective participative environment? The SOMUS project [1] set out to explore these questions by making a number of case studies where citizens and public sector representatives developed and utilised social media tools and services to tackle societal issues.

Social media tools require new skills and processes

Social media challenges the traditional ways of citizen participation [2]. Online tools and services offer powerful platforms for active citizens and lower the barrier for participation in societal issues. Cities and municipalities can utilize the collective wisdom of its citizens for problem solving and innovation. However, successful utilisation requires coordination skills and processes that benefit from and support citizen participation. There will also be increased pressure for transparency in decision making. A city can support citizen participation by opening its data for free and in machine readable format. Open data enables analysis and application development by giving the citizens facts and opportunities for informed participation.

Open participatory research

Our leading themes, social media and openness, were utilised from the beginning: the project proposal was drafted in an open wiki, and this attracted researchers from universities as well as active citizens creating the core project group. All project work was done in open manner supported by online tools. During the actual project, we co-designed new social media services with high school students and their teachers, immigrants and their associations as well as Ministry of Justice [3].

Innovations through social media

Social media may be utilised in two ways: existing social media services may be used or new services may be developed. Using existing social media services enables building on available communities, networks and content, but one must play by the rules of the service in question. When creating new services, popular social media features that have become familiar to users can be included to make also new services easy to learn and use. Collaboration with real users from the problem definition through use is critical to success. Crucial new ideas may come from any participant and fresh ideas emerge best through experimenting and testing. New tools and clever use of current tools can themselves become innovations and create new business opportunities, and they may generate new innovations by gathering a versatile group of people to collaborate.

Social media enables self-organization. It works in a small group, but large crowds need gluing elements or tools to compensate the lack of formal organization that is normally used to organise such activities. This is particularly the case, when the action requires a longer time to complete and the target is to have an impact outside the online world. Dealing with openness and incompleteness, networking, managing varying roles, facilitating networked processes, agility and ethics are needed when utilising open social media in public processes.

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Gamification as an enabler of mutual learning in complex health care systems

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Introduction

Innovations in cities are usually systemic in nature. Systemic innovations require changes in organisations, network relationships, technologies and models of operation. [1] Our focus in this article is health care innovations in public sector where new services foster quality and efficiency of services provided to citizens. Ageing population, increase of chronic diseases, new ICT solutions and citizens' increasing expectations has led to situation where our health care system needs radical changes. For example, the introduction of new ICT solutions makes it possible to connect more and more distant actors to the same service activity. However, at the same time, the service as a whole becomes complex and thus uncontrollable. From the viewpoint of the customer, the care appears as a fuzzy process. Customer-oriented thinking and ways to coordinate services have been suggested as a solution. A change towards customer-oriented health care services requires a paradigmatic change and changes in multiple levels. In Finnish health care system, the silos of organisations and profession as well as expert- led health system where customers are not considered as expert in their own health are significant barriers of implementing new customer-oriented services. It is essential to create dialogue between organisations, professionals and customers to promote system innovation and thus create high quality health care services. For this, gamification, the use of game-like elements and game-design principles in non-game applications [2], is seen as a potential tool for promoting dialogue and innovation.

Promoting dialogue – complexity theory, societal embedding of innovation and gamification as methods

In recent years the idea to consider health care as a complex adaptive system has gained ground in research. We have collated and further developed the recommended managing principles of complex adaptive sociotechnical systems (CASS). In CASS, individual actors self-organize and interact with each other thus changing the context and affecting the self-organisation of other actors. This creates intrinsic unpredictability and uncontrollability in CASS. [3] The management of CASS means trust and support to self-organisation of actors and building of engagement to the shared purpose [4].

Another approach used in our research is societal embedding of innovation. Societal embedding of innovation is a research and development approach which has been developed by VTT in different research projects since 1990`s. It has been used to enhance novel health care services and environmentally friendly innovations. [5] It aims at facilitating and initiating new innovations in a multi-actor network. An important objective is to create a dialogue between different actors and give them a possibility to create a shared understanding of the elements of the solution. By opening up the perspectives of the different actors it aims to produce mutual learning.

Gamification can be seen as a promising approach for mutual learning. For instance, storytelling among a group of players assuming different roles, using visual aids such as playing cards and boards, can be adapted to game-like approaches. This allows systemic aspects of health care processes to be discussed from different perspectives in an inspiring setting, and coherent storylines involving different stakeholders to be created in order to concretize the often hazy interactions between different actors and actions. Games can also emulate complex interactions found in real-world service chains and in their management, providing a platform on which people can experience, discuss, and experiment with different future conditions and states.

In our research project MOSAIC, CASS, societal embedding of innovation and gamification has been studied in practical cases. In one of our cases, a substantial change in technical systems is introduced which induced also the need to change the process and operational culture. After the interviews of selected stakeholders and health care professionals, we are developing gamified solutions to support the management of complex care chains. One example of these development activities is a workshop where we applied “role-switching game” in multidisciplinary teams aiming at improving medical care process.

Integration of methods as one solution?

Typically there are no simple solutions to complex problems. CASS, societal embedding of innovation and gamified approaches can be seen as valuable tools to understand, manage and create dialogue to foster change processes in complex health care service systems. In MOSAIC project we are integrating these approaches to study and support complex change processes.

Acknowledgements

The authors would like to thank Pirkanmaa Hospital District, Vaasa Central Hospital and Tekes - the Finnish Funding Agency for Innovation

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Decision-making support: A smart city perspective

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Introduction

Today, we have moved to interconnected, open and global living environments. Smart solutions and networks are surrounding us almost everywhere and security has become a priority in all aspects of life, including business. As a result, decision-makers at all decision-making levels are pressured to find ways to deal with the new technologies, their benefits and security risks, and to make sound investments on them. Secure society and business environment is often regarded as a public good but how to assure that the investments are acceptable and cost-effective?

Need for improved decision-making

Decision-makers typically have trouble evaluating alternative designs and justifying technology investments because the benefits are typically difficult to estimate. Decision-makers responsible for planning and introducing investments on new technologies and smart solutions usually find themselves confronted with numerous stakeholders with multiple needs, requirements and value perceptions. In this multi-stakeholder situation, consistent estimates and other information on costs, benefits and risks of investment alternatives are crucial for decision-making and increase transparency and reliability of decisions. To balance increasing need for security and economic constraints, decision-makers have to increase their awareness of the overall impacts of their decisions.

Evaluating the effect of investment alternatives

Typically a decision-maker is influenced by factors that are clearly financial but also by factors that cannot be easily quantified in financial terms. Thus, the investment appraisal problem can be set up as a multi-criteria optimisation problem, and a variety of methods should be used for the evaluation. VTT was part of the consortium [1] developing a framework for assessing the security investments. The approach and the subsequent tool are based on the three pillars (Figure 1):

- Risk reduction assessment: Calculating the expected reduction of risks by the investment alternatives
- Cost-benefit analysis: Comparing those positive and negative effects of the investment alternatives which can be expressed in monetary terms
- Analysis of societal factors: Evaluating all criteria influencing the decision which cannot be expressed in quantitative terms.

By widening the assessment process through which the investment decisions are taken, the decision-maker is able to make the optimal

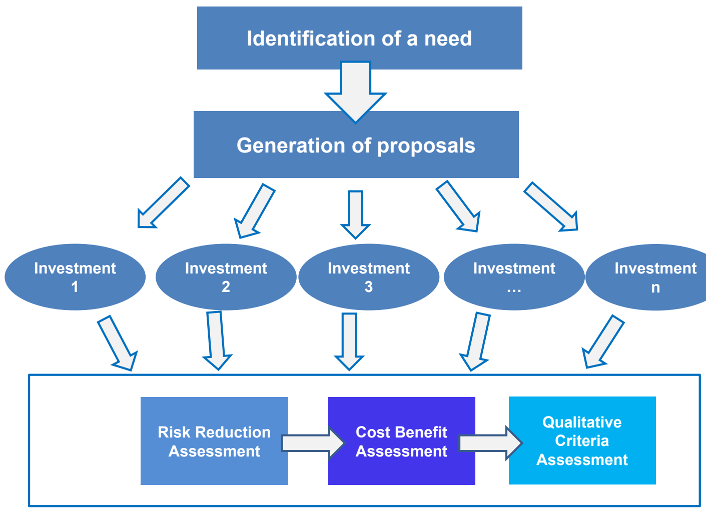

Figure 1. Framework for three pillar assessment of investment alternatives [1, 2, 3].

trade-offs between monetary and non-monetary considerations based on his/her individual preferences and values.

Valuable decisions

The multi-dimensional investment assessment provides a holistic view to investment decision-making by combining and integrating several evaluation methods into aggregated analysis. In addition, the approach enhances transparency of investment decision-making and contributes to more comprehensive use of available information affecting the profitability of investments.

The software tool based on the developed approach is already being successfully applied in the area of communal security planning, air transportation, public mass-transportation, public mass events, and cyber threat. The developed method is also applicable to the evaluation of investments on smart city related solutions and networks.

Acknowledgements

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Intelligent buildings and urban spaces

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Buildings are an essential element of a Smart City infrastructure. In the future city buildings will, as other city structures, have an active role in the seamless communications and services. An intelligent building integrates technology and processes to create a facility that is safer, more comfortable and productive for its occupants. At same time it needs to beoperationally efficient for its owners. Advanced technology – combined with improved processes for design, construction and operations – provides a superior indoor environment that improves occupant comfort and productivity while reducing energy consumption and operation staffing.

According to many recent studies the service systems and BUILDING management have close relationships with the well-being of citizens. The building environment affects wellbeing and comfort in homes and workplaces. In addition buildings influence productivity and satisfaction. In order to achieve such indoor environments intelligent embedded technologies are needed. In addition the importance of human technology interfaces becomes evidently important. To create the desirable impact it is essential to combine multidisciplinary research together with the industrial perspective of sustainable development.

Smart design, operation and management enabled by building information models (BIM) based processes and integration with advanced building energy management systems (BEMS), helps to communicate with different stakeholders and create better mutual understanding. Visualisation of different building and urban space properties enhance the options to create better living and working environments.

Buildings are connected to their environment; also inside the building different components are interacting. Therefore it is evidently very important to use multi-target optimization for a holistic optimal performance. This optimisation is not only done for technical performance but also for user experience

Intelligent urban spaces – automatic real-time responses to people behaviour

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Introduction

With intelligent urban spaces we aim to create spaces that are capable of reacting in real time to the behaviour of the people who are present. The urban space adapts to the people's needs and intentions – providing just the right services at the right time in the best possible way without direct control of the services by the users. We offer a depth sensor based people tracking system to acquire data on people behaviour and a service to analyse and model the behavioural data. The people tracking and modelling system can provide a competitive advantage for various application domains, from immersive spaces to smart lighting, facility management and retail.

Benefits of a people behaviour modelling approach

Current people-tracking solutions are based on various sensor technologies (RGB cameras, RFID, Wi-Fi, Bluetooth, etc.) and can provide general information on people's movements in the environment. Our depth sensor based solution provides more accurate and reliable track data on which people behaviour can be modelled in order to target the service to the people who are present (Figure 1). This information is valuable for many application and service domains (Table 1).

People behaviour monitoring and modelling

Since 2010 when Microsoft released the Kinect sensor, the price of depth sensors has fallen, enabling the adoption of previously high-end technology for new application domains. The first version of the VTT people tracking system was built on a one sensor approach using these cost-effective depth sensors. The networked solution [1] in which a centralized server collects and fuses the detection events signalled by the sensor nodes has been demonstrated on many occasions in the last couple of years and has attracted interest. The novelty of our solution is in the developed data analysis functionalities, enabling behaviour modelling and leading to intention awareness as well as to prediction of people behaviour [3], [4]. The basic people tracking system has been integrated with external services: lighting control [2], interactive spaces, customer monitoring and facility monitoring services.

People behaviour modelling – unleashed business potential?

The current application domains for the people behaviour monitoring system have been defined based on the interests of various stakeholders. As already described, we have recognized many distinct use cases, and we believe there are many more still to be found. We will continue developing the analysis and modelling functionalities towards a semantic understanding of people behaviour, e.g. activity recognition or group behaviour. The intelligent sensored spaces lead to increased efficiency and provide a competitive edge for companies as well as possibilities to define new business concepts and models.

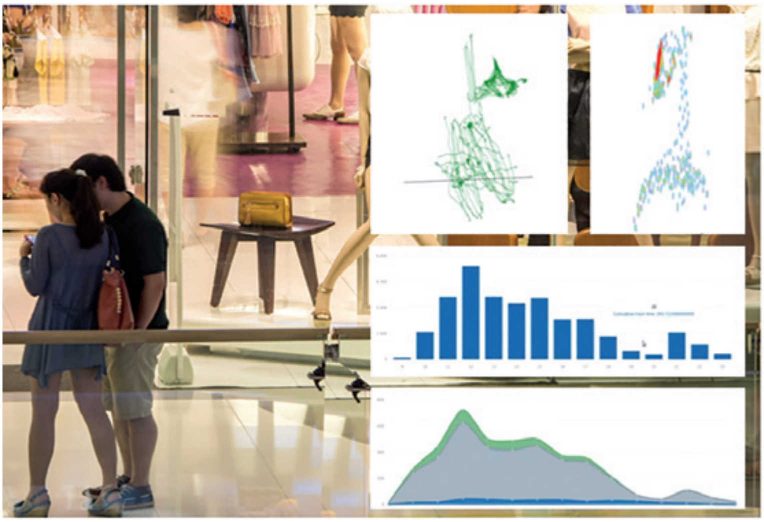

Figure 1. The depth sensor based people tracker provides accurate real-time information on people behaviour: track visualization, heat maps, statistics and behaviour segmentation

Interactive sensored spaces	Presentation and selection of content based on people's actions, natural and invisible interaction with the users, intention awareness
Brick-and-mortar retail	Exact information on customer behaviour, intention-awareness leading to real-time response and immersive shopping experiences, interaction with digital content in the store, customer modelling
Assisted living	Behaviour information on the elderly, behaviour patterns, anomaly detection
Facility management	Exact real-time information on the use of facilities, enabling new ways of working, input for facility design
Smart lighting	Dynamic control of lighting systems based on real-time information on people behaviour, guidance solutions, automatic adaptation to current tasks

Table 1. Application domains that benefit from people behaviour knowledge

Acknowledgements

The people tracking system has been developed in various internal and co-funded research projects since 2010: Pro-IoT programme, New ways of working (internal projects); ViCoMo, Empathic Products, Digital Service SHOK, SparkSpace, FLOW3D (partially funded by Tekes) and Flexible Space Service (EIT ICT Labs). The work has been a joint effort by a number of VTT researchers.

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Occupancy in smart buildings of smart cities – case hospital smart lighting

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Introduction

Smart cities consist of buildings with smart sensors. The idea of intelligent lighting that uses presence sensors for energy savings is commonly known. However, the intelligence itself is based on technology and does not necessarily involve the occupants fully. The occupants need to be involved in order to benefit from the full potential of the installed technology.

What positive influence do the occupants have on smart buildings?

The facility managers have estimated the savings of smart buildings based on pure technical calculations, but the behaviour of users should have a positive influence on the final savings. Lighting with presence sensors and switches to select 'auto' lighting is just one of many technologies in which the users are actively connected to the realization of the calculated potential.

Project including smart lighting – lessons learned

The case hospital added presence (and luminance) sensors to a group of patient rooms to assess the effect of energy savings as part of the piloting activities of the Re-Co (Re-Commissioning) EU Project. The original idea was to control some of the lights automatically depending on the presence status and the amount of natural light. The user's role was to choose the 'auto' or normal on-off position on the light switch depending on the need. The patient room (facing south and west) data were collected for one year to assess the real potential of the savings per year using natural light and the presence sensors (Fig. 1).

In the second year, the user motivation was followed by further programming of the 'auto' position of the switch. The users proposed that the presence sensor not be active during the night to avoid unwanted light. Consequently, the second year of measurement showed slightly better use of the 'auto' position of the switch. The lesson learned from the two years was that the users should have been involved from the very beginning when planning the energy-saving technology. Fig. 2 shows the occupants' practical challenges. The users have proven that they choose mainly the normal on/off switch – probably because it is the simplest scenario to handle.

The hospital now knows the high savings potential, and in the future it will involve the nurses and other staff in the planning phase to ensure the highest possible use of the intelligence of the lighting controls. It is anticipated that a better user interface together with pre-motivation will give better results. The hospital has started to install presence sensors in its refurbishment.

Impact of occupants vs measured potential

The light automation saving realized from a patient room was 6 € per year, of which natural light accounted for 2 €. This is a tiny part of the potential 42 € per year, of which natural light accounted for 16 €.

The light automation saving realized for the office room was 13 € per year, of which natural light

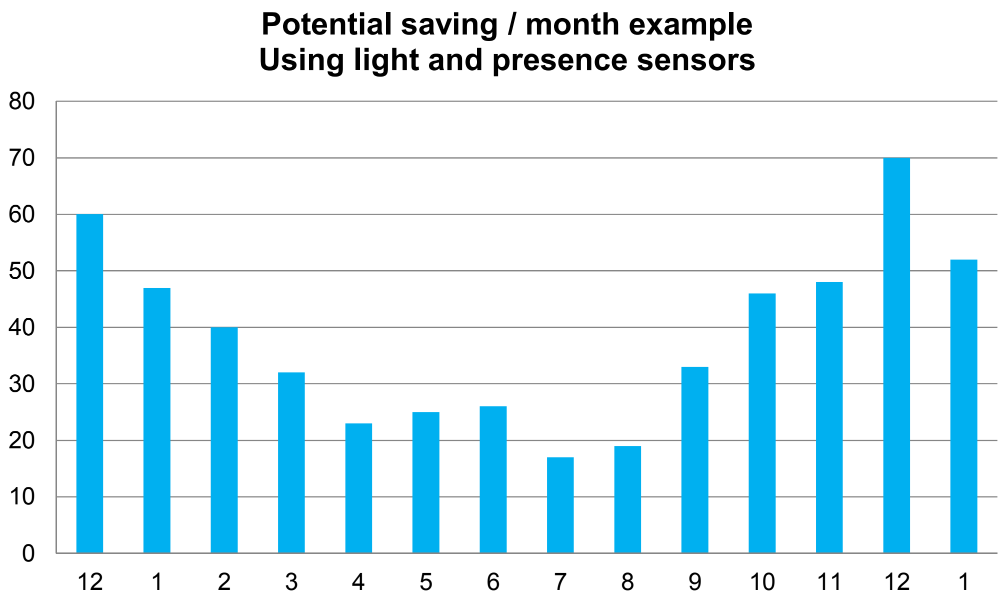

Figure 1 and 2. Calculation of the monthly saving (%) potential of one room with lighting and presence sensors that are fully utilized and Practical problem for the end-user

accounted for 3 €. Accordingly, the potential savings were 81 € per year with natural light accounting for 8 €.

These calculations clearly show that the payback period of a sensor could be less than two years if installed along with the other refurbishment. However, this requires a much higher utilization rate than that experienced in this project.

Links

http://www.re-co.eu/

Acknowledgements

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Mobile augmented reality for building maintenance

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Introduction

Augmented Reality (AR) is a promising new technology to help mobile workers obtain timely and accurate information related to maintenance targets. We implemented a prototype of a mobile AR system based on the BIM representation of the building, combined with FMS and other data sources. Technical challenges included indoor locationing and 3D tracking of the mobile device. User evaluations were conducted in two phases: first, providing valuable input for system design, and, secondly, showing very positive results on technology acceptance.

Providing new tools for building maintenance workers

Building maintenance workers have a number of locations to visit and are constantly on the move, thus their tools should support mobile work. The workers also frequently meet with new locations and unknown equipment, requiring tools to provide them with up-to-date information on site. Mobile Augmented Reality can be used to visualize alerts and operating instructions directly on the target, thus helping mobile workers with improved situational awareness and reducing the workers' need to shift their attention from the work target to external devices or manuals.

Mobile AR system implementation based on participatory design

We were among the first in the world to implement a mobile AR system for building maintenance workers. Technical challenges in the implementation included accurate indoor locationing and 3D tracking for mobile devices. The implementation was based on participatory design (PD) and user-centric (UCD) principles, involving several users and experts from a group of industrial partners. The users were first involved in the design phase of the application [1], leading to a set of features and functionality now available in the final system prototype. The second round of the user tests with a real world pilot case verified user acceptance of the proposed solution [2]. Figures 1 and 2 show two use case scenarios.

A video of the pilot is provided on YouTube http://youtu.be/uYFtYbqvoq0.

Discussion

The users involved in the group interviews were very enthusiastic about discussing how technology could be used in everyday work duties. They provided a large number of good quality ideas effortlessly and generally felt that a mobile tablet application could easily be used in their work. One of the most important findings in the first round of the user tests was the obvious need for other data sources besides BIM such as FMS (Facility Management System) to be integrated into the system. Other features that were proposed by the users included a Virtual Reality (VR) view for remote inspections. Several ideas from the first round of studies were taken into account in the final system implementation. The second round of user tests showed very positive results for user acceptance of the prototype application.

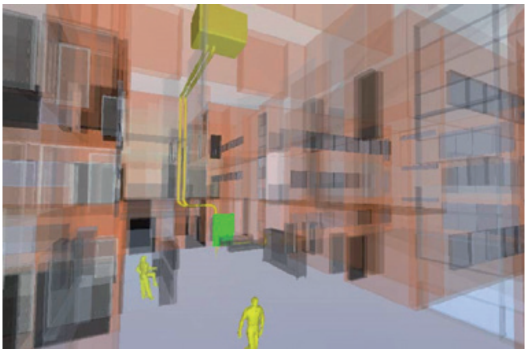

Figure 1. BIM with malfunctioning devices highlighted.

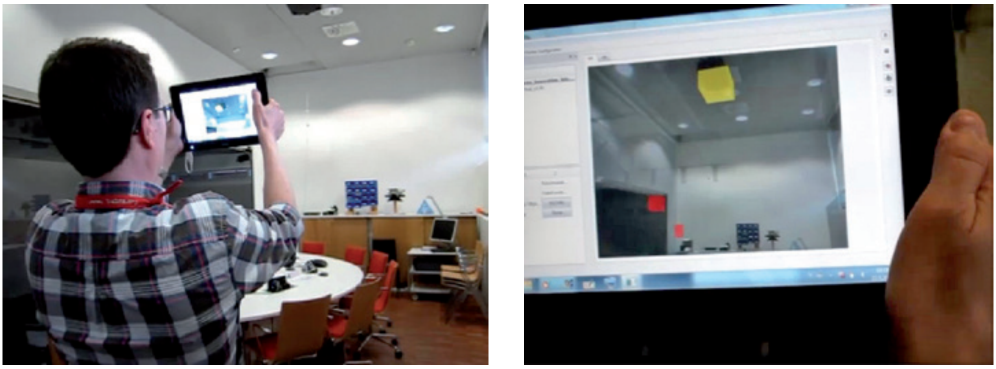

Figure 2. Mobile user finds warnings and alarms in a room (left).
Alerts highlighted in mobile AR view (right).

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Acknowledgements

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Autonomous management system for buildings and districts

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Introduction

So far, control systems for buildings have been developed as individual systems. Fairly new Energy Usage Analysis tools provide the capability to analyse energy profiles of scattered buildings of large corporations. The energy usage analysis and planning at district level are only emerging. Energy Usage Modelling is not yet leveraged in control schemes. The EU project AMBASSADOR aims for more effective building control solutions by exploiting the potential of each smart building to contribute to district level energy optimization schemes. AMBASSADOR's vision: flexible buildings to make eco-friendly districts.

Optimization at district level

AMBASSADOR will use real-time adaptive and predictive behavioural models of buildings and districts exposed to weather conditions, a human presence, and energy-efficient materials and technologies. They will allow optimal balancing of supply and demand. Energy management systems for buildings will become real-time configurable systems, bringing flexibility to the building. The project investigates and validates the contribution of certain technologies to the district's energy-optimization objective. AMBASSADOR's results will be validated on three demonstration sites in France, Greece and the United Kingdom.

Research method

AMBASSADOR addresses the question of energy flows management at district level, for electrical and hot/cold water networks. At the heart of the system is DEMIS (District Energy Management and Information System), which aims to identify the optimal energy flows by answering a specific objective assigned to the district. The systems and objects within the scope of the project are the buildings, district hot/cold water networks, local production and storage resources, electrical vehicles and public lighting.

Thermal energy transport networks

DEMIS will handle electricity as well as heat and cold distribution and district storage capabilities. A detailed model is currently being developed for the integration of all the subsystems that make up the district heating and cooling network. Subsequently, a reduced model will be created and implemented in a real time control system. Models in this domain are being developed by the partner Tekniker. The main contribution

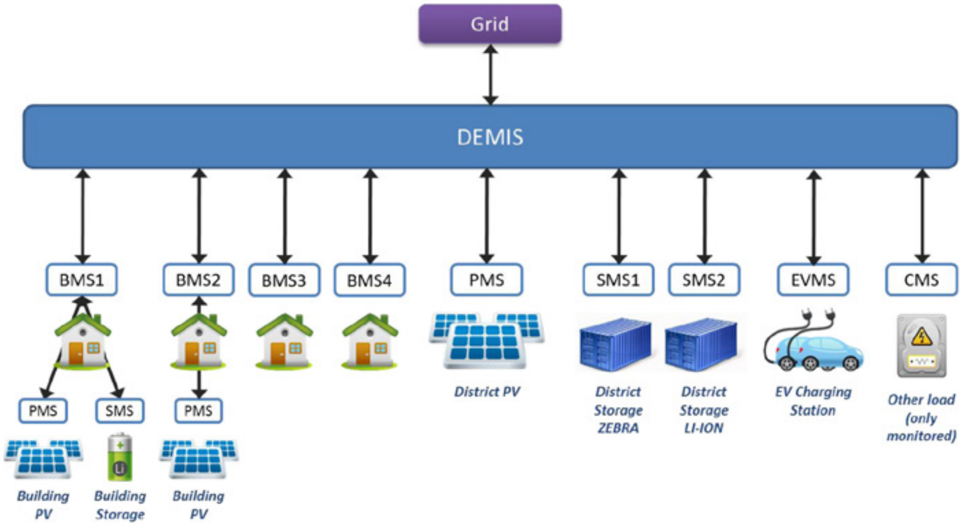

Figure 1. Simplified communication architecture for the Ambassador demonstrator at INES

from VTT in this context is validation of newly developed models with its existing sophisticated tools, e.g. APROS [1], for district heating networks. VTT also contributes to the thermal storage and solar thermal model development with other experience [2]. It is important that detailed/simplified models of AMBASSADOR handle events properly with fast dynamics like local loop control and slow dynamics such as a district heating network or energy storage.

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Multi-objective optimization for the minimization of environmental and economic impacts on buildings at district level

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Introduction

Finding optimum combinations of on-site and district levels of energy generation and storage that fit with different profiles of a building's energy demand is a very complicated task. This is due to the existence of a huge number of possible combinations of energy generation types and capacities, energy conversion and storage methods, the building's energy-efficiency measures and methods for demand-side management. This is further complicated when considering new emerging energy concepts in which an annual balance of a selected energy metric should be achieved (e.g. Net Zero Energy/Emission Building concepts), energy sharing between buildings and interactions with the energy grids, not only the electrical grid but also bi-directional heating/cooling grids. On the level of smart city/district/buildings, it is therefore necessary to find an efficient, robust

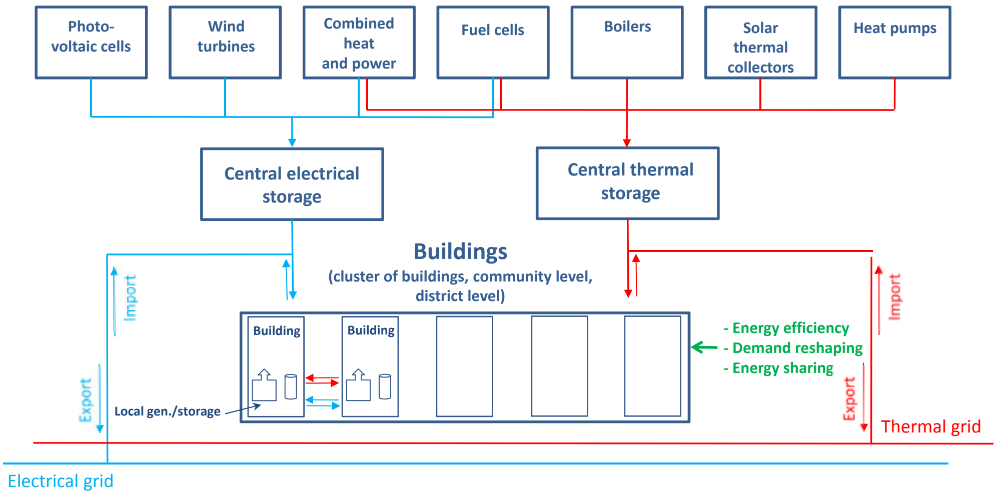

Fig. 1. Possible connections of on-site/off-site energy generation and storage, energy sharing between buildings, interaction with different grids and energy-efficiency measures.

and less time-consuming method that can find the best connections and match the different types of energy flows indicated in Fig. 1.

Multi-objective optimization

With multi-objective simulation-based building optimization, it is possible to find optimal values of decision variables that can achieve defined conflicting objectives and, at the same time, satisfy specified constrains. Various decision variables can be considered on a single building level (in the building envelope, technical systems, on-site energy generation/storage, etc.) and on a district level (centralized energy systems, energy conversion, distribution and management, etc.). Examples of the objectives are minimization of the environmental impacts (energy consumption, carbon emissions, etc.), cost (investment cost, operating cost, life cycle cost), equipment size (generation units, heating/cooling systems, etc.) and/or maximization of energy matching, financial return, indoor air quality, etc. Constraints may indicate that various criteria (e.g. total investment cost limit, primary energy consumption, thermal comfort, etc.) are satisfied. Optimization techniques can be used in the conceptual and early design phase, as well as the operational phase, of intelligent buildings.

Examples of implementation

The author has contributed effectively to the implementation of advanced multi-objective optimization methods in real-life building optimization problems including case studies on building envelope optimization, achieving low-energy buildings, nearly-zero energy buildings, maximizing indoor-air thermal comfort, the building's energy generation management and development of algorithms and software [1-6]. For the latter, our newly developed Multi-Objective Building Optimization software (MOBO) [1] http://www.ibpsa-nordic.org/tools.php is an advanced tool that can be used efficiently to find the optimum solutions to optimization problems in buildings and energy.

Acknowledgements

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Intelligent street lights adapt to conditions

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Introduction

Rising energy costs and concerns over carbon emissions are the primary driving factors for the adoption of new technology in lighting globally. Energy savings in lighting are currently reached via the switch from traditional light sources to more efficient ones such as LEDs [1, 2]. Nonetheless, smart control is required to achieve the green targets set by many countries [3]. Smart lighting can be defined as a technology developed for energy savings and user comfort with added benefits such as a long operating time and reduced maintenance costs. In addition to these much-appreciated features, there are major refurbishment needs in lighting, for legislative reasons, such as the European Union Ecodesign Directive (2005/32/EY), which is about to ban many lamp types widely used in, for example, street lighting. This will further induce the development towards LED-based intelligent systems.

Street lighting is an excellent demonstrator of the energy savings of smart control. It is estimated that the world's 220 million street lights use 159 TWh of energy annually, generating 81 megatons of CO2 emissions [4]. By employing new LED-based street lighting systems, a city of one million inhabitants, for example, could generate energy savings worth 2-3 million euros annually [5]. The environmental and economic impact is significant because street lighting is widely deployed, the power level in luminaires is high (18-400 W) and the intelligence level is traditionally low.

Traditional street lights work on full power when turned on, and the amount of light is not usually adjusted. Active control of street lighting was not previously feasible due to the difficulty

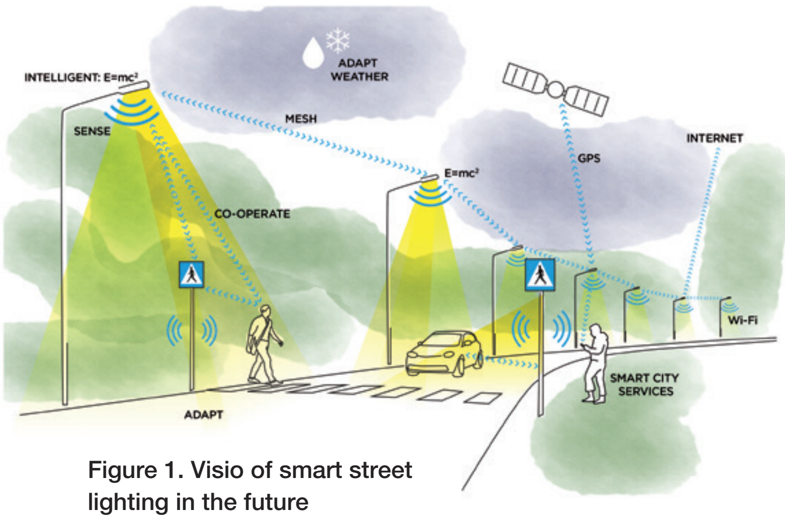

Figure 1. Visio of smart street lighting in the future

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of dimming traditional light sources. With the current LED revolution, smart features have become reality, and intelligent software-controlled street lighting systems have started to emerge on the market.

In the AthLEDics project, VTT demonstrated a street lighting system that adapts to the ambient conditions with the help of sensors and wireless communication, allowing the luminaires to be dimmed based on natural light, environmental conditions (for example, light reflected from snow) and the presence of pedestrians. In order to maintain comfort, several characteristics that are important to road users, such as the amount and colour of light and the shape of the light beam, were considered in the luminaire design. The system developed with intelligent street lights was tested along a pedestrian road in Helsinki, with commercial luminaires installed as a reference. The research aimed to demonstrate energy savings in a real use environment without sacrificing end-user comfort. To validate the results, the energy consumption was recorded with different intelligence modes. With lighting levels adjusted according to the presence of users or to natural lighting conditions, an energy-saving potential of more than 40 per cent with integrated ICT was shown. Research partner, Aalto University, carried out a survey of the experiences of the pedestrians and the developed luminaire received the best feedback in the survey. [6, 7]

Urban impacts and implementation

Lighting is needed everywhere. As part of smart cities and smart buildings, lighting is developing towards a more controllable, automated and energy-efficient part of our lives. It is easy to understand how added intelligence can bring comfort and performance to people in their everyday tasks. In addition, lighting will be developed in connection with multimedia and take advantage of social media channels to be another carrier of feelings and experiences. With the new features and applications, there is good business potential with positive economic growth expectations. Fortunately, part of this growth could be realized in Finland where new start-up businesses in this area have developed successfully. Beyond illumination, lighting will be increasingly integrated with communication, and sensor and actuator technologies in the near future.

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Citymills leading the positive change in recycling

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Introduction

Paper city mills are leading the positive change to reduce waste via increased recycling and utilization of side streams. Smart utilization of recoverable resources brings novel ecosystems into the cities alongside the people living in them. These novel ecosystems include recycling of water and paper, with improved energy efficiency and waste reduction. This is a true multiple-WIN scenario for all. These city mills truly reuse large streams from people's everyday activities (paper, board and water), providing an opportunity to use less valuable resources via recycling.

Long traditions in paper-making have changed

Traditionally main raw material has been wood and paper mills have therefore been located near forests and the energy is sourced from either wood or water streams. As raw material recovery has increased, the location of the units has been more efficient to change to be nearer the users living in the cities. This has brought new possibilities.

The raw material has changed (but is still fibre based)

The raw material recovery has increased over the last few decades from the negligible level of the 1950s to the current European recycling rate of 72% [1]. Recovered paper is collected from various sources like paper converters, printers and distributors. It also comes from used paper products from shops, consumers in private homes, offices and institutional settings. Used paper collection is a successful business venture, especially in densely populated countries with high paper consumption per capita [2]. People of the cities have made this change toward circular economy possible.

P&P industry products are used in many sectors and combined with other materials. Many of the consumption habits for the products are 'built in' at societal level. One of largest sectors is the food industry.

...needs are changing at an increasing rate

New generations consume paper differently to the generations before them, and as they age, the total demand for paper and board changes. The substitution of paper in many applications, such as advertising and communication, has changed with the Internet. For packaging applications, the need is growing. Tighter legislation, e.g. landfill taxes, will influence production costs, putting pressure on developing products that contain zero waste and higher recycling potential. Fibre scarcity in some areas is already a reality, putting pressure on developing new applications with lower fibre use.

Work has been done to prepare for this change

Three larger steps were made: In the first step at academic level, strong (raw materials, water, energy and chemicals) management expertise was built. This management expertise was needed to function in a more enclosed environment with energy and raw material stream optimization using energy- and resource-efficient production technologies. This work was funded by Tekes (Cactus and Process-Integration programmes [3, 4]). These programmes aimed to build strong raw materials, water, energy and chemical management expertise in a more enclosed environment combined with energy and raw material stream optimization. This created the necessary foundation for slow change, which is typical of large production facilities. In addition to this, the EffNet programme [5] has focused on a completely new type of energy- and resource-efficient production technology for web products and designed fibre-based production concepts and new products that help to reduce the environmental impact of the mills.

The second step was taken at the industrial level. This work used the base that was created, and production units were made that could implement the change efficiently. As an example of this new efficient way, Holmen Paper Madrid sets the standard when it comes to paper and recycling, turning old into new in just a few seconds [6]. At this unit, production is based 100 per cent on recycling of recovered paper; with the production process also using 100 per cent recovered and treated water. This work continues, e.g., in on-going projects like Reffibre [7] (funded by EU, FP7), started in November 2013, and is aimed at developing tools tested with innovative concepts, including fractionation of input materials and production of novel products from side streams.

The third step, which is now starting, is the strategic level shift, which extends beyond the individual company. This step requires strong commitment from both industry and society, with political will. The strategic level change in many value chains that arises from the generated knowledge has started, and novel value chains have begun to form, e.g. novel side stream utilization models [7] have been started to explore reducing the waste generation in urban areas. This strategic level shift extends beyond the individual company and benefits the companies in the value chains linking to it. It thus also gives benefits to the countries in which the value chains operate. This requires strong encouragement to happen, but the will is there.

Discussion

The three-step approach from management expertise via industry-level production unit change to strategic level shift combining all streams of production and use has and will make increases in resource recovery from users possible also in the future. Consumers are an important part of this chain, since they provide most of the raw material required by the production units, making the cities more self-sufficient and produce less waste. People make the city a better place to live in.

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Distributed renewable energy and energy management

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The main global drivers of the energy system are growth in energy demand, due to the increasing population and economic output, and challenges linked to energy security and the mitigation of environmental impacts, especially climate change. Globally, the annual growth in primary energy use was on average almost 3% at the beginning of the 21st century. The energy sector is presently the largest source of greenhouse gas emissions on a global scale. Revolutionary changes are needed in the energy sector to cope with future challenges.

Our city energy system is currently in transition. Optimal use of local and renewable energy sources together with others with low emissions is becoming increasingly important. Currently, the district-level heat and power demand is decreasing due to energy-efficient smart buildings and connections to vehicles. At the same city level, electricity use is increasing due to electric vehicles and the rise in devices in buildings. The use of various and a greater share of renewable energy sources can help in finding a balance and reduce emissions.

Smart energy management is the key to maintaining people's well-being under the pressure of resource efficiency. Increasing the share of wind and solar energy production will raise the importance of intelligent interoperability and control of systems as well as possibilities to use options such as energy storage or demand side management. The key priorities are advanced ICT-enabled concepts and secure solutions for Smart Grid monitoring and management, including energy-related information management, analytics and real time exploitation in new digital services for the smart energy value chain actors. At the same time, these solutions enable new energy services, for instance, zero-energy/zero-emission and integrated hybrid/multi-energy systems on a district scale, e.g. building and vehicle energy system integration.

Holistically operating energy-efficient districts have a better ability to react to changes. Holistically functioning energy-efficient cities integrate sustainable land-use planning with localized energy planning. Holistic planning enables optimized solutions for society, resulting in cost savings, increased safety and reliability through better utilization of intelligent, integrated and optimized networks.

VTT is focusing on holistically operating low carbon energy systems in its innovation programme Ingrid+ to create new innovative solutions for city energy systems.

Highlights from the Smart Grids and Energy Systems programme

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Joint national effort for future energy systems

VTT has participated in the national Smart Grids and Energy Markets (SGEM) research programme coordinated by Cluster for Energy and Environment (CLEEN). The programme started in 2010 and will run until early 2015. SGEM is funded by Tekes, and it follows the SHOK programme concept and integrates research institutes and companies for joint applied research objectives. With a partner volume of over 30 M€/a and an annual volume over 10 M€/a, SGEM is significant even at international level.

Covering the whole value chain of smart energy systems

SGEM has been planned to cover different aspects of smart energy systems efficiently. As such, the smart grid calls for the integration of traditional power system engineering, ICT and communication to enhance monitoring and control of the system and enable new business roles. Such an approach has been an integral basis of SGEM from the beginning. On the level of substance, SGEM ranges from overarching visions to specific topics such as management of active networks, microgrids, integration of renewable energy resources, demand response, ICT architectures, communication technologies, etc. The research work is completed with real-life demonstrations and laboratory test set-ups.

VTT strongly involved in specific areas

VTT's involvement has been extensive throughout the programme. It has, for instance, contributed to coordinating the research theme "Microgrids and DER". While VTT's activities have covered, for instance, load modelling, customer behaviour, wind and solar power, energy storage integration and microgrid management systems, specific attention is given here to the results on demand side management and interoperability of power and telecommunication networks.

Demand side management

Demand side management includes demand response and energy efficiency. It is increasingly important to use them from a system point of view instead of limiting them to only local optimization. Demand side management is a critical enabler of cost- and energy-efficient solutions for smart grids, energy markets, smart cities and smart communities. The approach taken includes different types of aggregation of distributed energy resources (distributed generation, storage units and controllable loads), modelling, forecasting and optimization of the responses of flexible energy resources.

Within SGEM, VTT has participated in the development of demand response in a competitive electricity market context, communication interfaces, optimization methods and field tests

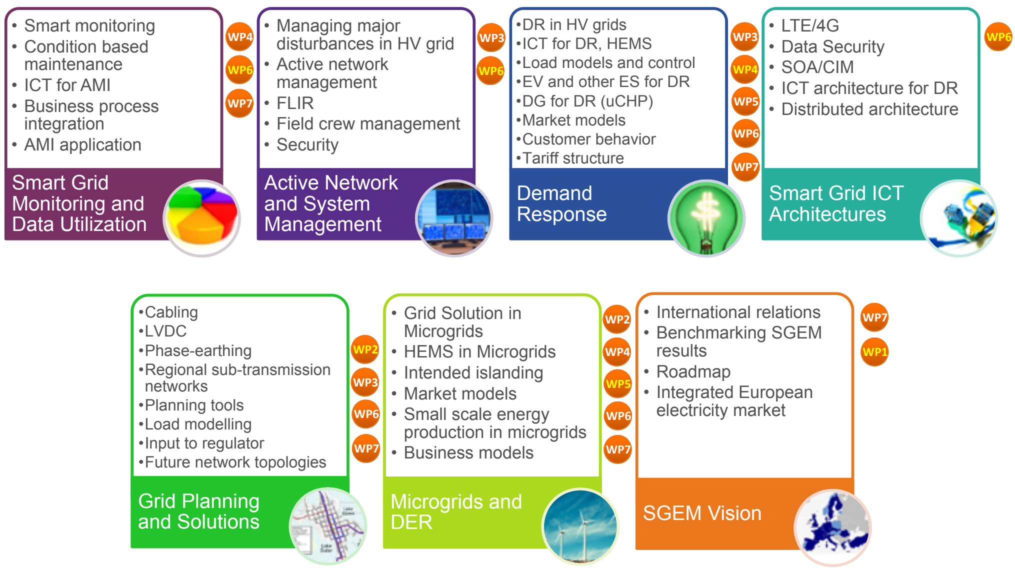

Figure 1. Overview of SGEM themes (NOTE: VTT is not involved in all the themes)

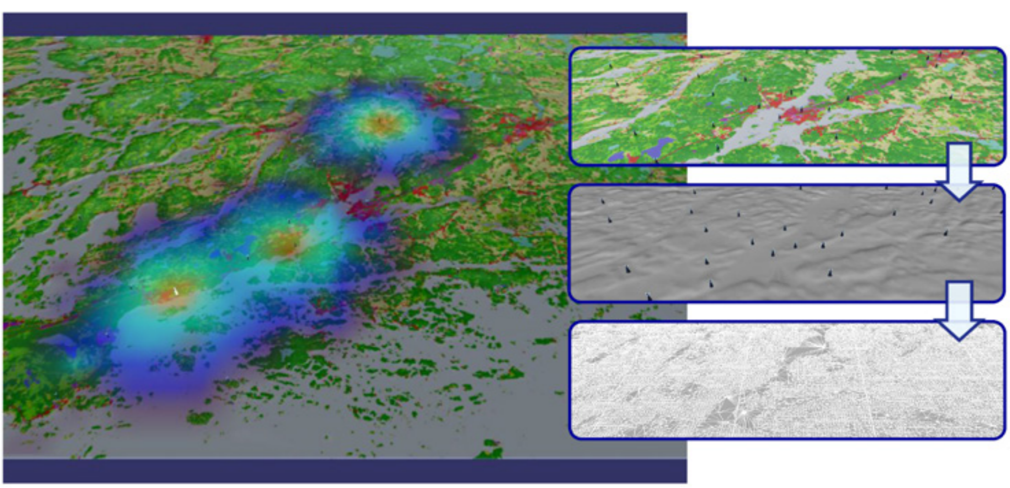

Figure 2. Example of telecommunication network redundancy during a particular event

for load control. VTT has long experience of this topic from preceding EU projects such as EU-Deep and ADDRESS.

Interoperability of power and telecommunication networks

Research work conducted by VTT addresses the increasing interdependency of electricity distribution and mobile communication networks. Such interaction is evident from the increasing use of automation and remote control in smart grids. However, these interdependencies have not been studied extensively before SGEM. The actions taken have focused on suburban and rural areas in the southern and northern parts of Finland, complemented with field tests in both areas.

The main approach is based on modelling environmental factors (for instance, terrain heights, tree stands, clutter), electricity distribution networks (for instance, substations, feeders, disconnectors) and mobile communication networks (for instance, 2G/3G coverage, base stations, terminals). New tools are developed by integrating these factors. These tools enable analysis of interdependencies between electricity distribution and mobile communication networks. They can be further used to improve the management of electricity distribution during storms and maintenance crew management and to develop precautionary actions that improve system resilience.

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Active distribution networks with full integration of demand and distributed resources

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Introduction

Smart grids enable active participation by domestic and small commercial consumers in electricity system markets and the provisions of service to different electricity system players. In the smart grids, there will be a growing need for more active participation of demand in power systems and an increasing concern by consumers about environmental and energy efficiency issues. In this context, the aim was to develop a comprehensive technical and commercial architecture to enable active demand at small commercial and domestic consumers and to exploit the benefits of active demand with supporting activities.

Architecture and main concepts

All the players in the electricity system are considered. The active demand is provided by domestic and small commercial consumers with a connection to a low voltage network with 100 kW maximum power consumption and/or generation. An energy box is used for optimization and control of appliances and distributed energy resources and the interface with the aggregator. The aggregator is the mediator between consumers and markets/active demand buyers, collects requests and signals from the markets/active demand buyers, pools flexibilities of consumers to build active demand services and makes offers to the markets. VTT was responsible for developing the aggregator toolbox. Markets and contracts are used for energy supply, relief of overload and network congestion, balancing services, ancillary services and load-shaping services. The distribution system operator (DSO) plays

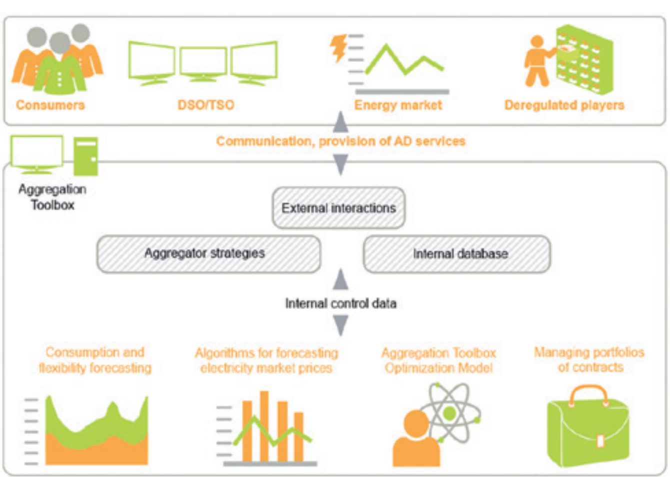

Figure 1. Conceptual architecture and aggregator toolbox

Figure 2. Field test sites

a key role since the consumers considered are directly connected to the distribution grid, and it is responsible for the secure and efficient operation of the grid, see Figure 1.

Implementation of active demand

Active demand had three test sites in three European countries with different network topologies and social and cultural backgrounds. The combination of these three test sites provided validation for the entire concept in different climate conditions. In Italy, it validated the distribution system operator algorithms and prototypes to enable and exploit active demand on real and operating medium and high voltage networks. In Spain, it validated active demand from the aggregation platforms to controllable appliances with about 300 consumers fed by a variety of medium voltage feeders and secondary substations all over a city. In France, it validated the whole chain from active demand buyers to controllable appliances but on a smaller scale with about 30 consumers and one medium voltage feeder and low voltage network and a relatively high penetration of active demand; see Figure 2.

Discussion

Once implemented, this architecture and the applications are expected to contribute to the achievement of flexible, reliable, accessible and economically efficient grids by enabling and exploiting the flexibility of consumers. Active demand-based solutions are also proposed to remove commercial and regulatory barriers to the full integration of a distributed and renewable generation, thus supporting sustainable energy consumption.

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Integration of variable power generation into urban energy systems

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Introduction

Cities require inputs from the outside world to function. With abundant fossil fuels it has been relatively easy to power cities by importing fuels and converting them into heat and power when needed. However, fossil fuels are becoming more expensive and climate change is creating another imperative to reduce their use. Consequently, it looks likely that cities will increasingly rely on imported and locally generated power from sunlight and wind. However, these energy forms are not always available when needed and sometimes there can even be a surplus. Cities can help: power can easily be converted into heat, cities use large amounts of heat and heat is relatively inexpensive to store.

Who can be a flexible energy consumer?

The potential flexibility in the everyday use of electricity is limited – using electricity for lighting, electric appliances, washing, etc. usually has a much higher value than saving electricity even when that electricity has to be supplied from more expensive sources. However, this kind of flexibility can be important during the highest peak loads to avoid investment in additional power plants and grid equipment. On the other hand, heat use can be flexible most of the time, if heat storage is available. This can be the case in detached houses heated by electricity and, more importantly, in district heating and cooling networks. Electric heaters or heat pumps with heat storage can also enable more flexible operation of combined heat and power plants. Flexibility becomes more important with the increasing share of variable generation from PV and wind power. This is an opportunity for decision-makers involved in energy planning.

Analysis of variable power generation and urban energy systems

The analysis used an energy system model that optimizes the investments and operation of power systems and district heating networks. First, the model was run without being able to invest in 'heat measures' (electric boilers, heat pumps and heat storage in district heating systems). In the next run, these were allowed. A comparison was then made between the cases. Heat measures were also compared with alternatives, e.g. flexible charging of electric vehicles, and heat measures were found to be highly competitive.

Discussion

The research so far has demonstrated the possible value of flexible use of heat in district heating networks. More research is needed to analyse household level options for storing heat in dedicated hot water boiler tanks or building structures. As the share of houses with very good insulation increases, it becomes important to understand the potential of these types of houses as well. Cooling networks can also offer similar possibilities and should be investigated. At household level, ice storage connected to an air conditioning unit could be an important source of flexibility.

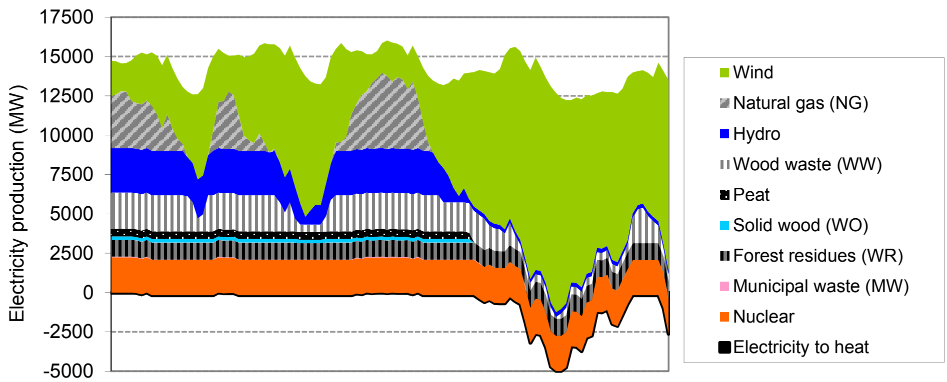

Figure 1. Four days of power generation from the analysis. Negative generation indicates the use of electric heat boilers and/or heat pumps.

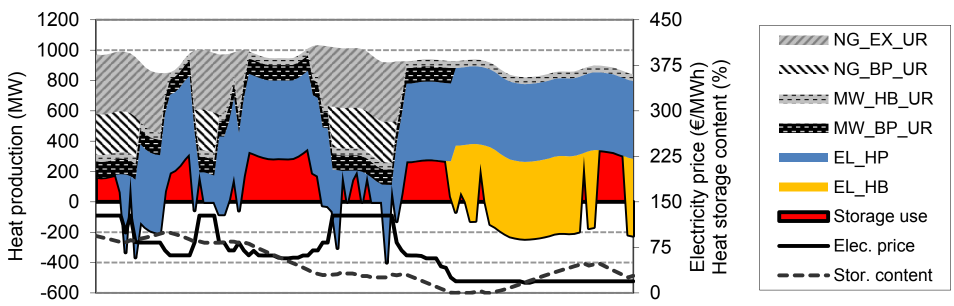

Figure 2. Four days of heat generation from the analysis. Negative generation indicates charging of heat storage.

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Future district heating solutions for residential districts

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Introduction

According to the EU's objective, all newly constructed buildings should be nearly zero-energy houses since the beginning of 2021. Accordingly, energy consumption and heat demand in district heating systems will decrease. The possible solutions for district heating to meet the challenges due to this trend are being explored. The requirements for nearly zero-energy solutions implicate an on-site renewable energy generation and storage, often including solar.

District heating in low demand areas

In the future the operational environment will become more challenging for district heating technology. Therefore, a comprehensive planning of the whole system, comprising production, distribution and consumers will be more important than ever. To satisfy this need it is relevant to simulate and predict behaviour of the systems and to build know how by developing and/or combining existing tools to be capable to carry out dynamic simulations of complex systems. Such knowledge serves not only district heating companies as service providers but also provides background for authorities in formulating national code regulations in the future.

Research method

A new model of district heating substation including solar heating panels and a storage tank was developed using IDA-ICE energy simulation software toolkits. This enabled the detailed building

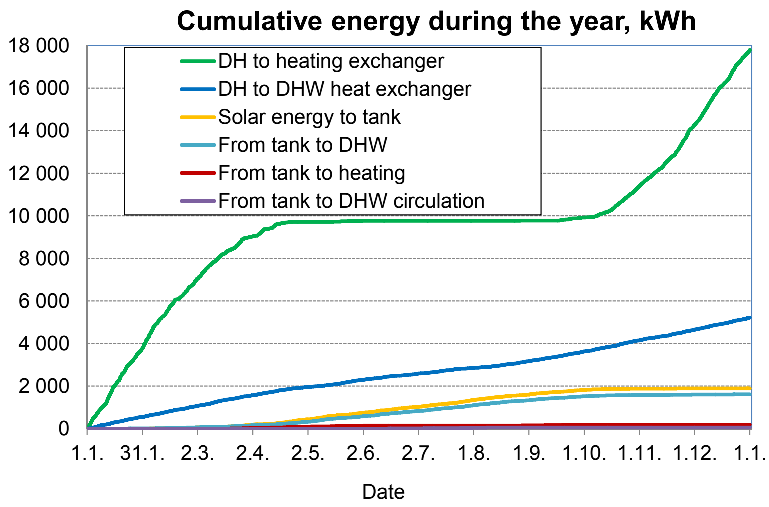

Figure 1. Cumulative energy intake from solar collectors, solar tank and district heating in a studied house.

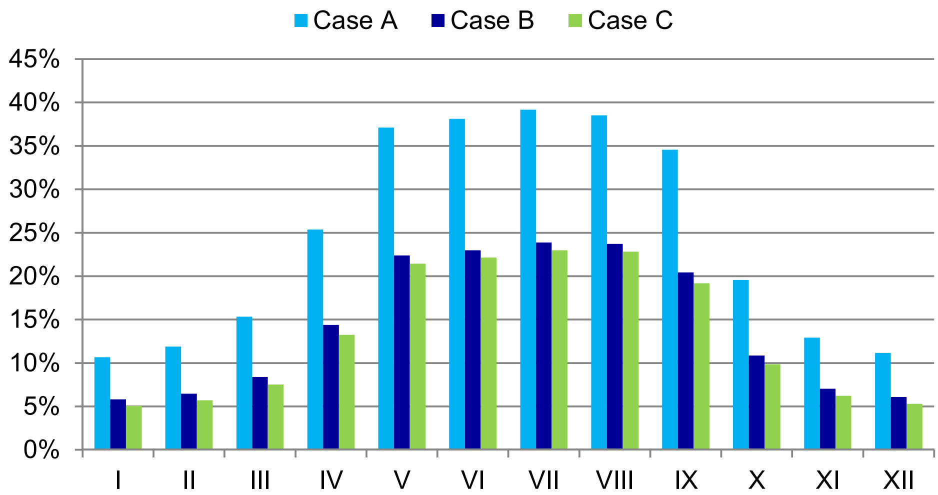

Figure 2. Monthly relative heat losses for three studied cases.

energy simulation in combination with a detailed district heating substation model, including solar heating. Such coupling made it possible for the first time to simulate the performance of the combined solar and district heating system, taking into account the heating load in each room and domestic hot water consumption at each time instant. For the network part, the district heating network model was used, developed by VTT, which performs dynamic temperature simulation. Thus, the whole energy chain was covered in the simulation.

Discussion

Simulations showed that solar collectors in district heated small houses may help to save approximately 50 % of the energy needed for heating the domestic hot water in Finnish climate, whereas the impact on the space heating energy was marginal (Figure 1). Solar thermal integration with district heating will affect the return temperature of the primary side during the summer time [1]. Simulation of a low heat demand area with three separate cases with alternative connections exposed a strong correlation between heat demand density and efficiency in terms of relative heat losses (Figure 2). Also temperature variation and drop especially outside heating season were observed [2].

Acknowledgements

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Smart metering cyber security

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Introduction

Full-scale AMM (Automatic/Advanced Meter Management, aka smart metering) roll-out was completed in Finland in 2013, based on the requirements and schedule defined by legislation. At the same time, there are no common requirements for implementing AMM cyber security. Thus, a project was carried out by VTT and the key stakeholders to clarify the cyber security position of smart metering of electricity consumption in Finland.

Cyber security challenges in smart metering

Finland is among the forerunners in the roll-out and utilization of AMM and way ahead of most other countries in the selected features. Our legislative requirements for AMM, that is smart metering of energy consumption, include: 1) consumers' settlement must be based on real, hourly interval-metered consumption; 2) the consumption data must be simultaneously available to all the authorized market actors; and 3) smart metering must enable load management operations.

The smart metering systems are connected to many other systems in order to make the roll-out profitable. Beside consumption data, smart metering can furnish other systems with voltage and disruption data, remote switching and load control operations, on-line status of meter installations and operational condition and over-the-air update of meter configurations and software. As part of this totality, the Distribution System Operator (DSO) is liable for smart metering and cyber security.

Smart metering cyber security analysis

The project was set out to study the cyber security of smart metering of electricity consumption in Finland, with goals as follows: 1) to seize the picture of cyber security – threats, vulnerabilities and risks – and to clarify it to the DSOs and service providers, 2) to propose development targets, including company-specific objectives for the stakeholders, and 3) to write a public report, a road map, for cyber security improvements.

The working method was organized expert workshops with the project parties. Each party brought its expertise and viewpoints into the discussion, as depicted in Figure 1. VTT elaborated on the results that were finally walked

How we did it: Smart metering project parties in collaboration

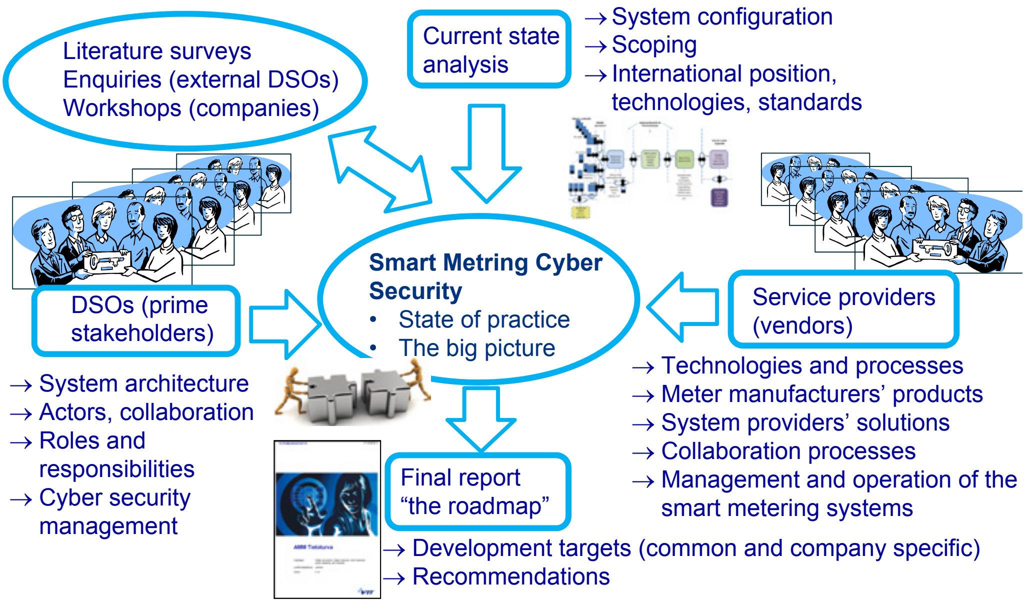

Figure 1. Joint effort for shared understanding and baseline of cyber security development

through in a joint closing workshop, where the risks were also eventually analysed. The common results are available in [1].

Bottom line

The work, including recommendations for further action for smart-metering developers and DSOs, helps the liable parties to create a firm baseline for trustworthy smart metering.

Acknowledgements

Compliments to the participating companies and the Finnish Energy Industries' research pool for the resources to commit to this work.

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ICT for neighbourhoods' energy management

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Introduction

Efficient energy management systems in urban neighbourhoods are key elements of impact resource efficiency while maintaining people's well-being and optimizing cities' expenditures. This can be realized by developing an open integrated neighbourhood energy management and decision support system that integrates the building, neighbourhood and grid levels (electricity, heating, cooling) with relevant stakeholders, affecting the energy generation, storage and consumption.

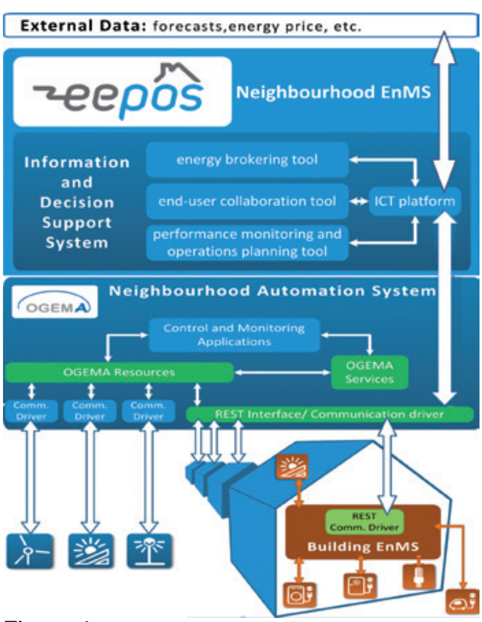

Figure 1: EEPOS system

Energy-positive neighbourhoods

In an energy-positive neighbourhood, the total average yearly energy production is bigger than the energy consumption. This can be achieved through solutions based on the integration of advanced ICT, energy and automation technologies. One of the key issues is efficient integration, management and operation of energy supply and demand. Optimal use and management of local and renewable energy sources are also important. This is the core of the EEPOS research and development project funded by the EC under the 7th Framework Programme.

The innovation of the EEPOS system is based on the integration of the following dimensions:

- New business models and services enabling a win-win situation between the stakeholders of the electricity and heat trading chains
- Neighbourhood-level energy management system with open interfaces to the grids and local prosumers
- Information and decision support system for optimizing the use of energy beyond the buildings
- Information platform with user interfaces for different stakeholders, with a key role in stimulating users to reduce energy consumption without compromising comfort
- Validation in a real environment with benefits and costs of operation

Tools and decision-support systems for neighbourhood energy management

In the EEPOS system, the ICT platform works as a mediator between the different tools, the neighbourhood energy management system (NEMS) and the external services. The ICT platform interacts with the neighbourhood automation platform (based on OGEMA), which communicates with energy consumption and production systems (Figure 1). The main applications developed are the Energy Brokering Tool (EBT), the operation planning & performance monitoring tool and the end-user collaboration tool. The EEPOS system is being validated in two extensive field tests in Finland and Germany as well as in complementary laboratory tests in Germany and a simulation-based virtual prototype study for the Municipality of Asparrena, Spain.

VTT research focuses on neighbourhood performance monitoring, the operations planning tool and the end-user collaboration interfaces. The neighbourhood performance monitoring tool is divided into three modules: performance monitoring, data analysis and visualization. The functionality will include fault detection as well as predictions about the energy consumption of the neighbourhood. The neighbourhood-level visualization module is based on the Unity 3D game engine and plugs in to VTT's building-level visualization engine based on the integration of the Building information model (BIM) with data from the Building automation and control system (BACS). This interface is design for neighbourhood service providers and users. The end-user interface will combine information and experiences from previous projects and test them in the interface made with the Unity game engine. The default browser interface (PC) can also be transformed into a Windows standalone or a mobile Apps covering iOS and Android (Figure 2).

Towards resource-efficient and carbon-neutral cities

EEPOS aims to provide solutions, with the aid of the latest ICT developments, which are easy to use and therefore have the chance of a high acceptance level and impact. New ICT-enabled business models will bring a win-win situation between stakeholders of the electricity and heat-trading chains. Information and decision platforms with user interfaces to different stakeholders will take advantage of variable tariffs and diversity of supply in order to provide profound end-user motivation ("personal drivers") and understanding of energy consumption. The development of energy-positive neighbourhoods could achieve a significant reduction in energy consumption while optimizing costs and resources.

Figure 2: Example of the data at neighbourhood level in mobile devices (Android)

Acknowledgements

These results are under development within the FP7 project EEPOS (www.eepos-project.eu/) co-financed by the European Commission and developed together with the following partners: Caverion Oy (FI) and Fatman Oy (FI), DERlab: European Distributed Energy Resources Laboratories e. V. (DE); Ennovatis GmbH (DE); AIT: Austrian Institute of Technology GmbH (AT); Solintel M&P S.L. (SP) and the town of Asparrena (SP).

Energy-Hub for residential and commercial districts and transport

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Introduction

The challenge of future energy management systems is to control low energy or even energy-neutral or positive districts and to increase the share of renewable energy. The challenge is to optimize the use of different energy sources in the best way, using smart energy management systems and energy storage. The new actors and business models may evolve into a district energy field.

Holistic approach with Energy-hub concepts

The objective of the eHub project (Energy-Hub for residential and commercial districts and transport) is to develop a district system for multi-resource input, conversion, storage and distribution of energy carriers for maximum use of the renewable energy potential harvested at district level. Energy hub systems optimize the use of renewable energy and required information exchange in a district. An Energy Hub is "a physical cross point, similar to an energy station, in which energy and information streams are coordinated, and where different forms of energy (heat, electricity, chemical, biological) are converted between each other or stored for later use" [1].

Simulation as a tool for developing new control strategies

The project developed the eHub simulation tool for overall analysis of energy concepts, including models for energy consumption and production and an energy management system (Figure 1). The smart control algorithms implemented in the simulation environment will control smart house appliances, indoor temperatures, district energy production and energy storage. The management system matches the supply and demand of heat and electricity using the multi-commodity matcher (MCM) developed during the project.

Storage technologies are needed to match supply and demand

The project has developed storage solutions to improve the matching of supply and demand in thermal energy. The thermo-active foundations, thermo-chemical materials and control strategies associated with these applications have been studied.

New business concepts for stakeholders

The questionnaire survey [2] was conducted for the main stakeholders, e.g. end-users and service providers, to find out what kind of new services are needed by the end-users now and in the future (Figure 2), what kind of services are expected from service providers, what kind of services are offered by service providers and what kind of new services they are willing to offer in the future. These results were used as a basis for the development of new business and services (see other paper in this book and [3]). Many of business concepts are based on energy consumers and producers having a certain amount of flexibility available in their energy demand and supply.

Users' involvement in the development process

The role of consumers is changing from passive users of energy to active participators in energy management. Consumers will be actively involved in energy management (regarding, e.g., load shifting and real time pricing) and will also be producers of renewable energy. Consumer

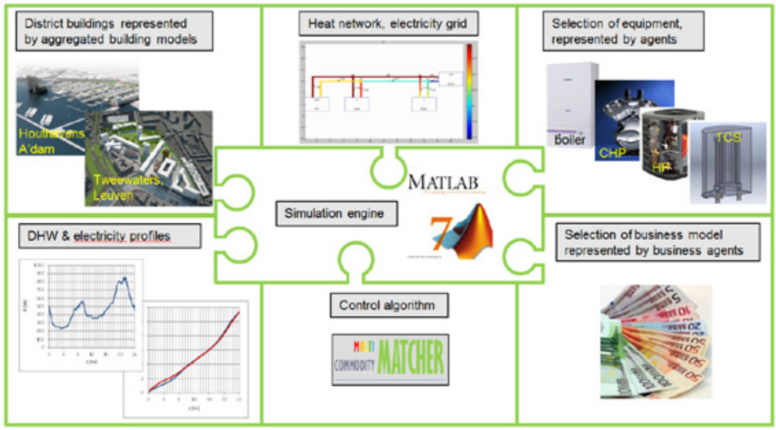

Figure 1. eHub simulation platform [1]

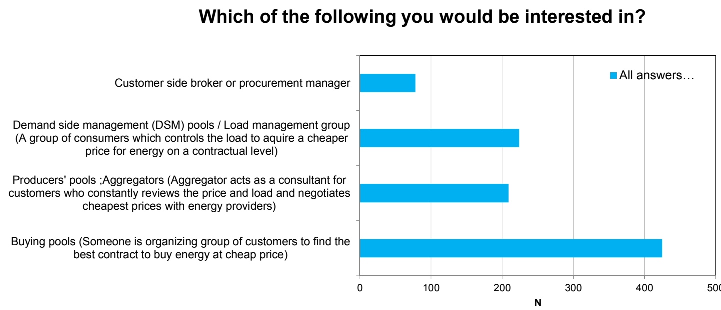

Figure 2. Interests in different service models [2]

acceptance is a key success factor of the diffusion of new energy management solutions and, for this reason, it is important that the new technological solutions are developed from the end-user perspective. The user study was performed to find out about occupant attitudes towards different levels of automation in domestic control systems [4].

Demonstration and feasibility studies are showing the benefits of energy business concepts

The performance of the proposed business models and control strategies is tested in feasibility studies. A MultiCommodity Gateway for the agent-based control system was installed in each unit of the building (106 dwellings and 9 commercial units) in a real district at Tweewaters in Belgium. Four other cases were studied by simulations: Freiburg (Germany), Bergamo (Italy), Hounthaven (the Netherlands) and Dalian (China).

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ICT-supported business in energy positive neighbourhoods

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Introduction

Energy Positive Neighbourhoods (EPNs) are those in which the annual energy demand is lower than the energy supply from local renewable energy sources [1]. The IDEAS project strives to demonstrate how EPNs can be cost-effectively and incrementally implemented by designing, testing and validating energy management and urban planning tools and related user interfaces and business models in a residential neighbourhood in Porvoo Finland and a university campus in Bordeaux, France. This paper presents preliminary results on ICT-supported business in EPNs that will be validated through real case demonstrations [2].

Methods and aims

The IDEAS project will illustrate how communities, public authorities and utility companies can be engaged in the development and operation of EPNs. The methods used in this research include interviews and workshops with representatives of all the key stakeholders involved in the demonstrations including representatives of energy companies, city authorities, facility managers and energy consumers. Business model concepts are developed to support the development of EPNs. They are demonstrated in the pilots with the key stakeholders and will be up-scaled to a wider European scale and different contexts beyond the demonstrations.

Results and discussion

Based on the identified stakeholder needs and the ability to create EPNs, a local actor – named "Energy Positive Neighbourhood Service Provider" (EPNSP) – has become a necessity (see Figure 1) [3]. It would provide several physical, centralized and distributed infrastructures to support the use of renewable energy sources and help to reduce and manage smartly the energy demand in real time through different ICT-based services and economic incentives. Such an actor does not yet exist and is being tested in the project as a combination of different organizations, i.e. in Porvoo with the local city authorities and the local energy companies that generate, distribute, sell and/or buy electricity and/or heat from renewable energy sources. Instead of only optimizing local solutions, it is key to integrate the local energy solution with the existing national energy systems and infrastructures. There are still regulatory and financial barriers that hinder the full implementation of EPNs. Once these can be overcome, the solutions should be up-scaled to city scale.

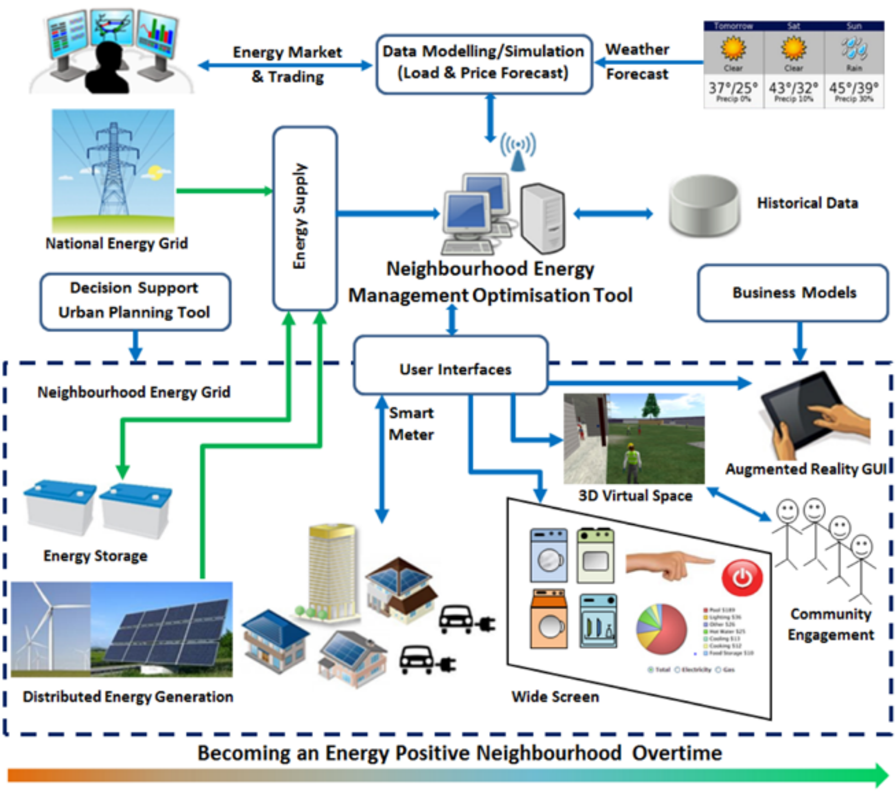

Figure 1. Elements underpinning the business concept of an Energy Positive Neighbourhood Service Provider [3]

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Renewable energy and energy efficiency in new districts – how to accelerate systemic change towards smart cities

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Introduction

Heating houses consumes about one-quarter of the total energy consumption in Finland [1]. To reduce emissions and combat climate change, it is important to increase energy efficiency, introduce renewable energy solutions and find smart ways to heat houses. However, while technical solutions are available, several pilot projects have been conducted, and EU- and national-level political targets and legislation create pressure to change, there has not been a systemic change. Why not? The research question of this research highlights what kinds of issues shape and hinder the paths to renewable and energy-efficiency solutions in new districts.

Why this research and for whom?

This research identifies critical changes that decision-makers in the government, municipalities and companies need to implement together in order to accelerate Green Growth and the path to renewable and energy-efficiency districts. An understanding of these changes including the actors, drivers and barriers shape the system, simply by changing the ways to work, e.g. public-private collaboration, or by changing the system constraints, e.g. state subsidies. The research also highlights the role of consumers as system shapers.

How was the research applied?

The starting point for this research was the multi-level perspective [2] framing society and the development of the new innovation system in it as a multi-level process focusing on micro-level actions, such as experimentation, collaboration and attitudes. The current regime was studied by expert interviews. Niche-level developments and drivers and barriers to change were identified in three case studies: Eco-Viikki in Helsinki and Vuores and Härmälänranta in Tampere, which were analysed using the innovation system functions [3]. The functions were also used in international comparisons between the Austrian, Dutch and Finnish passive house innovation systems. A consumer point of view was identified by conducting a phone survey with 1000 respondents.

Discussion

The barriers identified include a lack of knowledge and understanding of new solutions, including new ICT solutions, in houses, limited public-private collaboration, lack of service business and shared vision of the whole as well as a passive role of consumers who do not identify themselves as system shapers. To overcome these barriers, six complementary change paths were structured (Figure 1): 1)

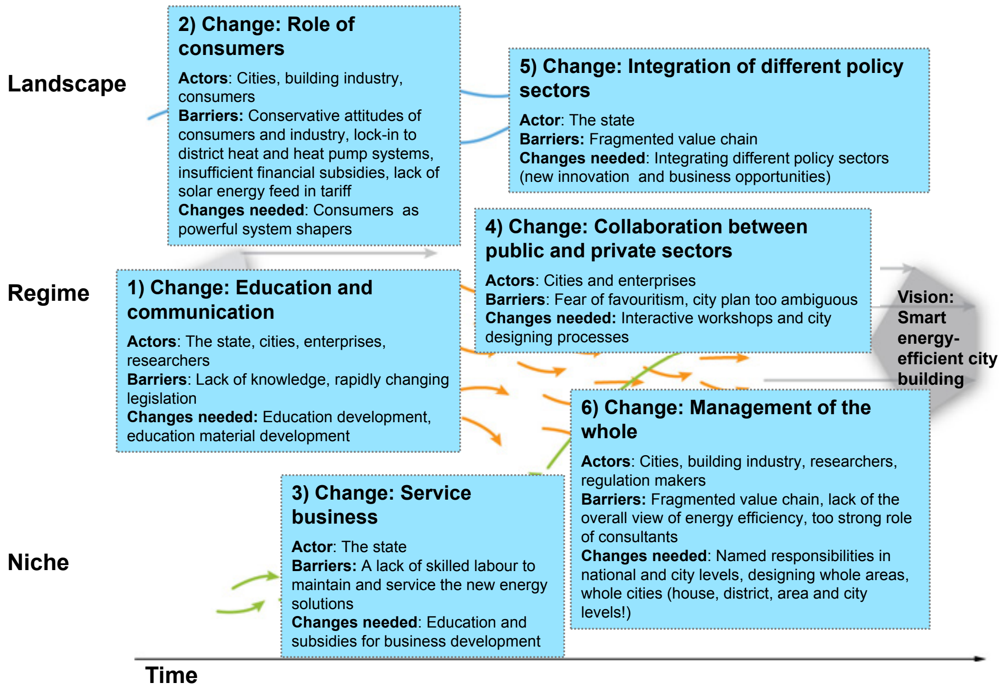

Figure 1. Change paths and barriers to applying renewable energy and energy efficiency in new districts presented in the multi-level perspective frame.

Comprehensive integration of the most recent knowledge about renewables and energy efficiency in the education and communication in the construction sector, 2) empowerment of consumers, 3) creation of service business for renewable energy and energy-efficiency solutions, 4) improved collaboration between public and private sectors, 5) integration of different policy sectors and 6) a holistic view of the planning and building of new districts.

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Acknowledgements

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Internet of Energy: Electric Mobility with Smart Grids

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Introduction

The Internet of Energy [1] refers to the challenge related to seamless, secure connectivity and interoperability when connecting the Internet with the smart energy grids. Electric mobility is one potential application area for the Internet of Energy. It includes aspects of distributed Embedded Systems, their hardware and software building blocks, wireless Internet connectivity, interoperable machine to machine (M2M) services and smart charging infrastructures. Smart charging solutions are needed for electrical vehicles (EVs) because of needs for interoperability, improving energy efficiency, lowering fuel cost per kilometre, and significant lowering the CO_2 emissions especially in densely populated urban areas.

Electric Mobility with Smart Grids

The smart electric mobility solutions needs to be able to interoperate with smart homes, building automation systems, distribution grids, distributed energy resources, energy providers, vehicles, consumers, prosumers and many other novel stakeholders, such as e.g. charging operators, in the future Internet of Things/Cyber-Physical Systems. The resulting electric mobility infrastructure with enlarging population of EVs is expected to trigger significant changes in modern urban environments, and therefore this research are seen to be essential and important.

Smart Charging of Electric Vehicles

The operational range of EVs is usually limited due to the limitations of batteries, and therefore

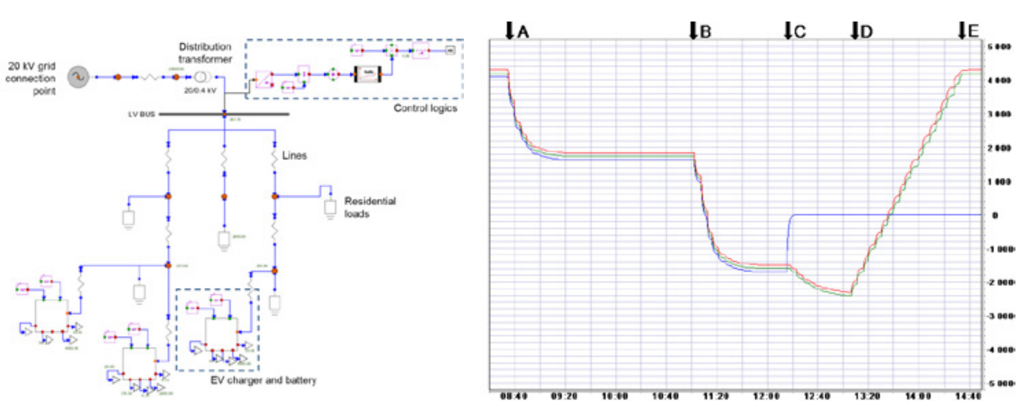

Figure 1. Simulation based study on the use of EV charging for help in balancing local distribution grid.

scheduling of charging sessions, charging point reservations and navigation are especially important for drivers on the move. From the energy distribution grid point of view, it is important to predict the load in advance or at least be able to balance the production and consumption to manage demand response situation in distribution grid.

Enabling the required smart charging system requires such steps as location of nearby charging posts, querying their reservation status, reserving charging posts and cancelling the existing reservations. These actions require smooth mobile connection between the vehicle, charging point and back-office systems related to charging point and energy system management. VTT and group of Finnish companies have developed enablers for such smart charging systems, which enable e.g. standard based charging of EVs, remote reservation of charging posts, and smart charging of electric vehicles taking into concern energy price and situation in the local distribution grid [2, 3].

When the EV is plugged into the charging point, it is connected with the local distribution grid via the Electric Vehicle Supply Equipment (EVSE) using e.g. ISO/IEC 15118 standard. Then it becames to be a part of the smart grid and charging infrastructures, where the dynamic elements in energy consumption (e.g. EVs) and production (e.g. wind mills), keeping the electric grid in balance, peak loads, lack of energy storages and increased uncertainty and cost for energy companies are essential challenges. VTT has studied the possibility for using EV batteries and charging infrastructures for help in balancing local energy grids by means of simulations [4, 5]. In the solution, the changes in the load of the simulated local distribution grid (simulation model), trigger changes in the charging powers of each specific simulated EVs.

Discussion

It has been estimated that significant lowering the pollution and the Co2 emissions is especially required in densely populated urban areas. The results of this research are estimated to significantly contribute towards that direction via smart charging solutions. Especially, the contributions related to interoperability and balancing local distribution grid indicate that enabling smartness contribute towards that direction.

Acknowledgements

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New concept of collaborative and elastic mobility

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Introduction

The ongoing (2012-2016) EU project 'Tomorrow's Elastic Adaptive Mobility' (TEAM) introduces a new concept of collaborative and elastic mobility aimed at developing systems for drivers and travellers that will help them to make better travelling choices by explicitly taking into account their needs and constraints as well as those of other participants and the network itself. Collaborative and elastic mobility should be understood as an extension of cooperative systems, moving to a concept of elastic infrastructures and collaborative behaviour of travellers and drivers, meaning that information is exchanged and also transferred into decisions and behaviour that enhance the efficient and sustainable mobility of the whole TEAM community.

Creating a collaborative transport system

Road users will benefit from the new TEAM technologies through real-time traffic recommendations balanced with global mobility and environmental aspects. In this way, TEAM turns static into elastic mobility by joining drivers, travellers and infrastructure operators into one collaborative network, in which the usage of the whole transport network is optimized. Collaboration is the key concept that extends the cooperative concept of vehicle-2-x systems to include interaction and participation by all road users. To find out how users are accepting and adopting the new collaborative transport system, TEAM is developing an evaluation framework.

TEAM approach

TEAM is built on the benefits that will accrue in making the transition from a static concept of mobility to a community-aware and adaptive concept of mobility, capturing the needs and intentions of all travellers by monitoring the interactions between all the network actors including the travellers, vehicles and infrastructure operators in real time. Community awareness refers to collaborative strategies that benefit all road users as a group. Adaptive mobility refers to the ability of the road operator to capture the needs of all road users and respond to them, and vice versa to indicate the changing needs and goals of road users, using bidirectional technologies. It also means an ability to respond to the changing needs and goals of drivers and travellers, creating a novel highly elastic road infrastructure.

A key enabler of this is the widespread use of smartphones and positioning technologies in traffic. There is growing awareness of the pressing need for municipal, regulatory and standardization bodies to address future mobility problems holistically. This makes it possible to extensively and in a fully integrated way tackle, through distributed and eco-friendly collaborative optimizations, important problems with active, real-time participation by all interested stakeholders, such as car manufacturers, suppliers, and telecommunication and road infrastructure operators that coexist and operate in parallel, and also employ available bi-directional communication technologies to interact with road users.

Assessing benefits of TEAM

To find out how users are accepting and adopting the new collaborative transport system, TEAM is developing a multidisciplinary evaluation framework. The evaluation activities will

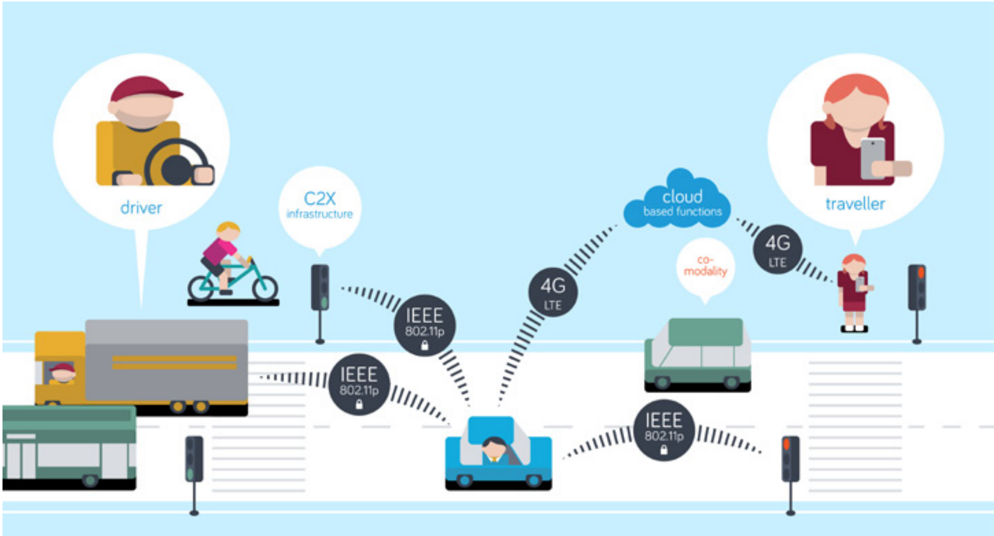

Figure 1. TEAM concept (http://www.collaborative-team.eu/)

cover all travellers on various modes of transport, including multimodality.

The technical performance of TEAM applications will be studied with respect to correctness, reliability and real-time performance. The technical performance will be tested and enhanced stepwise during the adaptation and integration procedures at the pilot sites. In the final testing, in Greece, Italy, Germany, Finland and Sweden, the technical performance of the components and applications will be compared with the technical success criteria set for TEAM applications.

User reactions and acceptance of collaborative systems will be studied as well as the users' willingness to participate in the new collaborative transport system in general, including their willingness to use the systems, pay for the systems, act as an input for the systems and follow the instructions given by the systems and hence change their travelling and driving behaviour. The results will be interpreted in terms of future potential to deploy collaborative systems. The objective of the impact evaluation is to study the impacts of TEAM applications on mobility, traffic flow, efficiency and the environment.

Discussion

The applications themselves do not yet transform the transport to make it more sustainable – travellers need to adopt the new technologies and change their behaviour accordingly.

Related publications

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User acceptance and potential of Intelligent Transport Systems (ITS)

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Introduction

The success of new services in cars depends greatly on their technical performance as well as the users' acceptance and behaviour. How well do the users adopt the new technology? Are they are willing to act as input to the systems? Are they willing to change their (travelling) behaviour according to the guidance given by the systems? Penetration rates are crucial for unlocking the true potential of the systems, and the users' rejection jeopardizes the whole deployment.

User acceptance studies

User acceptance has been studied in several European projects dealing with the introduction of new in-vehicle technology and cooperative services. The findings presented below are based on the projects INTERACTION (2008-2012) and DRIVEC2X (2011-2014). In the studies, thousands of users participated in web surveys and dozens in focus group discussions across Europe.

More comfort for users

The results of the studies show that if in-vehicle and cooperative systems are designed ergonomically and used appropriately, they have the potential to significantly enhance safety, mobility and driving comfort. The services are well received among the study participants, in particular those with an affinity towards technology and innovation. Users see the potential of these services to increase their driving comfort and enable more relaxed driving.

Design should be user centred to avoid distraction

Findings in both studies emphasize the importance of user-centred design and evaluation of the systems in real traffic, especially since users reported interacting with the systems (even while driving) on the one hand and experiencing challenges understanding how the systems work on the other. This was reported even with quite widely used systems, such as navigation. The drivers' primary task is always driving, and using the systems is considered a secondary task, which should not distract the driver and hence increase the risk of ignoring important driving-related information.

Perceived usefulness and usability are important

Results indicate that willingness to use is primarily influenced by perceived usefulness, while

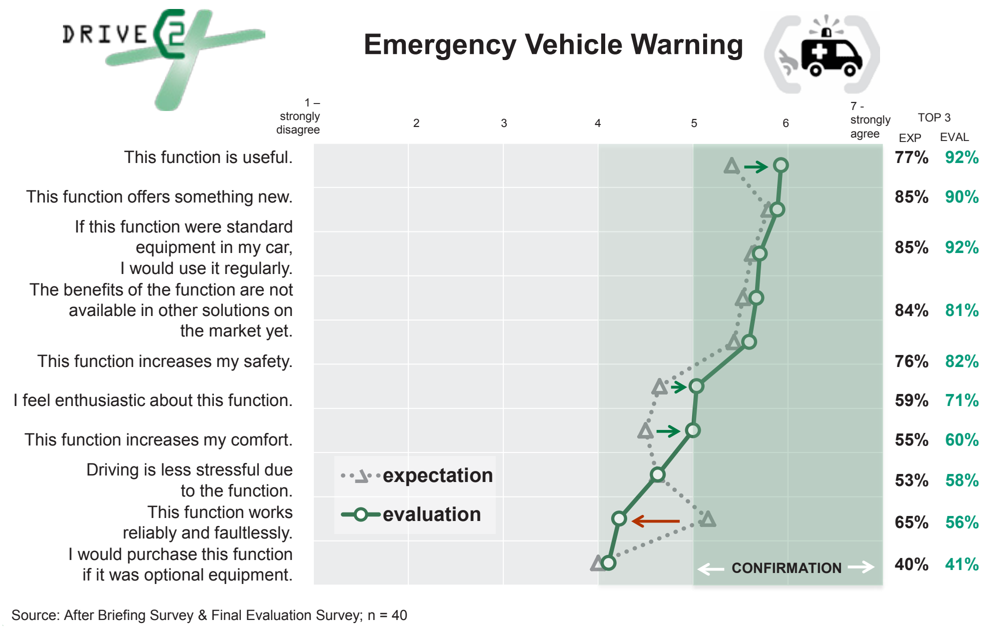

Figure: Intelligent transport systems
Figure by Joerg Rech / FACIT

willingness to purchase is more influenced by the usability of the system. According to the participating drivers, the most basic and safety-critical functions should be free of charge. However, many drivers would be willing to pay for additional, comfort-increasing systems and services.

Acknowledgements

The research leading to these results has received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 270410, DRIVE C2X.

Related publications

Aittoniemi, E., Penttinen, M., Rämä, P., Rech, J. 2014. Evaluating user acceptance of C2X systems by focus group discussions. Proceedings of 10th European Congress on Intelligent Transport Systems, Helsinki, Finland. ERTICO, Brussels (2014).

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Improving safety with cooperative systems

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Introduction

DRIVE C2X was designed to provide a comprehensive, Europe-wide assessment of cooperative systems through field operational tests. The test results were part of the preparation of the roll-out of cooperative systems in Europe. The objective of the impact assessment was to provide comprehensive knowledge of the impacts of DRIVE C2X functions on different levels, ranging from driver behaviour to the transport system and society level in Europe.

Studies in real traffic

In DRIVE C2X, more than 750 drivers tested eight safety-related cooperative functions in a real driving context. The operational tests took place at seven test sites in Finland, France, Germany, Italy, Netherlands, Spain and Sweden.

A broad set of functions was implemented in the DRIVE C2X reference system: obstacle warning/ road works warning, traffic jam ahead warning, car breakdown warning, weather warning, approaching emergency vehicle warning, in-vehicle signage, and green-light optimal speed advisory and emergency electric brake light. The Finnish test site in Tampere tested cooperative warnings on road works, broken down vehicles and speeding as well as in-vehicle signage of all kinds. In winter conditions, the Finnish test concentrated on cooperative warnings on hazardous road weather and speeding.

Cooperative functions contribute to traffic safety and comfort

The tests clearly demonstrated a positive impact of DRIVE C2X. The functions primarily concerned safety, and the impacts, when found, were mostly changes in speed and its derivatives. Never-theless, there was clear proof that drivers reacted to information and warning signals provided by the cooperative function by reducing their speed in most cases.

To provide some more specific examples of driver behaviour results, the In-Vehicle Signage (IVS) function had positive impacts on driver behaviour. In areas where special attention should be paid to vulnerable road users, drivers reduced their speed in the relevance areas of IVS for child and 'pedestrian crossing ahead'. Changes measured in driver behaviour were interpreted in terms of traffic safety. The IVS on speed limits and Weather Warnings (WW) showed most potential to decrease fatalities. Assuming a 100% penetration rate, IVS on speed limits that provides continuous information would on average reduce fatalities by 23% and injuries by 13%. WW would lead to 6% fewer fatalities and 5% fewer injuries.

Figure: Cooperative in-vehicle signage function providing information on a give way sign

From an efficiency perspective, functions such as the IVS on speed limits and Green Light Optimized Speed Advisory (GLOSA) indicated significant effects for both the environment and traffic efficiency.

User acceptance was high with 90% of the test users welcoming the cooperative systems. Users indicated that they were willing to use the function if it were available in the vehicle. The qualitative mobility assessment revealed positive impacts. Specifically, journey quality was improved in terms of decreased user uncertainty and stress, and feelings of safety and travel comfort.

Conclusions

The DRIVE C2X project succeeded in providing evidence on impacts of Day-one cooperative functions, which primarily focus on improving road safety. The analysis revealed that the safety results are promising for the DRIVE C2X functions individually. When the cooperative systems are brought to the market, they will be offered in bundles of systems on vehicles, i.e. multiple systems in a package.

Acknowledgements

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Car users' awareness and demand for green in-vehicle ITS

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Introduction

The effects of ITS on the sustainability of transport are an active research topic. Recent projects have explored the topic by developing and evaluating ITS applications for eco-driving, fleet and traffic management [1] tools for real-time measurement and control of CO2 emissions from traffic [2] and by facilitating the development of a common framework for impact assessment [3].

Objectives

The iMobility Challenge project [4] aims to demonstrate, promote and boost the deployment of ITS for energy-efficient and sustainable mobility. The project also takes safety into account in all its activities because safety is an essential element of sustainability of transport and mobility and it is also reflected in the work carried out by iMobility Forum.

One of the studies included in the iMobility Challenge project was the study of car users' awareness and demand for in-vehicle ITS applications that contribute to sustainable mobility. This information was considered essential for planning and targeting promotional activities to be carried out during and after the project. The objective of the study was to analyse European car users' demand for a few selected applications that contribute to the objectives of iMobility Challenge and iMobility Forum and are available to consumers on the market. The applications selected for analysis in the study were speed alert, emergency braking, eco-driving, start-stop assistant and real-time traffic information.

Methods used in the study

Users' awareness and demand for the systems was studied with a questionnaire that was answered by over 5000 respondents in five European countries. The responses to the questionnaire were collected by a standardized Internet survey with closed-ended response alternatives. The questionnaire was aimed at active car users.

Study results and discussion

The results on car users' awareness of the systems under analysis are illustrated in Figure 1. The results showed that there is a moderate level of user awareness of the systems, but only a minority of car users have experienced the systems by themselves.

In addition to user awareness, the study investigated car users' willingness to pay for the systems, see Figure 2.

The results indicated that a moderate level of user awareness exists for all of the studied systems. The share of users who indicated they

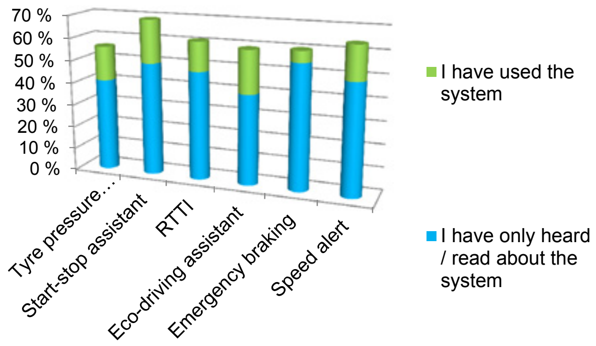

Figure 1. Car users' awareness of five iMobility systems

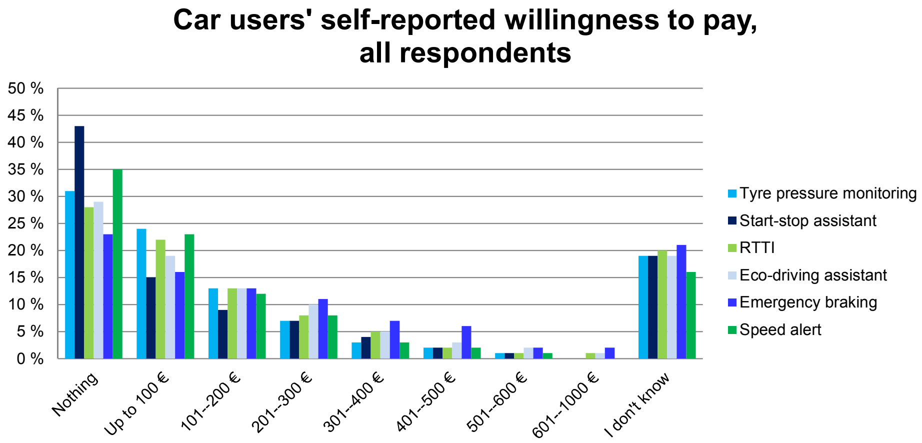

Figure 2. Car users' willingness to pay for the systems, all respondents.

would be willing to pay for the system ranged from 38% in the case of the start-stop assistant to 56% for emergency braking. In conclusion, this suggests that a moderate share of users is willing to pay for the systems analysed in the study. The results of the study also suggest that most users are willing to pay an additional cost of €200 at most for the systems included in the study.

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Acknowledgements

The study was done as part of the European iMobility Challenge project. The work carried out by VTT was funded by the Seventh Framework Programme of the European Union, VTT, Ministry of Transport and Communications, Finland, and the Finnish Transport Safety AgencyTrafi. I wish to express my thanks to the stakeholders that have made the project possible.

From field operational tests to better services – methods and tools

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Introduction

In Field Operational Tests (FOT), users have the opportunity to use systems in a real use context. User acceptance will be studied in FOTs but, even more importantly, evidence will be gained on the impacts on user behaviour aimed at finding the most cost-effective solutions and promoting deployment. Research activities, such as impact assessment, take place in the middle of the development and deployment process, and typically with time pressure. Therefore, FOTs call for effective tools to handle the many parallel activities.

Tool to define research hypotheses and indicators

The tool focuses on the starting phase of a FOT. Research questions (RQ) and hypotheses will be formulated for driver behaviour – the primary interest in a FOT – and then just copied and liked to the other target areas (safety, efficiency, environment, mobility). This is important because all other impacts are implications of changes in driver behaviour, and hypotheses need to be consistent for different target areas [1]. The theoretical structures in each target area support analyses and cover all possible impacts system-

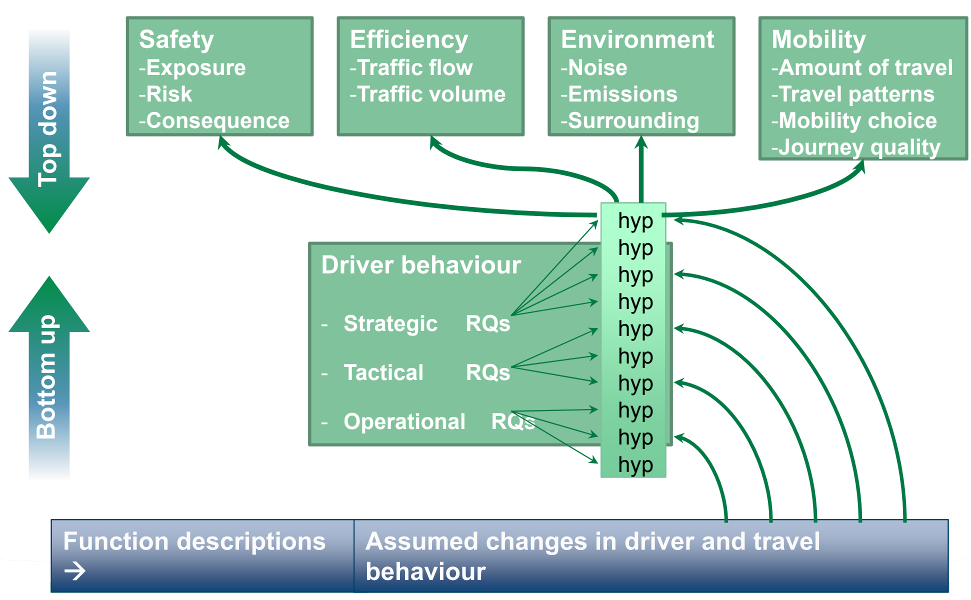

Figure 1. Schematic figure on the creation of research questions and hypotheses

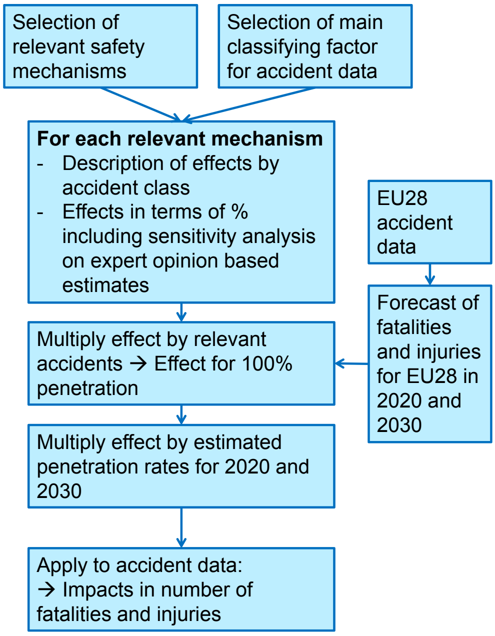

Figure 2. An overall schematic picture of the safety impact assessment tool ERiC

atically. Furthermore, each hypothesis is linked with an indicator and measure for designing driver behaviour logging.

All this information can be collected in a big spreadsheet for prioritization for the final analyses. Linking hypotheses with situational variables enables more detailed analyses.

European risk calculation tool (ERiC)

The tool supports safety analyses close to the final steps in a FOT and scaling up of safety estimates at European level. Based on system descriptions, expected and measured impacts on driver behaviour and literature, the first estimates on the effectiveness of safety functions have been provided. In all, nine safety mechanisms [2] are analysed starting with so-called direct effects, long-term effects, effects on non-users, exposure and consequences. All estimates need to be applied to the targeted accidents and situations.

The tool includes all the (EU28) accident data by several classifying factors. It provides the scaled-up results at EU28 level, taking into consideration how frequently the systems are in a traffic flow.

Conclusions

The approaches and tools presented here are based on long experience in expert assessment and filed tests. They have been powerful in supporting research activities in development projects in which time for critical work phases is typically limited. They also support consistent and theoretically sound approaches, taking into consideration all impacts – positive and negative, intended and unintended. Moreover, the use of tools supports reporting of the results.

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Acknowledgements

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Assessing impacts of a real-time warning service

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Introduction

Automatic warning about people in the vicinity might be one way of improving traffic safety in the future cities. The research on reindeer warning presented here is not directly aiming at this goal, but is anyway a step towards the required technology. The number of reindeer accidents in Finland has remained high in recent years. About 4000 reindeer die yearly in traffic accidents causing costs in vehicle repairs and reindeer recompenses. As a new way to cope with this issue, an in-vehicle information service providing real-time warnings of reindeer sightings has been developed, and it is being tested and evaluated in this project. The aim of the study is to help drivers foresee conflicts and to reduce the number of incidents.

Real-time reindeer warnings

This study investigates how professional heavy goods vehicle drivers accept the real-time reindeer warning system. About 25 drivers participating in the field test receive real-time warnings based on sightings of reindeer on or near the road on a smartphone installed in the vehicle. The information is provided by the same selected group of professional drivers as well as a group of reindeer herders. The real-time warnings as well as information on areas that are especially prone to accidents can be observed on a website. The service is currently being tested on two test roads in Northern Finland. Results are expected in the beginning of 2015.

Expected benefits

The project allows for a new driver information system to be tested and evaluated in real traffic. New ways of warning drivers, activating them and raising their awareness of the road environment are promoted. Co-operation between different parties, such as freight companies and reindeer herders, is improved. The potential impacts of the warning system on driver behaviour, foresight and traffic safety will be assessed.

Related publications

Aittoniemi, E., Rämä, P., Penttinen, M., Lahtela, A. 2014. Assessing the impacts of a reindeer warning service. Proceedings of 10th European Congress on Intelligent Transport Systems, Helsinki, Finland. ERTICO, Brussels (2014).

Figure 1. Real time warning service

Acknowledgements

Paikkatieto Online Oy has developed and maintains the reindeer warning service. Acknowledgements are also extended to the Finnish Transport Safety Agency, the Finnish Transport Agency, the Centres for Economic Development, Transport and the Environment of North Ostrobothnia and Lapland and the Reindeer Herders' Association for their support of the study.

Impacts of nomadic device-based services on safety and mobility

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Introduction

Road transport carbon dioxide (CO2) emissions form an important part of the greenhouse gas generated in most of the developed countries. Among the policy options to reduce these emissions is green driving or eco-driving. Reducing fuel consumption significantly by teaching drivers to change their driving behaviour is potentially a cost-efficient way to cut energy use and emissions [1]. The fuel consumption and mileage of a bus are typically higher than for a passenger car. Consequently, the potential of green driving or eco-driving applications on buses is of interest. The purpose of this study was to assess the impacts of a real-time green driving application in city buses on fuel consumption, speeding and passenger comfort.

Method

The equipment chosen for the field operational test was an active real-time operating green driving application, RASTU, developed at VTT Technical Research Centre of Finland starting in 2004. Specifically, it provides recommendations on the intensity of acceleration and feedback on the current speed and its relation to the target speed. The test subjects of the study were professional city bus drivers working for the Nobina transport operator on a frequently operated bus line (550) in the Helsinki metropolitan area. A total of 143 drivers contributed to the data, including long-term users of the system, novel users and non-users used as reference. The subjects engaged in naturalistic bus driving as part of their daily work.

Results

The main results showed that the use of a green driving application reduces fuel consumption and speeding and increases passenger comfort. Specifically, novel users of the application drove more fuel efficiently in 30-50 km/h speed limit areas with up to 30.0% less fuel. For higher speed limits, the result varied depending on a combination of traffic conditions and speed limits. The average impact over all traffic conditions and speed limits was an 8.9% reduction in fuel consumption due to the green driving application in use for novel users.

For long-term users, there was also a decrease in fuel consumption for almost all traffic conditions and speed limits in summertime. Specifically, the impact was found to occur at night in higher speed limit areas, but at peak times in lower speed limit areas. In daytime traffic, the impact was observed in all speed limit areas except at 60 km/h. However, the reduction in fuel consumption was smaller than that of novel users (3.8% in summertime). It seems that novel users followed the guidance given by the device better than long-term users (typical novelty effect). The motivation for better compliance with the guidance may be more recent training, which in itself may also have improved over time. It may also be that long-term users trust their own skills in this respect and feel that they do not need the guidance in all situations. This was supported in discussions with long-term users.

In wintertime, the impact on fuel consumption for long-term drivers was also mostly

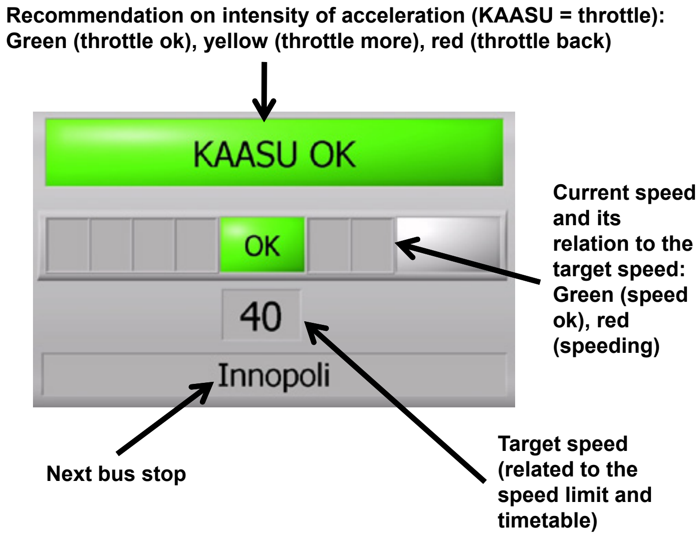

Figure 1: User interface of the green driving application

positive but smaller than in summertime. The strongest impacts on fuel consumption were found in areas with lower speed limits (30-40 km/h) during the daytime and in peak traffic in winter. Slippery and snowy winter conditions such as those in Finland affect both the driving dynamics of a single vehicle and the dynamics of the whole traffic flow. A smoother driving style needs to be adopted naturally in order to be able to control the vehicle and drive safely. In addition, driving in slippery conditions requires more attention than driving in non-slippery conditions, leaving less opportunity to follow the in-vehicle device.

Conclusions

In conclusion, the use of a green driving support system is beneficial for safety, cost-effectiveness and passenger comfort even after years of use. Novel users reap greater benefits from using the system than long-term users do. Thus, there is a novelty effect that decreases with time. However, long-term users show a transfer effect when not using the system. Novel users do not show this trend, thus the transfer effect (though smaller than that from actual use of the system) takes more time to develop than the four-month treatment period included in this data set. Continuous encouragement to use the system is therefore recommended, in addition to green driving being included in driver training. Finally, we conclude that it would be beneficial to install a green driving application in the whole bus fleet and to instruct all drivers to follow the recommendations given by the system, which would help maximize its benefits.

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Acknowledgements

The authors would like to thank the TeleFOT project for funding the impact assessment and the HDENIQ project for allowing them to use the green driving application. We would also like to thank Nobina Finland Ltd. for its support and cooperation during the study.

Electric urban bus systems

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Introduction

Mobility and transport are undergoing a transformation. Some of the key challenges faced by the urban transport system are the carbon footprint of the fleets, local emissions, noise and congestion. Traffic systems are not only experiencing technological change in terms of new vehicle technologies (e.g. electric vehicles, automated driving and increasing connectivity) but also in societal terms. These include sustainable mobility with increasing numbers of clean vehicles, multimodality, shared use and ICT services. Electric bus systems can facilitate the change when the focus on passenger and resident comfort increases and transport becomes a service.

Why electric buses?

In the smart city context, personal mobility must be based on public transport, cycling and walking. Most public transport systems are based on electrified rails (trains, trams, metro) and buses. We are now seeing the beginning of the electrification of the bus system. Electric bus systems allow several of the issues mentioned above to be addressed. Even more important, it appears that optimally, this can be achieved without compromising productivity and economy in the transport system. Bus operators can potentially reduce the total cost of ownership in their bus fleet provided that electric buses, operation concepts and recharging infrastructure are properly designed and optimised. Cities and traffic authorities can offer sustainable traffic chains with higher passenger comfort. In societal terms, the carbon footprint and emissions can be reduced and quality of life improved.

Electric bus demonstration environment

Addressing e-mobility transformation requires a comprehensive system-level approach encompassing different value chain steps. VTT, together with partners, has created a multi-dimensional demonstration environment for electric buses, systems and their supporting infrastructure. It covers laboratory-scale measurements and simulations from single components to complete heavy duty electric vehicles on chassis dynamometers, a fully functional electric bus prototype as a development platform, and real-life testing and analysis of fleets in commercial operation. In order to speed up development, Helsinki Region Transport (HRT) decided to create a pre-commercial electric bus pilot by procuring a fleet of 12 battery electric buses. This fleet will provide a step between research and large scale implementation of electric buses. The test fleet will also provide a living lab environment for developing new passenger services and innovative technologies.

Future value proposition

New value creation and businesses arise from both the electrification of the vehicles and the digitalisation of many components and subsys-

Figure 1. Commercial electric buses and VTT's prototype eBus in commercial line operation by Veolia Transport Finland in the city of Espoo

tems. For example, a large amount of data are processed within the vehicle control system and they could be utilized in proactive maintenance and intelligent control. The same applies to system-level aspects relating to fleet management. The supply chain of electric energy to the bus fleet has to be properly managed in order to claim the commercial potential in terms of the reduced total cost of ownership combined with environmental impacts. To achieve all this, careful techno-economic systems engineering is required.

Related publications

M. Pihlatie, S. Kukkonen, T. Halmeaho, V. Karvonen, N.-O. Nylund. Fully Electric City Buses – The Viable Option, IEEE Transactions from IEVC 2014 conference (DOI not yet available).

Acknowledgements

The research and development described here is carried out in the large networked project entity ECV (Electric Commercial Vehicles) and projects eBus and eBusSystem within that consortium. The projects are supported financially by the EVE programme of Tekes – the Finnish Funding Agency for Innovation. Key partners in the electric bus projects are Veolia Transport Finland, Helsinki Region Transport (HRT), city of Espoo, Fortum, as well as Finnish universities and industries involved in the ECV network.

Foresight to smarten up urban transport systems

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Introduction

Finding the synergetic balance between societal, economic and environmental aspects of sustainability is vital when addressing the mobility of people and goods in cities where ICTs and smart mobile applications currently form the core of many development projects. Furthermore, a broad time horizon is required to ensure alignment between actions in the near term and profound long-term interventions in the transport system. Foresight can facilitate such strategy work where the fundamental need for mobility, and how it may change over time in urban, suburban and interurban contexts, is at the centre. This knowledge is combined with research technologies, innovations and user preferences and further applied to serve product and service development or decision-making and policy planning. In short, the goal is to smarten up transport vehicles, powertrains, infrastructure, user contexts and governance systems in liaison with domains beyond mobility.

Foresight as an approach

Foresight provides a range of methodologies and tools to address future-oriented challenges of urban transport, such as climate change, air pollution, safety and congestion. The aim is to understand what political and behavioural changes are required and which enabling technology solutions could best suit the case. Foresight can be applied to facilitate innovation processes, assess new emerging business ecosystems and value chains, support public authorities to outline and prioritize action points, etc. The participatory aspects of foresight are essential in identifying and involving citizen views, ensuring user acceptance, creating mutual agreement among stakeholder networks and motivating involved parties in joint efforts even in complex transition processes requiring long-term future orientation. Consequently, foresight provides a platform for various urban actors to build the future together.

Urban mobility solutions of the future

The research portfolio for applying foresight to promote smart sustainable mobility includes various projects to envision, structure and pave the way for future transport and logistics systems. For example, the study on safe and secure transport until 2100 [1, 2] presented a method for long-term visioning and, as a result, a view of intelligent automated transport as a solution to several societal challenges. Potential drawbacks related to robot cars, privacy, social inclusion, etc. were also identified and evaluated. Concerns over the currently fossil-fuelled transport on the other hand have been a driver for a project studying electromobility, biofuels and innovative public transport as a combined effort to reduce greenhouse gas emissions in urban transport [3].

National research is strongly complemented by European collaboration, and an example of successful Nordic networking is the project in which prospective value chains for renewable road transport energy sources in the 2050 were identified to give advice to policymakers [4]. Foresight has also supported priority-setting and networking within an on-going research programme [5]. In addition, methodological development to aid foresight-driven decision-making and policy planning has been fruitful (see the example of a visualization tool in Figure 1), and multi-discipline approaches to serve public and private organizations struggling with issues

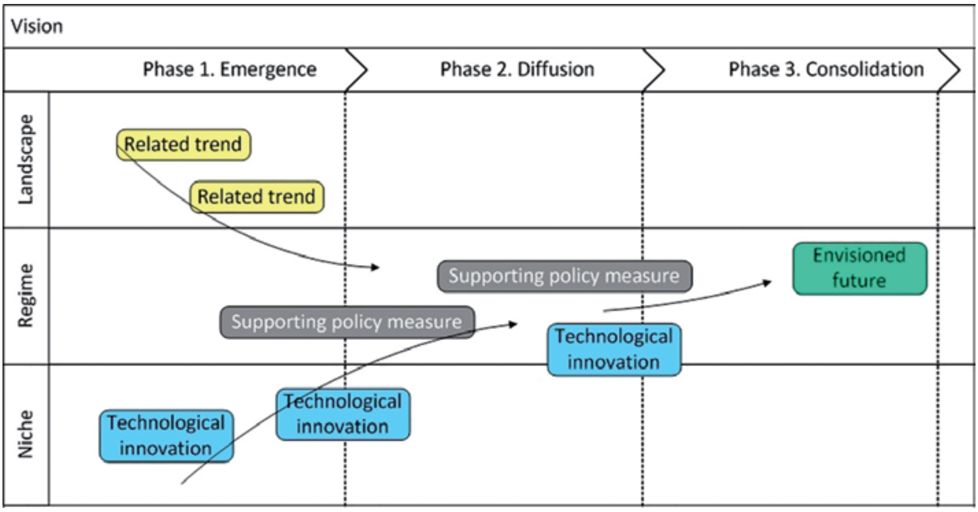

Figure 1. An example of a foresight visualization tool: system transition roadmap (a template). Drivers and changes are structured on three levels and along three temporal phases: trends contribute to a favourable environment for change, technological innovations evolve and policy measures support a desired development path towards the envisioned future. [3]

related to urban transport in transition have been further elaborated into a customisable toolbox for different stakeholders.

Acknowledgements

Examples of recent research presented under this topic cover several projects, in which researchers from different disciplines have given their contributions. In addition, experts and authorities from private and public organizations have been involved through interviews and workshops. Research funding has been obtained from several sources, and a special acknowledgment is given to the support from the Traffic Safety 2025 research programme (http://www.vtt.fi/proj/tl2025/index.jsp), the TransSmart research programme (http://www.transsmart.fi/) and Nordic Energy Research (http://www.nordicenergy.org/).

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Monitoring and controlling facilities in a smart city

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Introduction

Buildings play a key role in the fight against climate change, using 40% of the energy consumed in cities. The improvements in energy efficiency of retrofitting, control, operation and maintenance, and influencing occupant behaviour are crucial. In addition to the traditional passive solutions, such as additional insulation, low-cost active technologies must be applied. They rely heavily on ICT to optimize energy consumption without compromising indoor environment quality.

Obtaining real information from mass data is a great challenge

A huge amount of data are collected from buildings and building systems. On a large scale, the problem is one of creating relevant information for various stakeholders and their needs from the big data mass. The owner's project requirements (OPR) and key performance indicators (KPI) are the starting point for processing them. At the building level, the problem is the data hidden in systems that do not forward them. VTT and

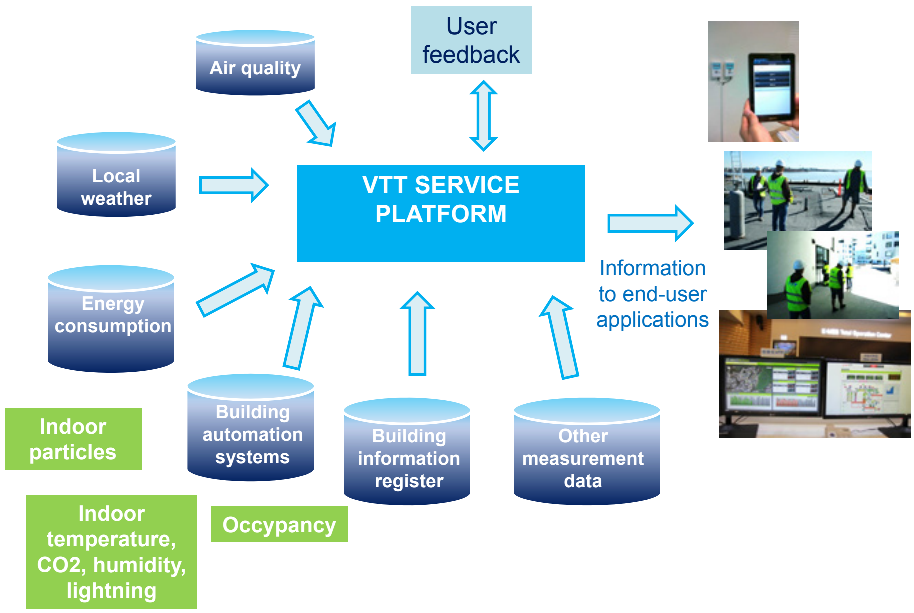

Figure 1. Leading with data: from data to end-user applications

Figure 2. Otaniemi GreenCampus, services for users

several companies are working together to find ways to obtain and process the information into a usable format.

Real life testing in the Helsinki and Otaniemi regions

Data from the energy companies' smart meter system are collected, additional energy meters with appliance recognition features have been installed, thousands of indoor environment sensors have been deployed, public databases have been utilized… The data sources we use provide a basis for data analysis and the development of a platform for new services. The results are collected on, e.g., an energy monitoring platform for city personnel in Helsinki and a public platform to visualize Otaniemi campus' journey towards a zero energy campus.

New business from open data

Controlling and monitoring business in buildings is dominated by large multinational companies, and their solutions are often difficult to connect to other systems. For local property owners such as municipalities it would be more beneficial to use open communication, which also allows small and medium-sized local players to offer novel services and create new local business. VTT has started wide-scale operation in the Asian region, especially the Chinese market, to find new business cases for Finnish SME companies and VTT products.

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Public view to Global Energy Operating Center in a K-MEG project www.kmegfinland.com/eoc

Acknowledgements

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Smart alarms and simulation for urban flooding

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Introduction

Urban stormwater is one of the biggest problems facing our waterways today. Urban cloudbursts and the resulting rapid stormwater that overflows along surfaces and in networks are more and more common in cities due to increasing impervious surface areas, climate change, aging infra-structure and often undersized, centralized stormwater networks. Contaminants such as metals, pathogens and pesticides are common in runoff. VTT has developed the first concept and related research prototype of a local early warning and simulation system for urban floods caused by heavy rains in order to better manage stormwater problems.

Who needs better tools to manage urban stormwater and alerts for cloudbursts?

Cities, the property sector, rescue authorities, service providers, the security sector and governmental authorities need heavy rain and flood predictions in order to minimize the damage to property and business and inform the relevant actors and authorities. Local early predictability of flooding gives time to react. Urban planners can apply detailed surface and underground 3D flow simulations with different cloudburst or climate change scenarios when designing effective solutions to manage stormwater quantities and qualities.

Development of smart alarms for urban flooding

A unique 3D flood forecast simulator has been developed that can link and be continuously calibrated by live data sources (from short-term weather predictions into wireless sensor networks) with a wide range of dynamically integrated models (surface, stormwater and sewer network, water quality, underground and building space models) to provide detailed, accurate forecasts of water levels, flood depths, flows, velocities and water quality parameters also in real time. Other integrated methods include LIDAR scanning (accurate street-level 3D models of urban areas), measurements (weather radar, rain gauge sensors, water levels, network flows, surveillance cameras, etc.) and modern ICT technologies, such as web services and other IP-based data communication, GPS, Google Maps, and IOS-based tablet and smartphone technologies. The test site for the system was the centre of Helsinki, the capital of Finland, with many flood-prone properties both above and below ground. The risks are evaluated from the property owners' point of view and each critical threshold is evaluated individually. The prototype raises alerts by reporting targeted information on flood events to key building security personnel, rescue services, local control room operators, etc. The system reports exact locations in the target area that are, or will be, in a critical situation now or in the coming minutes or hours (10 min, 30 min, 1 hour, 2 hours, etc.). The system also gives other flood-related information, such as emergency procedure recommendations.

New business opportunities also from the insurance sector

More than 3 billion people have been affected, with major flood events causing the death of almost 7 million people and causing damage of about 441 billion USD over the last century. This has meant huge insurance compensation. The insurance

Figure 1. Examples of recent urban cloudbursts

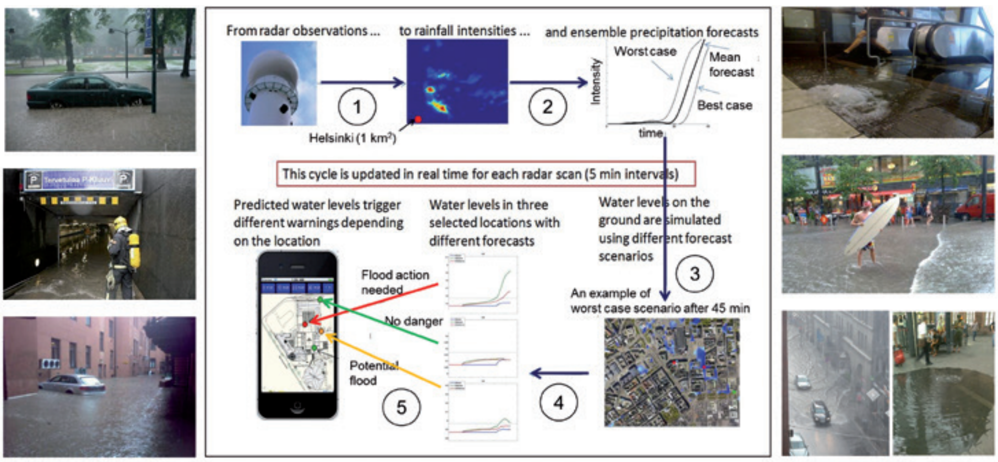

Figure 2. Concept of the local early warning system for urban flooding from heavy rains

industry is currently developing flood protection policies and insurance products, but there are no tools to evaluate the building level flood risks, which is a very data-intensive and challenging task. Thus, it is difficult to establish accurate prices for property insurance. Large companies in the property sector are also interested in flood risks relating to their buildings.

Acknowledgements

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Climate-adaptive surfaces: control of urban flooding

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Introduction

Urban environments are becoming densified, with a high amount of horizontal surfacing covered by structures and pavements. Climate change expectations are for greater rainfall intensities, while governmental directives require municipalities to implement new methods for handling stormwater. Research has been done to develop new materials and subbase structures for pervious pavements, while verifying their performance for Nordic winter conditions. The pavements allow for direct filtration to the ground, thus reducing flooding and ice accumulation, enhancing societal well-being and promoting green urban areas.

Who will use pervious pavements?

Cities, owners, stormwater management companies and urban planners will have greater confidence specifying, designing, constructing and maintaining urban areas with pervious pavement surfacing. There is an understanding of the lifetime performance of materials and their interaction with the environment, which is ensured by monitoring the infrastructure's filtration and durability behaviour. A new product market has been created with the focus on environmental and water quality technologies, which can also be promoted internationally.

Pervious pavement development

The project has looked at cities' needs for stormwater management and new materials, prior to implementation in new urban constructions. Material studies have been conducted in cooperation with industrial partners to develop pervious concrete, asphalt and natural stone paver systems. The geotechnical structural

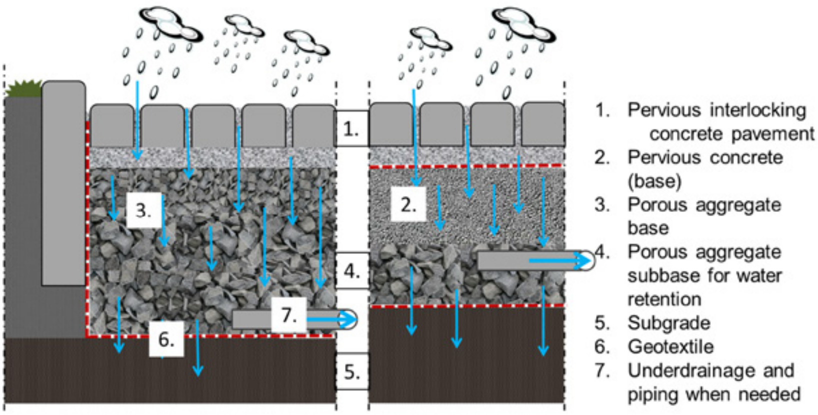

Figure 1. Examples on climate-adaptive surfaces, i.e. pervious pavements. Surface layer is designed to have high water permeability, and base and subbase structures are with high porosity and permeability, and are designed for water detention.

designs have been modified based on international experience but adapted to Finnish demands. This has also included information on how the pervious pavements are linked to other material parameters, such as drainage layers, geotextiles and stormwater collection systems. Stormwater modelling tools have been developed to incorporate the new materials and their respective designs and functionality. Climate change forecasts have been taken into account when evaluating filtration potential and stormwater model case studies with the new pervious pavements. Parallel work has been done in Sweden on the benefits of pervious pavements to water quality and urban horticulture for green environments. With all of these aspects, it has been important to plan the future demonstration and implementation work, including how the performance will be monitored through the use of ICT to ensure filtration functionality, water quality and winter durability.

Urban impacts and implementation

Finnish guidelines have been published detailing how pervious materials can be implemented in urban environments. The guidelines include aspects of material and component production that create new business opportunities. Geotechnical dimensioning, construction and maintenance are detailed, which ensures lifetime performance of the new structures. Cities and municipalities are moving forward with plans to implement the pervious solutions, including the use of ICT to assess performance and optimize urban stormwater management. The pavement functionality improves networking of the city for an enhanced environment, sustainability and better quality of life.

Figure 2. Hydrological simulation of water pervious structures and pavements. Water infiltration capacity, retention capacity, and if needed also water purification capacity, is simulated in a full-scale (adjustable: 330 - 1000 mm) rig, with continuous measurement of the amounts of water: sprinkler irrigation and water passed through the structure.

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Improving implementation capacities of cities and regions in water governance

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Introduction

With the rapid population growth, water withdrawals have tripled over the last 50 years, and they are predicted to increase by 50% by 2025 in developing countries [1, 2]. Competing demands for scarce water resources may lead to an estimated 40% supply shortage by 2030 [3]. The World Economic Forum [4] recently identified the water supply crisis as one of the top three global threats.

More transparent governance and communication on urban water management options and technologies will enable a more rapid introduction of state-of-the-art technologies and further improve the involvement of civil society and the private sector in cities, and it would strengthen collaboration between cities.

One of VTT's active involvements in the water sector relates to the European Innovation Partnership (EIP) on Water and one of its action groups City BluePrints. The group organizes interventions at local level to overcome barriers in the water-related governance systems that hinder the development and uptake of innovations in municipal water management.

The BluSCities project

In 2014, the group actions turned into a new European-funded project called BlueSCities (Blueprints for Smart Cities: Developing the methodology for a coordinated approach to the integration of the water and waste sectors within the EIP Smart Cities and Communities). The project aims to answer the European Commission's objective to develop a coordinated approach to the integration of the water and waste sectors in the 'Smart Cities and Communities' European Innovation Partnership [http://ec.europa.eu/eip/smartcities], identifying research and innovation needs for future actions and promoting the exchange of best practice between the public authorities and stakeholders involved.

The BlueScities project will deal with the integration of challenges in the management of water and waste in urban settings within smart city logic, therefore linking to the current approaches in transport, logistics, energy and the provision of social services. Cities are key to the sustainable development of the European Union, and good governance is the challenge.

Focus and involvement

Water, waste and the ICT sector have not previously been working together effectively in a synergistic way towards a carbon-free city and its functions. It is actually surprising that the role of essential societal material flows – water and waste – is not really covered in the current Smart

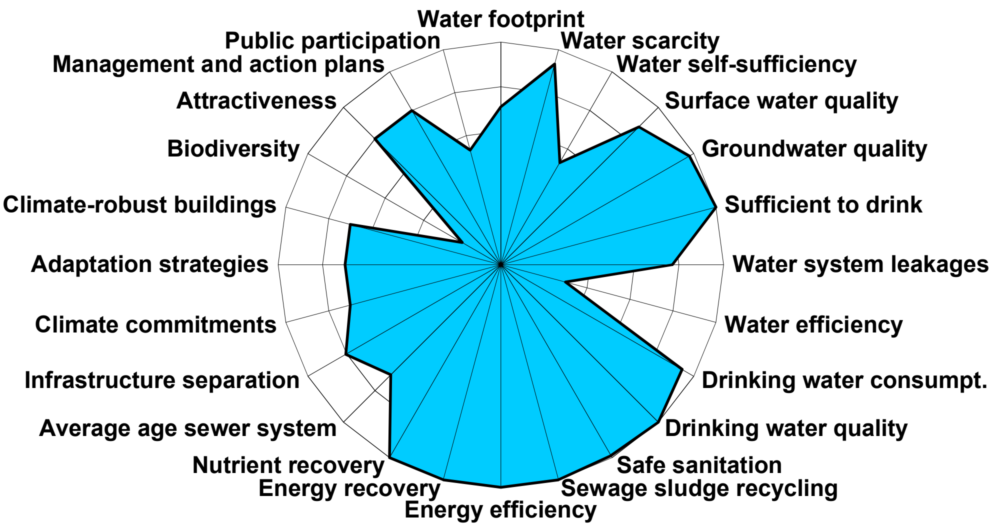

Figure 1. The blueprint of Helsinki Region Water

Cities' EIP strategic implementation plan. The plan only mentions as its ambition to "develop auditing tools/systems and define certification criteria for data and information on CO2, energy use, gas use, water use, etc…" (http://ec.europa.eu/eip/smartcities/files/sip_final_en.pdf).

The focus of BlueSCities is on the need to integrate water and waste into the smart city approach. It aims for technological improvements as well as raising awareness and widening learning experiences of, for instance, increased energy and water efficiency, and spreading knowledge about the motivation for recycling material and water flows. In this project context, this translates into producing a baseline assessment on the sustainability of water management in a city, providing the data required for a practicable planning cycle at different political levels. The baseline analysis will go into depth in four chosen case studies, of which Helsinki is one, and develop tools for integration and implementation, stakeholder involvement and international networking between different sectors with direct or indirect involvement in the EIP Smart Cities and Communities.

The analysis builds on the City BluePrints tool, which can be used as a first step or quick scan to benchmark the sustainable water cycle in cities, and it may help:

1. to communicate a city's sustainable water performance and exchange experiences,
2. to select appropriate water supply and sanitation strategies,
3. to develop technological and non-technological options as future alternatives for the water cycle in which several possible changes in the use of technology, space and socio-economic scenarios can be introduced. This should finally lead to:
4. a selection of measures, including an evaluation of their costs and benefits under different development scenarios, and ways to integrate these into the long-term planning of urban investments.

Many cities have been assessed at http://www.eip-water.eu/working-groups/city-blueprints-improving-implementation-capacities-cities-and-regions, within the framework of the EIP Water action group. VTT was involved in assessing Helsinki together with the Helsinki Region Water Services. The first benchmark for Helsinki (Figure 1), for instance, shows that Helsinki scores highly on energy efficiency, drinking water quality and water abundance, whereas protecting biodiversity and nutrient recycling aspects can still be developed.

From here, the BluScities project will continue by sharing best practices across Europe and facilitating direct contact between different cities at different stages of advancement.

Discussion

Integrating Smart City and smart water can have an impact at several levels and increases the mass of knowledge around tangenting issues such as energy efficiency. Water and wastewater systems are significant energy consumers. As an example, 3%-4% of U.S. electricity consumption is estimated to be used for the movement and treatment of water and wastewater. Given that water and wastewater treatment plants are not primarily designed and operated with energy efficiency as a chief concern, these systems can be overlooked when communities fund energy improvement projects. However, substantial energy and financial savings can be uncovered through operational changes and capital improvements at water and wastewater utilities [5].

Some estimates indicate that the application of ICT in water management and monitoring could produce growth of 30% per year. We see, indirectly, open opportunities for SMEs and other companies, especially in the ICT area for water and waste. According to the EEA [6], floods and droughts create significant damage at the level of tens of billions per year in Europe. A long-term European Urban Agenda can minimize this.

Acknowledgements

The action group team is led by NetwercH2O and the KWR Watercycle Research Institute and involves a wide range of knowledge providers, administrative bodies, networks and regional authorities for the development of the project: Richard Elelman, NETWERC H2O/ CTM, project coordinator of BlueScities and Kees van Leeuwen KWR Water City blue print developer. We also acknowledge the EU Horizon 2020 programme for funding of the BlueSCities. The author also acknowledges HSY Helsinki Region Water Services for readily providing data on their infrastructure and services.

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Improved city resilience against winter storms

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Introduction

Extreme winter storms disrupt citizens' normal lives by blocking roads and causing electricity and communication network outages. In addition, power interruptions may cool down all houses without wood-burning stoves. Loss of critical infrastructure services such as house-warming, electricity and communication capabilities may lead citizens to the brink of danger unless they are notified in advance or moved to safe places. The critical infrastructures can be made more resilient by discovering the vulnerabilities and reducing them with enhanced failure analysis tools. The improved resiliency includes effective evacuation defined by the analysis of the most vulnerable houses and population.

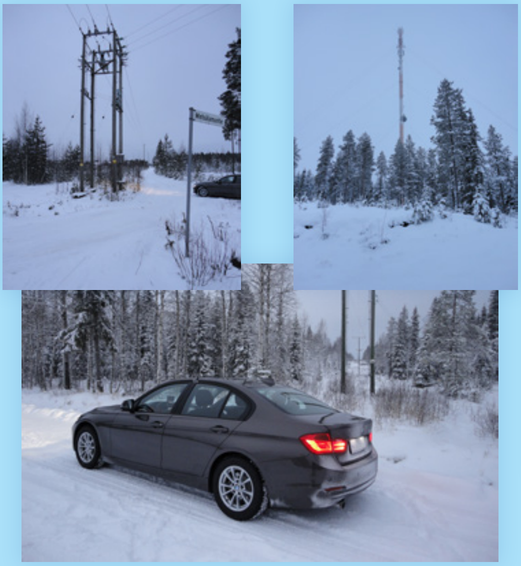
Shorter blackouts and more effective and focused evacuation

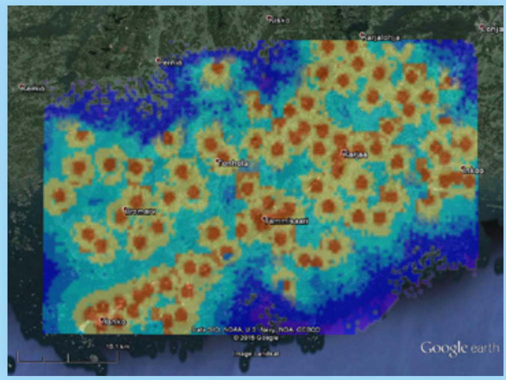
Interdependencies between electricity distribution and telecommunication networks were studied to determine effective solutions to make both networks robust, adaptive and resilient. The results of the studies help electricity and telecommunication companies to improve network automation and remote control to isolate faulty areas and shorten the outage time, as well as to plan more effective recovery actions. This information helps rescue services to analyse the most vulnerable targets by using the house-cooling models to start evacuation activities, which can reduce the blackout and rescue times.

Two studies – one goal: improved resilience to winter storms

The fault analysis tool for electricity and communication networks was developed in the Smart Grids and Energy Markets (SGEM) and Communication and Control for Critical Infrastructures (CONCARI) projects. The tool shows the extent of an outage in the electricity distribution network as well as the effects on mobile networks both in real time and in offline fault analysis (Fig 1). The tool enables testing of different technologies or structural solutions to improve resiliency and shorten the recovery time.

The analysis of cooling houses was done using the VTT House Model (connected online to a dynamic hourly-based calculation service) in the EU_CRISMA project. The model uses





building inventory and outdoor temperature as source information (Fig. 2). The data for buildings are available in the Finnish Population Information System (FPIS) and the outdoor weather can be given by users or read online from the Finnish Meteorological Institute's open weather data service.

Fewer expenses, improved safety

The electricity and communication network analysis is an essential aid to reducing the recovery time, which in turn minimizes operating expense (OPEX) costs. The tool promotes automation and wireless remote control, which helps companies to build cost-effective remote control systems and to detect and resolve outages without delay. Rescue services and municipalities can use the house-cooling model in two ways: in emergencies to find the most vulnerable citizens and rescue them, and in city planning to improve the building stock in the whole area.

Figure 1. Mobile coverage to support remote monitoring and control of medium-voltage network entities

Acknowledgements

These projects were conducted in co-operation with:

- **The fault analysis tool for mobile and electricity distribution networks: CLEEN-SHOK SGEM and TEKES funded the CONCARI projects**
- **VTT House Model: European Union 7th Framework Programme: CRISMA project (Modelling crisis management for improved actions and preparedness)**

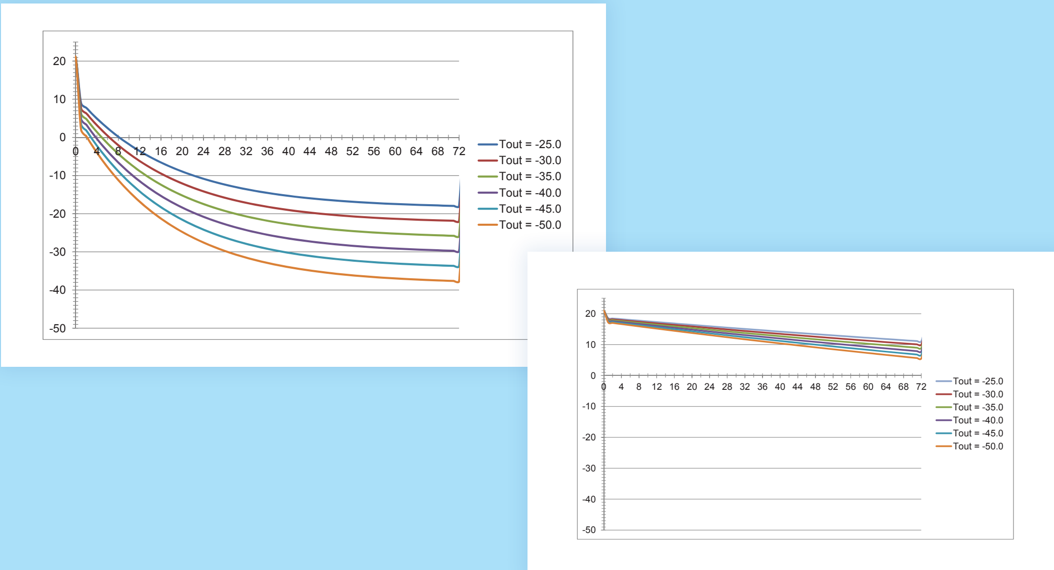


Figure 2. VTT House Model: Development of indoor air temperature levels in poorly insulated lightweight (on the left) and massive well-insulated (on the right) residential buildings after a power failure. (T [˚C] = f(Time [h]). Tout = outdoor temperature [1].

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Safety and security in the urban environment

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Introduction

Safety and security is a significant part of well-being and increases the attractiveness of the living environment. A high-quality living environment provides a variety of services and entertainment choices as well as opportunities to use and enjoy them without feeling fear. The feeling of safety affects people's behaviours and movements. A safe and comfortable living environment encourages residents to participate in public and private services and spend their time in public places like shopping centres, market areas and multi-functional centres. The movement of people increases the informal natural surveillance and in turn the feeling of safety.

Survey of residents provides information on safety and security

Many cities collect residents' views, comments and development proposals on current issues. The residents' comments are collected in relation to, for example, safety and security in their living environments. The survey can be carried out as a map-based Internet application in which the experiences of safety or insecurity are easily localized to a certain place. Gathered information on insecure places can be used to improve the structural or lighting conditions in such places. It is also important to be aware of places that are prioritized and favourable to residents and their well-being.

Diverse and high-quality services create well-being and safety

Safety and well-being can be improved with a versatile service supply. Beautiful parks, nearby resorts, good outdoor facilities and diverse leisure opportunities also create safety and well-being. Residents' information and ideas about their own living environments can be used in the identification of the business opportunities related to safety and security improvements. The residents can also be used for the evaluation and selection of ideas. They can give feedback on already available safety and security products or services. This will lead to solutions that achieve a level beyond the residents' wildest expectations.

Innovative solutions to counter security challenges

The perception of security by urban citizens can be increased by activating their participation in communities. Information and interventions can be provided in a transparent and sustainable way. This can protect citizens proactively as well as reactively provide more effective responses and assistance. New innovative technologies like city infrastructures, social media and mobile

Figure 1. Safety and security in the urban environment is important

phones can support the increasing and collective sense of security.

Discussion

A variety of local and regional authorities work with better safety and security in public places. The development and maintenance of safety and security require multi-player cooperation between public, private and third sectors as well as active-minded citizens. A positive consequence of this multi-actor cooperation is that safety and security issues are managed and observed from a variety of perspectives. This makes it possible to implement well-proven solutions in the new surroundings or to develop even more applicable solutions together with various stakeholders.

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Mobile city guide

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Introduction

The goal of this work was to create and test new ways for presenting news and event information for people/citizens on the go. Location based Mixed Reality (MR) technology was utilized for application development. The service concept of "mobile city guide" was developed in close collaboration with potential users in several phases. User involvement included 1) discussion and commenting in Owela Open Web Lab in concept development phase, 2) usability tests in city environment with the first prototype and 3) long-term field test during which user experiences were shared in Owela Open Web Lab. This article presents the results from user involvement in the development process of a novel digital service.

Mobile city guide application

The service concept prototype of Mobile Augmented Reality City Guide was designed and implemented. Augmented Reality (AR) is a technique of superimposing virtual information on top of a camera view of the real world. It can be used to deliver digital content embedded to the user's surroundings. [1, 2] In Mobile AR City Guide users can view and create messages and photos which are connected to physical geolocations, such as location-based news articles, events and public messages from other users. The content can be looked both in camera view and in map view.

Service development with users

The development of Mobile Augmented Reality City Guide was carried out utilizing the user centric approach, as described in Figure 1. Potential users of the City Guide participated the application development process already from the ideation stage. During the development process a prototype service was created and two iteration rounds of user testing were carried out. In the first user test the usability and the user experience targets of this novel media production and consumption model were studied (Figure 2). Based on the results from the first user test some modifications to the application were made. The second user test focused on the development of user experience during a six-week usage period.

Discussion

The users gave valuable input for the development of Mobile Augmented Reality City Guide. The prototype was continuously developed based on users' comments even in the course of the user tests. It was possible to react on the user feedback from the problems and challenges they had faced. Also development ideas and information about use context were fruitful information for further development of the application.

The participants were enthusiastic about Augmented Reality technology and many of them found it playful. However, the benefit from the use of augmented reality technology remained somewhat unclear. Also walking around in the city with a smart phone was considered natural and more discrete than doing the same with a paper map and giving and impression of being lost.

In the adoption of a new technology product the experience develops from anticipation through orientation and incorporation to identification simultaneously as familiarity, functional dependency and emotional attachment increase. [3]. During the development of the Mobile Augmented Reality City Guide the experiences vary from the opportunities for positive experiences in anticipation phase, through the feeling of excitement of novel features as well as frustration from usability challenges and lack of content, to still increasing interest.

In the concept development phase, the results were very promising especially in the technology acceptance point of view. The participants evaluated the services in the use situations often more interesting than useful. In addition, in most of the cases they thought that they could use the described service. This indicates that interesting, and probably entertaining, service would encourage using it, although the usefulness was anyway important for the participants. The user comments focused mainly on the content and the sources of information; that is there were only a few new ideas concerning the user interface and functionality. In usability tests the comments and new ideas focused naturally on usability and issues related to user interface. In the last phase, the long-term field test, the development ideas concerned different types of content, but also ideas for content providers and about the appearance were presented. For example, more surprising and playful features were suggested especially in AR view.

An example of participants' ideas concerning the content was information service for tourists, in which more specified data could be delivered than in a basic tourist guide, such as this cafeteria is famous from its delicious cakes. Also more background information, such as historical details could be given. The ideas for different sources of content included time tables for public transportation, opening hours of museums, art galleries etc., and information from the city, such as road works, and current and future building projects.

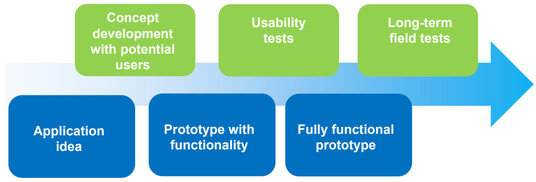

Figure 1. User centric development process of Mobile Augmented Reality City Guide.

Figure 2. Usability testing in Helsinki city centre.

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Service robots in public places: customer expectations

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Introduction

In the near future, robotics will provide new opportunities for customer service development in terms of efficiency, user experience and new types of service tasks. Economically feasible, quite sophisticated, humanoid robots with a reasonable degree of autonomy in everyday environments are available now. A new bottleneck for the application of these robots is the interaction with humans and user acceptance of services provided by robots. Understanding user expectations is the first step towards designing successful services based on advances in robotics.

Figure 1. Nao the humanoid robot carrying out reception service tasks. Nao is 57 cm tall so it was put on a table for the comfort of the service users.

Robots are able to elicit positive experience in service tasks

A service robot is "a robot that performs useful tasks for humans or equipment excluding industrial automation application" [1]. Service robots will assist and also add value to customer services such as reception, instruction and delivery in hotels, hospitals and care homes for the elderly. In service tasks, the robot does not have to look human, however, research has shown that people tend to perceive human-like robots more positively than machine-like ones [2].

Interaction and acceptance of robots in public places have been studied, especially with regard to the effect of robot appearance and behaviour. Summarizing some results, it seems that humans tend to treat humanoid robots as social actors. Humans prefer talkative robots to quiet ones [2], perceive robots to have personality traits [3] and can feel empathy for robots [4]. Although humans seem to prefer human-looking robots [2], people may feel uncomfortable when a robot is too human-like (the uncanny valley [5]). Based on this research, humanoid robots performing similar (simple) service tasks to humans can be expected to evoke positive responses in users.

Empirical study of user expectations of robot reception

We studied the impact of a humanoid robot [6] on customer expectations and experience of a reception desk service (Figure 1). The participants (visitors at the reception) mostly expected the robot service to be "available", "reliable and honest", "systematic" and "efficient", but less "pleasant" and "polite". Such human behaviour attributes as "warm", "intimate" and "personal" were not expected much from the robot. After trying the robot service, the participants found it to be more "helpful" than expected. Overall, the participants expected more from the human service than the robot service.

Discussion

At present, people may not expect much from robots carrying out customer service tasks. However, robots offer huge opportunities for service development, not only because no other technology is more interactive and connecting at an emotional level to people than robots. The emotional and social aspects perceived in robots afford even new kinds of services, for instance, the Paro robot seal therapy. In addition to good service design, other important factors in user acceptance and market success of robot services are the usefulness of the services and integration of them into the whole service system.

The success of Smart Cities depends on seamless interaction between their citizens and technology. VTT has taken the initiative to understand the interaction between service robots and humans to improve the chances of success for companies willing to take advantage of robotics in their service development.

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We thank the VTT Design for Life innovation programme for funding this research work.

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Many faces of mobile contactless ticketing

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Introduction

The real emergence of NFC technology, which is now available on various mobile devices, offers opportunities in terms of deployment of mobile services for end-users in urban areas. In this context, the technological developments have led to the deployment of mobile contactless solutions in the domains of transport and culture. The goal has then been to identify the main models that can be used in the management of mobile contactless ticketing systems. This allows for a clearer view of the ecosystem dedicated to NFC-based mobile ticketing.

Seven models for the management of mobile contactless ticketing systems

The conducted research allowed seven main models to be identified and compared regarding the management of mobile contactless ticketing systems within urban areas [1]. These were operator-centric, manufacturer-centric, identification-based, P2P-based, smart card-based, leeched smart card-based and inverse reader models. The comparison of the models provides a realistic picture of the various faces of such systems and their likely evolution in the urban environment. In this respect, the results are relevant to public authorities (at city level) that want to promote the ecosystem dedicated to NFC-based mobile ticketing.

Objectives of the smart urban spaces (SUS) project

The work was part of the SUS European project. The project explored the possibilities offered by the NFC technology in the field of mobile ticketing for city services. A study was performed to gain a more comprehensive view of the NFC-based ticketing systems. This study was based on the analysis of the existing ecosystem (best practices, strategy of the big players, etc.) and on the return, on the experience of the solutions deployed by the partners of the SUS project. The comparison between the identified models was performed with criteria considered relevant in the field of NFC-enabled services.

Possible evolution of the ecosystem dedicated to NFC-based mobile ticketing

Considering the diversity of situations an end-user may encounter, the identified models will certainly coexist in the urban environment. It should be noted that MNOs and manufacturers of mobile phones can put forward (what they already do) the operator-based and manufacturer-based models so that they become more prominent.

The challenge lies in being able to present a coherent picture of the environment so that the end-user can easily choose the most suitable model (system) in each possible situation. The development of a service aggregator (probably at city level) that provides such a possibility will offer new business opportunities.

Acknowledgements

This work was carried out within the framework of Smart Urban Spaces, an Information Technology for the European Advancement (ITEA) project, the goal of which was to define new mobile e-services for cities. The proposed services mainly take advantage of specific technologies, in particular NFC, in order to ease the everyday life of European citizens. We would like to thank the partners of the Smart Urban Spaces project with whom we have been working for three years and whose valuable contributions have made this work possible.

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Interoperability of mobile contactless city service

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Introduction

Interoperability of contactless city services has been emerging as a topic of discussion at many recent events and projects. Looking simply at technological interoperability does not help sufficiently when mapping service opportunities or analysing city services. There was therefore a need, in the context of the Smart Urban Spaces (SUS) European project, to define a framework (expanding the focus to other aspects of city services) to help understand the environment of contactless city services to analyse the relations between the different stakeholders and to provide relevant information concerning the level of interoperability that can be reached.

Interoperability framework for mobile contactless city service

The conducted research allowed for the proposal of a framework dedicated to the definition of interoperability and its evaluation in the context of mobile contactless city service [1]. The proposed system consists of an interoperability matrix (identifying the key entities as presented in Table 1) and a set of forms highlighting the requirements regarding the possible relation for each cell of the matrix. In this respect, the framework is relevant to companies and representatives of public authorities as it provides a practical tool for analysing the possible interactions of mobile services to be deployed (or already deployed) in a given urban area.

Interoperability in the context of the Smart Urban Spaces (SUS) project

The work was part of the SUS European project. During the project, more than ten workshops on how to delineate the contactless services in European cities (partners of the project) were organized. This effort allowed the main entities of the considered ecosystem to be identified, namely the Mobile, the User, the Service, the Infrastructure, the City and the Country. Each of these high-level entities can be mapped with another and an analysis can be made in the crossroads of this mapping. A set of dimensions have been chosen to give a structure to the analysis. These dimensions are Business, Legal, Usability, Social and Technical aspects.

	User	Mobile	Infrastructure	Service	City	Country
User						
Mobile						
Infrastructure						
Service						
City						
Country						

Table 1: Interoperability matrix

Possible evolution of the ecosystem dedicated to NFC-based mobile ticketing

Some partners of the SUS project started to use the first available forms, thus demonstrating that it is a practical tool because it allows, among others things, potential problems to be identified or similar services compared. The forms of the framework include quite simple questions (with yes/no/maybe answers), and the process that leads to the evaluation results is easy to achieve (with a clear view of the results through a Kiviat diagram). This tool helps to improve the business model related to the deployment of a given contactless city service and, in this respect, it could represent a competitive advantage for companies.

Acknowledgements

This work was carried out within the framework of Smart Urban Spaces, an Information Technology for European Advancement (ITEA) project, the goal of which was to define new mobile e-services for cities. The proposed services mainly take advantage of specific technologies, in particular NFC, in order to ease the everyday life of European citizens. We would like to thank the partners of the Smart Urban Spaces project with whom we have been working for three years and whose valuable contributions have made this work possible.

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New remote monitoring approach for chronic disease management

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Introduction

Type 2 Diabetes and hypertension are increasingly common lifestyle-dependent chronic diseases. They increase the risk substantially of serious cardiovascular events, which have huge costs for society. Remote self-monitoring of blood pressure and blood glucose has been shown to be effective in supporting the management of these diseases and preventing their exacerbation. In our new approach, we provide automatic guidance for patients and health professionals based on computerized analysis of self-monitoring data. The viability of the approach has been demonstrated in a clinical trial carried out at the Sipoo Primary Health Centre.

Automatic feedback for patients

In our new approach, depicted in Figure 1, we included blood glucose, blood pressure, weight and daily steps as monitored parameters. Meters for these parameters are inexpensive and easy to use, allowing the new care approach to be used also for elderly patients. The patients use VTT's mobile application – Monica – to upload measurement data to the server system. The data are accessible through the system to nurses and doctors. VTT's server software automatically analyses the monitoring data uploaded by the patient and generates automatic feedback for both patients and healthcare personnel. The system is based on a rule-based decision support engine that selects the most appropriate feedback messages to be provided in each case.

The feedback specifically aims to be supportive and motivational, encouraging a healthy life style and self-management for the patient. The contents of the feedback messages follow evidence-based care guidelines and the Information-Motivation-Behavioural Skills Model. The health professionals receive alerts based on the monitoring data in cases when the patient needs to be contacted. The new approach potentially frees healthcare resources from routine tasks, enabling the attention of health professionals to be focused on the patients in most need of personal support.

Implementing the technology and assessment of benefits

VTT's automatic feedback messaging software and the Monica application are modules with open interfaces. We have integrated the modules with a commercial Personal Health Record (PHR) system that is accessible to Sipoo Health Centre customers and personnel. The PHR provides patients with a view on essential personal health data, including their self-measurements, as well as the possibility of carrying out a questionnaire-based Virtual Health Check.

In order to evaluate the benefits of our monitoring approach, we carried out a randomized controlled clinical trial. The trial involved two groups of Type 2 Diabetes patients: intervention patients using the new monitoring technology (performing measurements, receiving feedback messages, accessing health data in the PHR

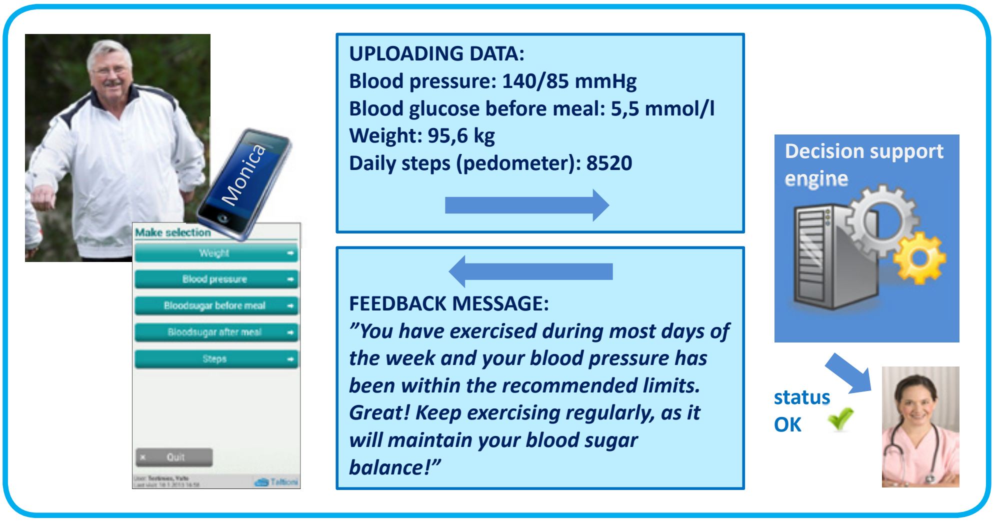

Figure 1. Automatic feedback messaging concept

and using the Monica application) and control patients continuing to receive the usual care. A decrease of 0.4% units was observed in the HbA1c value of the intervention group, indicating a statistically significant improvement in blood sugar control. A clear reduction of 2.1 kg in mean weight was also observed. The user satisfaction of the new care model and technology was very high according to the user questionnaire results.

Exploitation perspectives

Large-scale deployment of the new care model requires investments by the municipalities in both new technology and care processes. Despite short-term budgetary challenges, these investments are justified. Remote monitoring has been shown to bring benefits to the management of chronic diseases and, according to our study, also a big proportion of patients are compliant with the new care model. The potential of improving the efficiency of healthcare delivery is also high, thanks to the increased automation level of the monitoring process. The need to increase efficiency and quality of healthcare is global. The new monitoring technology components tested in the Sipoo trial are multilingual and expose open interfaces, allowing them to be integrated with other healthcare information systems in Finland and abroad. The technology is also applicable to the care of other chronic diseases.

Acknowledgements

We wish to thank the personnel of Sipoo Health Centre for their important contribution in carrying out the clinical aspects of the trial. Mediconsult Oy and Kustannus Oy Duodecim are acknowledged as the providers of the Personal Health Record system and the Virtual Health Check system respectively. The activity was carried out within the framework of the ITEA2/Care4Me project and funded by Tekes, VTT and Bayer HealthCare. Professor William A. Fisher and Adjunct Professor Kari Harno are acknowledged for their valuable contribution in the assessment of the trial results.

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Value from the food chain waste

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Introduction

In today's world we face a double-sided problem: resource depletion and waste accumulation. The direct consequence is an increase in the costs of raw materials and waste disposal. The food production chain generates waste and co-streams at every step of the way from farm to fork to bin. Dumping waste is no longer an option to be reckoned with. Burning the waste to turn it into energy and converting it into chemicals, materials and food ingredients are current and future solutions to the mentioned double-sided problem. Food waste and food-grade co-streams, which often contain a lot of water, are better suited to conversion processes. End products can be new foods and ingredients, and feed material as well as non-food and non-feed applications.

Valorisation of the food chain waste can benefit many industrial actors

The problem of resource depletion and waste accumulation is best tackled by developing technologies: i) to reduce the amount of waste by exploiting it as raw material for energy, chemicals and materials, as well as in food and feed production, and ii) to prevent waste generation through efficient usage of raw materials, water and energy in processing, and by preventing microbiological and chemical spoilage. These technology solutions can be applied at every step of the food production chain and they aim to benefit farmers, manufacturers of food and food ingredients, food retailers and processors of food waste generated in households and by consumers. [1]

Technologies to convert waste into food

The technologies developed to reduce food processing waste by converting it back into food are mechanical, physical, enzyme-aided, microbiological or combinations thereof. Vegetable co-streams can be processed bio-mechanically into edible films with good barrier properties. With microbiological processing, vegetable peels can also be introduced into the food chain as vitamin- or natural preservative-rich ingredients or E-codeless thickening agents. Further examples include bio-mechanical processing of berry and fruit press cakes (co-streams of juice production) into bioactive food ingredients and microbiological conversion of broiler chicken feathers into feed. These are just a few examples to show the potential of cross-technological processing solutions to solve the problem of accumulating food chain waste. [1, 2]

Discussion

As a result of the population growth, together with rising economic wealth in certain areas, the world will face an ever-growing problem of resource shortage and waste overload. There is an urgent need to find ways to convert waste back into raw materials to establish bio waste refineries. In Europe alone, over 100 million tonnes of food is wasted annually – agri- and aqua cultural waste is not even included. About a

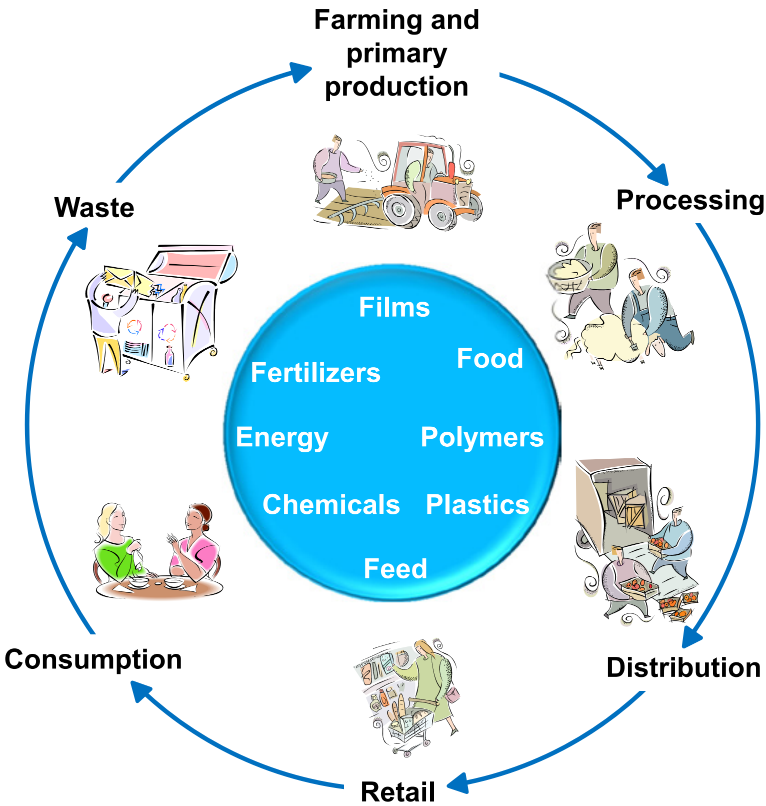

FIGURE: Sustainable food chain

third of the food meant for human consumption is wasted. The Roadmap to a resource-efficient Europe [3] identified food as a key sector in which resource efficiency should be improved. A major challenge here is how to reduce food waste without compromising food safety. In the EU, food waste reduction has a high priority, and the EC has therefore produced a waste prevention guidance document [4] (and is targeting considerable research funding in this area.

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Internet of Things – technology trends and future potential

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Introduction

In the next ten years, the Internet of Things (IoT) – comprising both enabling technology and new business models – will drive productivity and, at the same time, be the cause of disruptive changes. The interaction between smart devices and machines is taking an important role as it brings together the real physical and digital worlds. Thus, successful deployment of IoT is crucial for the survival and thriving of not only companies but also societies and cities.

IoT is a key enabler

The Internet of Things (IoT) escapes any clear definition, consisting as it does of a combination of technologies and a collection of applications and business opportunities, rather than any definable architectures or communication protocols. Different viewpoints result in different ways of defining the IoT. We see the IoT as a set of enabling technologies that can be used by almost all areas of business and society to improve productivity. The core enabling technologies are sensing, processing, communication, refining and managing information, while the supporting enabling technologies are energy harvesting and low-power embedded systems. In principle, the enabling technologies are application and domain independent, which is the key advantage of the IoT over domain-, application- or proprietary-specific solutions, which often still dominate today.

The availability of accurate, detailed, reliable, diverse and real-time information as a basis for well-informed decision-making, either automatic or human, is at the core of the idea of the smart city. The information covers technical areas such as traffic, energy production and consumption, water distribution and usage, recycling, and also human-related information including security and health. Collecting this information, analysing it and then acting on it relies on the IoT. Many of the most advanced cities, including Barcelona and leading technology companies such as Siemens, IBM and Cisco, are therefore investing in and implementing the IoT for city needs.

Discussion

The main source of productivity increase and innovation in the last three decades has been the development and rapid deployment of information and communication technologies (ICT). ICT is the primary enabler of 80% of innovations and 40% of the productivity improvements (A Digital agenda for Europe, EU 2010). In the coming years, this trend through digitalization will take the form of the IoT and its sister concept the industrial Internet. Increased productivity and, even more importantly, innovations involving sustainable – ecologically and economically – new solutions are needed in the public sector even more urgently than in companies. Our goal is to help industry and the public sector to improve productivity by leveraging IoT technologies in areas that are important to Finland and Europe.

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Roll-to-roll printed organic photovoltaics

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Introduction

Organic photovoltaics (OPV) is an emerging and attractive alternative to traditional crystalline silicon and other inorganic thin film PV technologies within the rapidly growing PV industry. By using novel functional materials and roll-to-roll (R2R) manufacturing processes, OPV technology opens up a wide range of novel application opportunities for flexible and lightweight autonomous energy harvesting in all end-use categories from consumer electronics to building-integrated PV as well as in future grid-level energy production.

Roll-to-roll printed OPV

R2R printed OPV technology (Figure 1) enables flexible, thin, lightweight, transparent, free-form design: in size, shape and colour, as well as low-cost production structure and environmental sustainability. Potential short- and medium-term application opportunities for printed OPV technology include autonomous low-power applications, interactive packaging and point-of-sale products, mobile consumer electronics, interior design products and reflective-type displays.

OPV from lab to fab

Instead of vacuum-based deposition processes, this research focused on the use of solution-based functional materials and a suitable large area for R2R printing processes. In the beginning, laboratory-scale printing tests were performed for all the functional materials used in the OPV device stack to find the best performance material and process combinations. After this, the OPV process technology was up-scaled using VTT's unique R2R printing facilities (Figure 2). Recently, VTT demonstrated functional decorative OPV modules – leaf shape design (Figure 3). The leaf-shaped module was integrated into a digital balance as an autonomous energy source to replace a battery (Figure 4).

Future scenario of R2R printed OPV

The world and society are digitalizing rapidly. According to scenarios of the Internet of Things (IoT), all objects around us will be connected to the network and have their own functionality to collect data, actuate and provide services for us. This requires many different types of novel sensors and connectivity systems that link objects to the network. Energy harvesting will be one bottleneck for such development. Unique features of the OPV technology presented before will play a key role in providing highly integrated energy harvesting solutions for IoT-based objects. Figure 4 presents a vision of how OPV energy harvesters can be embedded around our living environment.

Figure 1. An R2R-printed flexible OPV foil

Figure 2. An R2R pilot printing machine

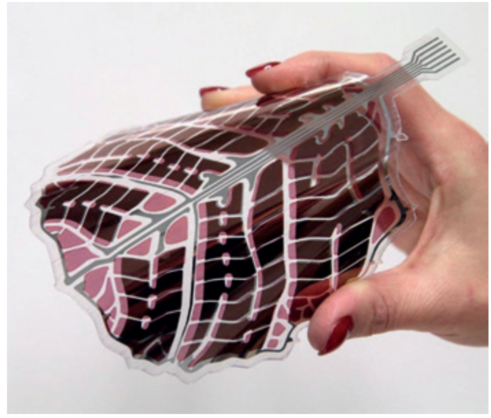

Figure 3. A leaf shape-printed OPV module

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New technologies for electrochemical energy storage

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Introduction

One challenge of using renewable energy sources (solar, wind, etc.) lies in the uneven geographic and temporal supply of the energy they offer. This calls for efficient and economical solutions to store energy. Another important requirement for energy storage arises from the need to level out the peaks of demand and supply of energy in the increasingly distributed generation and consumption. For example, in terms of electric vehicles, high-power charging stations need a way to ensure electricity supply at all times without exceeding the limits of the electric grid. According to many surveys, stationary batteries offer the most suitable solution for supporting energy and power management in both urban and rural use and business cases.

Areas of application

Electrochemical energy storage is an enabling technology at the crossroads of several emerging use cases and applications in modern society, both in societal and industrial terms. The transport system is undergoing a transformation towards electrification of urban heavy-duty fleets in which multimodality and shared use of stationary infrastructure will be beneficial. Industrial production such as mining and ports offer potential use cases for both mobile and stationary energy storage; these may actually have similarities with islanded communities with their own energy production and management. Power grids offer use cases for grid-connected storage, and storage in vehicles can offer ancillary services to the electricity system when connected and not serving the primary production purposes. All of the above open up for a very versatile set of requirements and technological solutions. Finding the added value that different electrochemical storage technologies can offer requires careful systems and techno-economic engineering. A pre-normative approach will also be necessary on the way to larger-scale adoption of the technologies.

Potential future storage technologies

Conventional batteries such as lead-acid, Ni-MH and Li ion batteries can be used, and in many cases they are still the technology of choice, at least in the short term. With regard to the near future, the stationary battery systems with most potential are redox flow batteries, metal-air batteries, Na-Ni-Cl batteries and other sodium battery systems. Table 1 presents the potential of the energy densities and cycle lives (the number of charge/discharge cycles the battery can endure until its capacity drops below a critical limit) of several potential battery technologies. [1, 2]

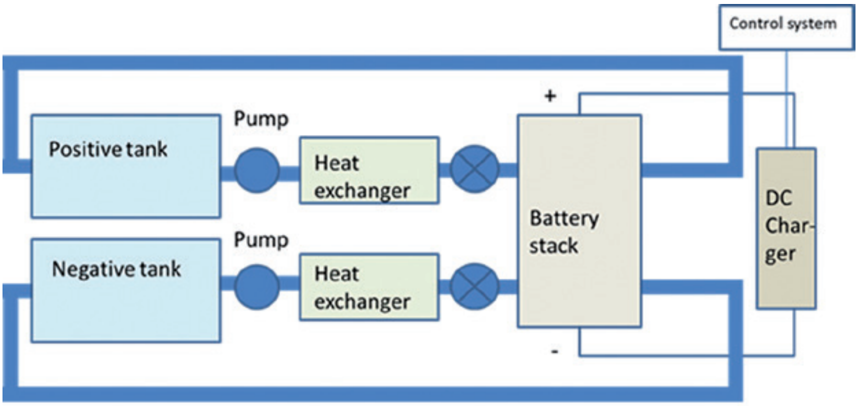

Figure 1. Schematic image of a redox flow battery system [2].

Redox flow batteries

Redox flow batteries have high potential as an energy storage technology with respect to stationary applications such as grid storage and loading stations for EVs. This is primarily due to their very long cycle life, low operational cost and environmental friendliness. There are already several redox flow systems in operation around the world, most of them based on vanadium redox batteries (VRB). [2] Flow batteries consist of two (in some cases one) electrolyte components that are stored in separated tanks and circulated in parallel separated by an ion selective membrane. The solid electrodes remain inert as the actual anode and cathode are species dissolved in the electrolytes.

Metal-air batteries

The metal-air technologies offer high energy densities and advantages related to cost and weight. Their cycle life, however, requires further improvement. A metal-air battery consists of a base metal negative electrode and an air positive electrode. The positive electrode is the oxygen contained in ambient air. Oxygen is an ideal cathode with strong oxidizing power and it is available in abundance. The negative electrode is typically lithium, magnesium or zinc. [3]

Sodium-based batteries

The sodium-sulphur battery consists of a molten sodium anode, a molten sulphur cathode and a solid ceramic electrolyte. Due to its high energy

Table 1. Battery technologies with their respective gravimetric and volumetric energy densities and cycle lives.

Technology	Practical gravimetric energy density (Wh/kg)	Theoretical volumetric energy density (Wh/l)	Cycle life (cycles)	Source
Li - air	3505	1520-1680	500	(9,10)
Zn - air	200	-	200	(11)
Na - S	110	360	5000	(9,10)
Na - Ni - Cl	90	160	3500	(9,10)
VRB	10-20	15-25	>10 000	(9,10)
Li - ion	95-200	250-329	>5000	(9,10)
Lead - acid	30-40	60-75	500-800	(9,10)
Ni - MH	60-120	140-300	500-1000	(9,10)

density, high efficiency of charge/discharge, low-cost raw materials and long life (~15 years), it has been applied in relatively large-scale stationary grid support and space applications [4]. [5] The Na-Ni-Cl battery (ZEBRA) is an advanced high temperature battery that offers several improvements over the sodium-sulphur technology: high voltage, maintenance-free operation, no gassing, no self-discharge [6] and other safety-enhancing features.

Summary of the technologies presented

In addition to those summarized in Table 1, properties such as cost, safety, environmental friendliness, storage life, etc. should be considered. Many properties are subject to change as ongoing, extensive R&D constantly aims for improvement. In the end, each use case and application from pilots to commercial operation will be driven, along with the technological development, by careful techno-economic systems engineering to facilitate the right choices.

Acknowledgements

The research described here is carried out in the large networked project entity ECV (Electric Commercial Vehicles) and, especially, in the public research entities eStorage3 (energy storage) and eCharge (systems and the power grid) within that consortium. The projects are supported financially by the EVE programme of Tekes – the Finnish Funding Agency for Innovation. The ECV network involves some 30 industrial partners and 5 research partners.

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Energy harvesting/ thermoelectrics

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Introduction

Energy harvesting uses ambient energy to generate electricity. It provides potentially low-cost, maintenance-free, long-life equipment by reducing the need for batteries or power chords. Energy harvesting (EH) is also known as power harvesting or energy scavenging. EH is considered to give benefits related to environmental friendliness, safety, security, convenience and affordability. EH can be used for brand enhancing. Technically, it can be used to make new things possible depending on visionary engineering (Pykälä et al., 2012).

So far, the main commercial successes include such things as photovoltaics on space vehicles, road furniture and consumer goods, electrodynamics in bicycle dynamos and wristwatches and piezoelectrics in light switches, and many forms of EH in building controls. Control devices without batteries and wiring have already been realized in many solutions. Energy harvesting is now being made affordable and feasible for several new, big applications including [1]:

90% of Wireless Sensor Networks (WSN) are impractical without energy harvesting. These mesh networks are rarely feasible (without energy harvesting) because, in the biggest projects envisaged, such as those in which nodes are embedded in buildings and machines for life or on billions of trees, the batteries would be inaccessible or prohibitively expensive to access.

1. Getting almost free power for electronics and lighting to developing countries where batteries are not obtainable.

2. Bionics and sensors are needed in human bodies that stay there for the life of the patient. These are the focus of a huge new research effort.

3. Mobile phones and laptop computers have batteries that frequently go down. In fact, the power situation worsens as more functionality is added; this inconvenience affects two billion people.

In all these applications, progress is being made by which new forms of lighting and electronics need far less electricity, and new forms of energy harvesting (e.g. thermoelectrics) are better able to provide it.

Technologies for energy harvesting

As energy harvesting is often understood as the use of ambient energy to provide electricity for small and/or mobile equipment, this report concentrates on small-scale production such as electrodynamic, microelectromechanical (MEMS), piezoelectric, thermoelectric, photovoltaic, micro hydro, tidal, biogas from waste, small-scale wind power, vibration and kinetic energy.

Figure 1 shows how the output power of harvesting devices is increasing and the demand for the electronic devices is decreasing. The

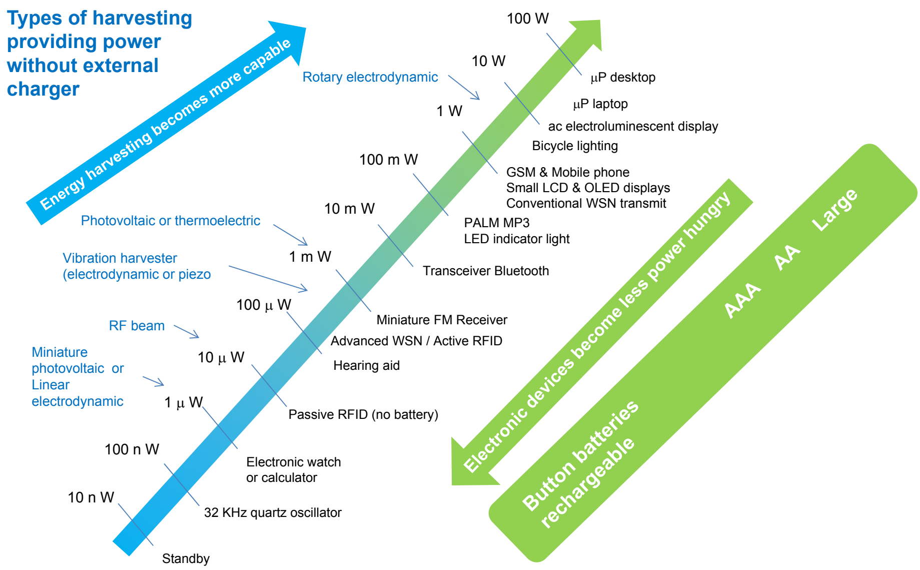


Figure1. Power demand of electronic devices vs energy harvesting possibilities (EH2 2011):
- arrow upwards: energy harvesting becomes more capable
- arrow downwards: electronic devices become less power hungry.

button batteries up to AA or AAA size can be replaced by energy harvesting systems.

The primary energy harvesting needs in global efforts on energy harvesting development differ from country to country. The report (EH1 2011) covers 160 case studies of ongoing energy harvesting in 31 countries. That is enough to give some idea of the leading countries, technologies and applications. In North America, the emphasis of energy harvesting is on applications for the military, aerospace and healthcare. In Europe the emphasis is on industrial and healthcare devices, and in East Asia consumer goods are the most important group of EH devices. The application sectors can be divided as shown in Figure 2. A combined approach uses a primary battery with an energy harvesting device. This means that the battery can be much smaller and last longer. Is this a possible interim approach with Wireless Sensor Networks (WSN) as we wait for smaller and more efficient and affordable multiple energy harvesting for these?

Although the price of the specific technology is decreasing, our average unit value holds up because of the change in mix. All the figures given below relate to the energy harvesting device, e.g. solar cell, and not the associated energy storage, wiring or electronics.

Energy harvesting technologies are explained and exemplified in the reports [3, 4].

The energy source of an electrodynamic device can be the movement of an oscillating weight in applications such as watches. Its power density varies from 1 to 200 mW/cm^3. An advantage is the high power output and a disadvantage is the moving parts.

Vibration and kinetic energy can be harvested using piezoelectric crystals, and piezoelectric composite fibres are considered the most promising energy harvesting devices for low-power applications. The power density of a piezoelectric device depends on the source: from machinery vibration 0.5 mW/cm^3 and from a moving shoe insert 0.33 mW/cm^3. Good features are simplicity and long life. Challenges are the availability of vibration or movement. One disadvantage is that moving parts have a chance of fatigue failures.

Piezoelectrics are being studied for use in self-powered sensors and controls in the human body, aircraft, trains, etc. The challenge is to control the energy (amplitude and bandwidth of the

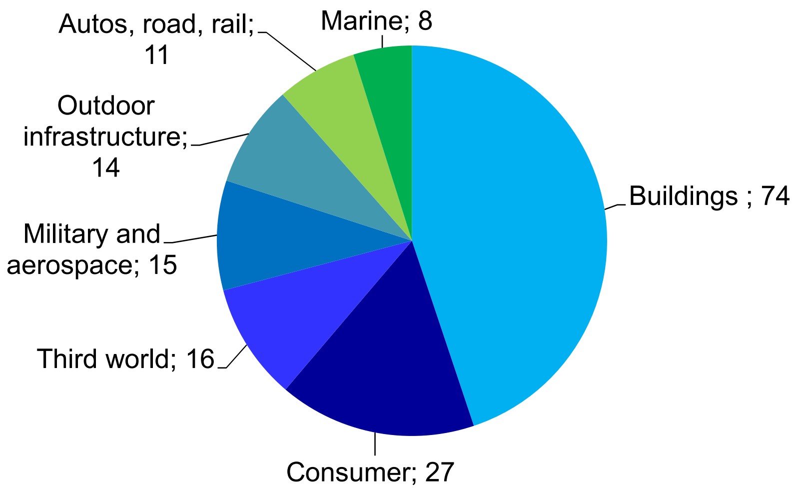


Figure2. Number of EH cases in different application sectors [3].

vibration frequency) going into the piezoelectric harvester. Mechanical energy input that is too high can lead to damage. Other opportunities such as thermoelectrics, magnetostriction and RF can be alternatives to piezoelectrics.

Vibration can also be harvested by electrostatic or electromagnetic conversion. Kinetic energy can be converted into electrical energy using a spring-loaded mechanism.

Thomas John Seebeck discovered the Seebeck effect in 1821. At that time there was no rush to commercialize thermoelectric generators. Charles Athanase Peltier discovered the Peltier effect eleven years later in 1834. For over a century, these effects remained little more than laboratory curiosities. The primary product based on the Seebeck effect became the thermocouple for temperature measurements. It was not until the 1950s that significant resources were put into thermoelectric research that led to actual power generation products (Stabler 2006).

Thermoelectric devices use temperature differences or thermal gradients to generate electricity. The power density of thermoelectrics (TE) is quite high when the source is an engine with temperature differences of up to 120 K: the power density from a heat flux varies from 1–3 W/cm3 to 20 W/cm3. There are no moving parts. It is not possible to optimize power and voltage at the same time. Fabrication costs are high and the heat difference is not available at all times. Thus, energy storage is needed to stabilize the power.

Photovoltaic cells are usually made of silicon-based material, although other materials are being studied (and used). Wireless sensor systems can use the solar energy harvesting devices directly or for charging their batteries in the daytime.

Energy harvesting in general has long been done using micro hydro, tidal and wave energy – the earliest being structures such as waterwheels. Tidal and wave energy solutions may be large-scale applications, but in this report the low-power applications carry the main weight.

Sewage water is used for heating in district heating systems, especially in the Nordic countries. The waste water temperature is over 10 °C after the water treatment establishment, so it is useable for heating by heat pump. The COP (coefficient of the performance) of the heat pump over the year is high. Condensate water from the power plant and other sources has the same heating potential to use heat pumps.

Groundwater and water in seas, lakes and rivers are also potential sources for heat pumps. In Finland, for example, groundwater is about 5–6 °C over the year, but the temperature of the other sources varies during the year following the annual seasons.

All the forms of heat pump applications also use electricity at about one-quarter of the heat output, so the most desirable applications are warm water sources for use without a heat pump.

Small-scale wind power

Nowadays wind power plants and wind farms present large-scale energy production connected to the distribution or transmission network. Small-scale wind power can still be installed in regions that cannot be connected to the common network.

Thermoelectrics

The variety of thermoelectric (TE) materials that can be used in energy harvesting is quite large, and the optimal material for a given application depends mainly on the temperature range in which the material is to be used. Although thermoelectric materials exhibit thermoelectric behaviour at all temperatures, their figure of merit (ZT) is quite strongly influenced by temperature, and the ZT value typically peaks in a certain temperature range. When evaluating the feasibility of thermoelectric materials for different applications, the material performance in the required temperature range, in addition to other factors like cost and availability, should therefore be taken into account.

Nanostructuring has led to significant improvement in the properties of thermoelectric materials. The main strategy has been to decrease the thermal conductivity via phonon scattering. Research is required to understand the interaction between thermal, electrical and entropy transport; controlling nanostructures that can be used in actual devices; and improvements in materials for soldering, ceramics, packaging, etc. (Benesch, 2012)

The main focus of the research is still on tellurides due to their outstanding properties. Some of the most interesting alternatives to make cheap and less toxic TE materials include Mg_2Si, $CoSb_3$, ZnSb, Zn_O and other oxides. All these materials have been known about for a long time. More explorative work is required to find completely new materials. [6]

Material manufacturing methods such as sol-gel and electrodeposition are considered to be scalable to industrial level, and new reliable and cheap techniques to sinter and compact the nanostructured material into a nanostructured bulk material are crucial. [6] Conducting polymers are a class of materials that could be produced directly from the solution without sintering. Benesch [6] suggests another completely different, barely explored strategy: to consider an electrochemical reaction to thermoelectric power generation.

The materials considered in this report are the ones that are most commonly used today and the ones that show the greatest promise for applications in the near future. Only bulk materials will be discussed, as nanostructured or otherwise

	Temperature Range (°C)	Conductivity Type	ZT	Toxicity	Price
Bi_2Te_3	0-300	n, p	0.5-1.0	High	High
$MnSi_{1.73}$, Mg_2Si	200-700	n, p	0.5-0.7	Low	Low
Zn_4Sb_3	200-500	p	0.5-1.2	Medium	Low
TAGS	200-600	p	0.5-1.2	Medium	Very high
PbTe	200-550	n, p	0.5-1.0	High	High
Skutterudites	200-600	n, p	0.5-1.2	Low	Low
Oxides	400+	n, p	0.5-0.8	Low	Low
La_3Te_4	500+	n	0.5-1.1	High	High

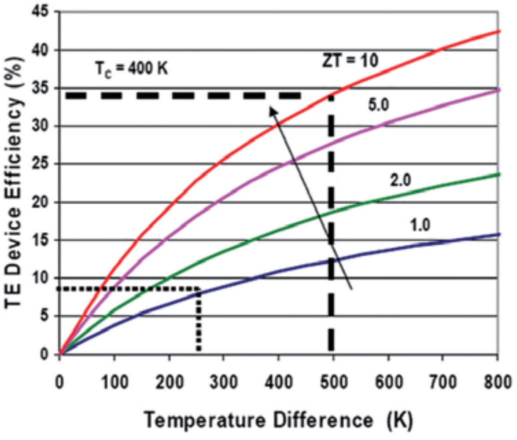
Table 1. Properties of some promising thermoelectric bulk materials.

exotic materials are still being researched on a laboratory scale and are quite a long way off commercialization. Table 1 lists the TE materials to be discussed and some of their relevant properties.

The temperature range listed for the materials in Table 1 is that within which their ZT values are at least 0.5, which is admittedly too low to compete with other methods of waste heat recovery but still high enough to make them useful in applications in which the advantages of thermoelectrics outweigh the disadvantages. Based on these temperature ranges, the materials in Table 1 can be roughly divided into low, intermediate and high temperature materials. Bi_2Te_3 is the only material in the low temperature category, oxides and La_3Te_4 go into the high temperature group, while all the other materials belong to the intermediate temperature group. The ZT values of the materials are not constant within the temperature range listed, so the variation in the ZT value is listed in the ZT column of Table 1. The ZT value is a good way to compare thermoelectric materials, and it also gives an estimate of the efficiency of the material in different temperature gradients. Figure 3 shows the estimated efficiencies of heat recovery for various ZT values in a temperature gradient.

The efficiencies of current state-of-the-art thermoelectric devices are in the 5–10% range,

Figure 3. Efficiency of a thermoelectric device based on its ZT value and the magnitude of the temperature gradient.



and it is clear from Figure 3 that the ZT values will need to be raised significantly for thermoelectrics to become competitive with traditional heat recovery methods.

TE materials must be efficient, stable, environmentally friendly, composed of elements abundant in nature and synthesized with a scalable method. The low-cost manufacturing process of the TEGs must also be addressed. Nowadays, manufacturing constitutes 50% of the cost of a TEG. At the moment, such materials and manufacturing methods do not exist or have not been explored sufficiently and constitute the main bottleneck for using this technology. [6]

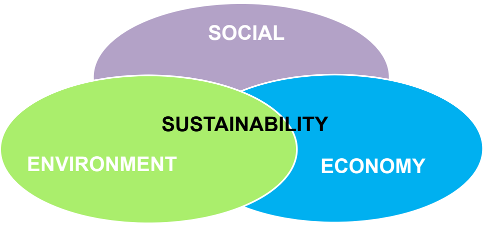


Figure 4. Three components of sustainability [7].

Sustainability

Meinander and Wahlström (2012) conducted a qualitative analysis of the sustainability of thermo-electric modules. Due to a lack of data, a quantitative LCA analysis could not be conducted. In order for a system to be sustainable it must fulfil the demands of all three parts, keeping a balance as illustrated in Figure 4. The sustainability of the TEs has been analysed based on economic, environmental and social sustainability. The environmental sustain¬ability is evaluated based on the material characteristics of the used materials. Environmental sustainability includes covering current and future demands for resource use. Due to the decreasing global resources of many rare materials used in the production of TEs, the environmental sustain¬ability is considered quite poor. Economic sustainability, i.e. profitability, can commonly be considered to be the main objective of any business and to be self-sustaining. As the materials used for TE production are becoming increasingly scarce due to heavy consumption in relation to the global resources, the material prices will probably continue to increase in the future, which is an indication of poor economic sustainability of TEs. Social sustainability includes not endangering any stakeholders throughout the life cycle of the product or service, including health aspects, social equity and exploitation. It is mainly dependent on the conditions for the employees during raw material extraction, processing and transport. There were no data on the origin of the materials, but as the majority of the production of the materials used in TEs is in emerging economies (where social conditions are generally poor) the production of these materials can be considered socially unsustainable.

The qualitative analysis does not enable a comparative analysis with another system, and the results of the sustainability analysis should therefore only be seen as indicative of where improvement and research are needed. The TEs are considered unsustainable due to the poor sufficiency of many of the used materials, as well as the lack of knowledge of their origin. By finding improved substitute materials and/or using recovered materials the environmental and social sustainability of the TEs could be improved.

Summary

Energy harvesting with thermoelectric generators is expected to have an important position among future sustainable energy technologies. With thermoelectric generators, waste heat can be converted into electricity. The existing sources of waste heat within societies were mapped. In the cases, the temperatures are typically lower than 300˚C and the heat sources are ubiquitous. The two main drawbacks of thermoelectrics are high cost and low efficiency, which limit the practical uses of thermoelectrics to low power applications such as wireless sensors and sensor networks. Such applications have not been available before and the novel low-power devices therefore provide new opportunities for energy harvesting applications. TE materials must be efficient, stable, environmentally friendly, composed of elements abundant in nature and synthesized with a scalable method. Enhanced research on thermoelectrics has been able to improve material properties, but progress is considered to be relatively slow. Another important factor affecting cost is manufacturing. Nowadays, manufacturing constitutes 50% of the cost of a TEG, and low-cost materials and manufacturing methods do not currently exist or are not explored sufficiently and constitute the main bottleneck for using the technology.

Recommendations given include further material science research on materials structure, electrical properties and performance, as well as processing and manufacturing to overcome obstacles related to price and production up-scaling. The work requires multi-disciplinary activity and co-operation. The utilization of advanced modelling supports the required multi-disciplinary actions.

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Title	Smart City Research Highlights
Author(s)	Miimu Airaksinen, Matti Kokkala
Abstract	All around the world, urbanization is a growing trend. As more and more people get together, smart systems and their integration need to be developed, not only to provide the services that people need but also to do so efficiently with minimum impact on the environment. It can be said that efficient ICT, one part of which is the Internet of Things, is a common dominator: tying together services, residency, mobility, infrastructure and energy. It is a global challenge to reduce environmental impact and the carbon footprint. At the same time, societal development needs to be addressed and the focus put on people's well-being. Pressure is growing to reduce our environmental impact, and there is a parallel compelling need for business to remain globally competitive. Sustainable transformation of cities is only possible when it is done in a smart way. Smart city design, operation and management need to be done at system level. Sub-optimization of individual components will not lead to optimal performance of the system. Multi-target optimization is not an easy task, but it becomes necessary as different components and systems are interlinked and interconnected – irrespective of where they are physically located. Traditional sector-based industries and value chains are also changing, and completely new business models are starting to emerge. Radical innovations and paradigm shifts are changing our whole city systems.
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Research Highlights in Smart City

This publication presents a compilation of extended abstracts of VTT's recent research on smart cities. The global challenge is to reduce environmental impact and carbon footprint. At the same time societal development needs to be addressed and people well-being must be in focus. Pressure is growing to reduce our environmental impact and there is a parallel compelling need for business to stay globally competitive. Investment and expenditure needs for improving energy efficiency, modernizing infrastructure and creating high quality living environments are enormous. Smart sustainability as a dominating driver of technology development can also be seen in the R&D portfolio of VTT Technical Research Centre of Finland. A clear focus of our research for smart cities is sustainable city development, holistic energy systems, eco-efficient and intelligent buildings and districts as well as smart transport systems. In addition we focus on services, ICT and material technologies for improving smart city functions.

Urban environment are in the key role when societies are mitigating climate change and adapting to its consequences. All around the world, urbanization is a growing trend. As more and more people get together, smart systems and their integration need to be developed, not only to provide the services that people need but also to do so efficiently with minimum impact on the environment. It can be said that efficient ICT, one part of which is the Internet of Things, is a common dominator: tying together services, residency, mobility, infrastructure and energy. It is a global challenge to reduce environmental impact and the carbon footprint. At the same time, societal development needs to be addressed and the focus put on people's well-being. Pressure is growing to reduce our environmental impact, and there is a parallel compelling need for business to remain globally competitive. Sustainable transformation of cities is only possible when it is done in a smart way. Smart city design, operation and management need to be done at system level. Sub-optimization of individual components will not lead to optimal performance of the system. Multi-target optimization is not an easy task, but it becomes necessary as different components and systems are interlinked and interconnected – irrespective of where they are physically located. Traditional sector-based industries and value chains are also changing, and completely new business models are starting to emerge. Radical innovations and paradigm shifts are changing our whole city systems.

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