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Abstract:

This report presents the major trends in technology, society and economy that are identified based on extensive analysing several studies and position papers by the project partners.

Keyword list: Embedded System Technology, Key Enabling Technologies, Technological challenges, Smart city, Internet of things, R&D&I, Smart, Trend map, Social challenges, Governance, Financing, Business Opportunities, Business Model

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1 Summary

This deliverable presents the results of activity 2.1.2 "Scout opportunities for business and research". Based on an extensive online research, 21 studies[1] on the national and international level were collected and analysed by the project partners. The studies contain good examples of best practices in the use of embedded systems technology for smart city projects or regions.

Current trends in technology and society, technical challenges and business opportunities in the area of embedded systems are summarized in this deliverable.

The findings in these three categories can be summarized as follow:

- **Trends in Society and Economy/ Vision for the Future**
  The growth of people living in cities, the rising proportion of the elderly population, resources scarcity and the virtualisation of communities are key societal challenges relevant to smart cities. Embedded systems are key technological building blocks for numerous innovative products and solutions in the area of smart cities. Mobile sensors, regulation and control services will be the basis for innovative applications in all areas of our lives.

- **Unresolved technological challenges**
  A technological cornerstone for smart city solutions is the "Internet of things"[2]. As building blocks of the "Internet of things" embedded systems are no longer considered only in isolated application contexts. Connectivity and closer interaction with the world put additional demands on embedded systems.
  Energy efficiency, interoperability, communication, standards, system complexity and dependability are challenges that are currently discussed and addressed in the analysed studies and position papers.

- **Business opportunities**
  Social challenges give raise to new needs which provide new market opportunities for developing new businesses. We have analysed and summarized the data concerning business opportunities according the Business Model Canvas[3]. Generally there are good market opportunities in the area of Smart Cities, where the biggest potential is in medical devices and the automotive industry. Other areas are Railway, Manufacturing, Security, Health and Mobility.

  Furthermore strategic partners are highlighted as a key element in all the companies' business models related to Smart cities. The partnerships can be in different areas such as R&D, funding, strategy and regulation.

This document serves as an important input for the SWOT analysis in deliverable 2.3.

[1] See Annex 1: List of Studies
[2] Internet of things, cyber-physical systems: Objects will be connected to the internet and will be able to identify themselves to other devices.
[3] See Osterwalder et al. 2010, *Business Model Generation*, Wiley

2 Analysis of existing Roadmaps for Embedded Systems / Smart Cities

The EU is determined to keep pace with its main international competitors. A key element to achieve this is to develop a world-class competitive industry with Key Enabling Technologies (KETs) as basis.

KETs are knowledge intensive and associated with high R&D intensity, rapid innovation cycles, high capital expenditure and highly skilled employment. They enable process, goods and service innovation throughout the economy and are of systemic relevance. They are multidisciplinary, cutting across many technology areas with a trend towards convergence and integration. KETs can assist technology leaders in other fields to capitalise on their research efforts.

Micro-/nanoelectronics, nanotechnology, photonics, advanced materials, industrial biotechnology and advanced manufacturing technologies (recognised as a "cross-cutting" KET) have been identified as the EU's KETs.

The CLINES project will contribute to the development of this world-class competitive industry. Micro-/nanoelectronics (embedded systems) are indispensable technology building bricks that enable a wide range of smart city solutions, the application domain which will be the focus throughout the CLINES project. CLINES will define how research driven Embedded Systems clusters can support the development of smart city solutions.

Analysis of the current situation in the area of embedded systems on a European level and identifying the most innovative developments in this deliverable will help to identify areas with high expected innovative potential in order to focus on high growth areas of research in the clusters.

3 Trends in Society and Economy/ Vision for the Future

3.1 Trends in Society and Economy

The CLINES approach is in line with the major trends in Society and Economy as could be concluded from analyzing several trend roadmaps and position papers. These are the major findings with respect to the trends:

- Embedded systems are key technological building bricks for numerous innovative products and solutions. Some quotes from the analysed roadmaps and position papers:
    - Embedded Systems will be everywhere
    - Embedding ICT in all types of artefacts is expected to have a massive impact.
    - Our digital and physical world will be integrated.
    - Mobile sensor, regulation and control services will be the basis for innovative applications in all areas of our lives.

- With a focus on Smart Cities, CLINES is addressing key societal challenges related to :
    - Growth of world population : 8.3 bn by 2030

  - Rising proportion of the elderly population. The average life expectancy worldwide will increase to 72 years by 2025 from 46 years in the 1950's.
  - The growth of people living in cities: from 3.5 bn in 2011 to 4.9 bn in 2030
  - The number of megacities (+10 mio inhabitants) which will rise from 21 (2009) to 29 (2025). In 2025, only in China, there will be 221 cities with more than 1 mio inhabitants. Europe currently has 35.
  - High density of city populations which increases the strains on energy, transportation, water, buildings and public spaces.
  - Resources scarcity: if we continue with a business as usual approach we will need 2.3 planets earth by 2050.
  - The virtualisation of communities which has changed our society and the way information and knowledge are exchanged.
- Embedded systems are defined as KETs and will be the basis for numerous applications. Success of those applications, i.e. Smart city applications, will have immediate impact on the success of the embedded system activities. But to make smart city activities flourish, specific challenges have to be taken into account.
  - To be able to create a competitive sector which can compete on a global stage, development, attraction and retention of highly skilled people is key.
  - New smart city solutions require rethinking of revenue models, eg. Governments are collecting massive taxes from fossile fuel; when implementing smart mobility solutions incomes from fossile fuel will probably be reduced.
  - Specific government support and government targets will have impact on adoption of innovative solutions.
  - Public authorities must have a clear policy/leadership related to innovation and new technologies.
  - A local digital agenda as a strategic tool is key to achieve digital cities in a planned and structured manner.
  - Cities should focus or create a new social and economic fabric based on creativity, innovation and new technologies.
  - Solutions will be more centered around the individual. Excellent human system interaction is needed.
  - Governance, financing and procurement models for smart city solutions are ill suited.
  - The huge amout of data generated by the billions of interconnected devices will need to be acuired and analysed

3.2 Visionary Scenarios

As CLINES wants to boost international cooperation between actors in the field of embedded technologies for smart cities, examples of visionary smart city scenario's may help to align stakeholders, to define common R&D&I projects, develop business partnerships and align cluster strategies.

These are the major findings in the analyzed studies with respect to the visionary secenarios in the Smart City:

3.2.1 Smart Mobility

3.2.1.1 Smart Mobility in a nutshell[4]

By Smart Mobility we mean ICT supported and integrated transport and logistics systems. For example, sustainable, safe and interconnected transportation systems can encompass trams, buses, trains, metros, cars, cycles and pedestrians in situations using one or more modes of transport. Smart Mobility prioritises clean and often non-motorised options. Relevant and real-time information can be accessed by the public in order to save time and improve commuting efficiency, save costs and reduce CO2 emissions, as well as to network transport managers to improve services and provide feedback to citizens. Mobility system users might also provide their own real-time data or contribute to long-term planning.

3.2.1.2 Visionary Smart Mobility Scenarios

Scenario 1: A world of fully-connected self-driving/parking cars offering maximum comfort to the passengers (safety, real-time information, premium audio/video entertainment) is Sub scenarios (or steps towards getting there) that are in particular relevant for Smart Cities are:

- zero-emission vehicles with a minimal impact on the quality of the environment (no CO2 or other harmful emissions)
- Vehicles that take into account the busy traffic in cities (involving pedestrians, cyclists, public transportation): crash avoidance & protection systems, advanced driver assistance systems (camera, radar…)
- Vehicles that are in continuous communication with their environment and the infrastructure (automatic speed limit adaptation, smart navigation and vehicle-to-vehicle communication for optimally balanced city traffic, etc.)
- Vehicles that automatically use the (limited) available parking spaces (auto-parking in narrow parking spots, etc.)
- The new generation is increasingly more interested in cars as a means of mobility when required, rather than some sort of status.

Scenario 2: Smart embedded computing in roads and vehicles will communicate traffic behaviour and intentions. This data will be aggregated and processed in real-time by large-scale compute services. The results will then be personalized and displayed by in-car interfaces to optimize traffic flow.

Scenario 3: Traffic management systems can be implemented. They are ICT-enabled systems, typically based on road sensors or active GPS to monitor real-time traffic information and manage city traffic in the most efficient and environmentally friendly. These objectives are to be achieved by speeding up the resolution of road network issues, reducing congestion and improving traffic flow. They primarily focus on mobility challenges but certainly have also impact on other smart city characteristics. Some examples of use cases:

- Traffic control centres mange incidents with real-time information, dynamically estimate traffic for the rest of the day, assess and confirm estimated travel times, and dynamically manages traffic lights

[4] Source : Mapping Smart Cities in the EU, EU DG Internal Policies, Dept. A Economic ans scientific policy 2014

- Cars are equipped with a device containing a telematics chip, which gathers relevant data from the central communication system of the car. Relevant sensor data, for example indicators of potholes or icy roads, are collected in-vehicle and transmitted to the cloud-enabled traffic centre.
- The actual travel times of vehicles are collected by means of 'smart' detection loops of traffic lights. Travel time savings are stored in a database, processed and shown on panels on Highway.
- Drivers receive from a data centre on their smart phones information about free parking spaces. In this way a central system guides each driver to the nearest parking spot.
- Using Radio and GPS technology enables traffic controllers to keep lights green if buses are approaching.
- The new services urge the citizens to move fast and smart while protecting the environment. The system informs in real time drivers via their Smartphone providing three alternative routes: the shortest, the most economical one, and the most environmentally friendly.
- An electronic journey planner delivers real-time information and calculates the best journey route for the traveller.
- Travellers use an ICT-based ticket the so called Travel Card. At the beginning and the end of a journey the card is read by an electronic sensor. The cheapest price of the journey is calculated and debited from the Travel Card.
- Commuters may no longer need to own a car. They use intermodal e-car sharing and e-bike service which can be booked via a smart phone application. The application includes information about possible kilometres to drive without charging the car or the bike, and checks on the remaining credit available for travel. In additional the application contains a map with e-bike and e-car stations and shows the next station.
- Public transport and electric vehicles are supplied by power of renewable energy sources.
- Bicycles are equipped with sensors in their wheels. These sensors measure environmental data like 'noise pollution, congestion and road conditions. The collected data are sent anonymously to the city in order to analyse environmental factors and measure the impact of traffic on the city infrastructure.

Scenario 4: Innovative mobility has to create tangible impact on societal level, such as: improved road safety, more comfort for individual users, reduced environmental impact. This can be realized by:

- Comprehensive planning and mobility assistants: A personal assistant application automatically comes up with suggestions to help the user plan their day and even makes travel arrangements on their behalf.
- Road safety through cooperating systems: Sensors in infrastructure and cars, communicated to backend servers and other cars (Car2X)
- Efficient and safe travel and the use of autonomous systems to coordinate traffic: Car maintains a virtual global model of the environment. Possibility to go into autonomous driving mode on especially equipped roads.

3.2.2 Smart Environment[5]

3.2.2.1 Smart Environment in a nutshell

By smart environment we include smart energy including renewables, ICTenabled energy grids, metering, pollution control and monitoring, renovation of buildings and amenities, green buildings, green urban planning, as well as resource use efficiency, re-use and resource substitution which serves the above goals. Urban services such as street lighting, waste management, drainage systems, and water resource systems that are monitored to evaluate the system, reduce pollution and improve water quality are also good examples.

3.2.2.2 Visionary Smart Environment Scenarios

Scenario 1: In the case of electric cars, energy efficiency can be realized by creating an ecosystem where the car can be either recharged from a household power supply or provide energy to the local grid, depending on the current energy price. To optimize efficiency, the car uses information on traffic conditions and weather collected by embedded sensors to plan its route.

Scenario 2: Micro infrastructures can be created by connecting as many things as possible. The objective is to connect as many entities, sensors and physical objects as possible in order to create run and manage this micro infrastructure with minimal direct human involvement. For example:

- Intelligent garbage cans: Solar energy allows automatic garbage compaction to reduce the volume of waste. Volume sensors allow efficient garbage collection.
- Smart streets: Lighting of the street adjusts to the level of natural daylight and the activities registered on the street.
- Monitoring system at the Parking area: Sensor network monitoring system at the parking area and outdoor areas of commercial buildings
- Smart water supply system: Monitoring in the pipe system provides data on such things as how slow the water is running, temperature, pressure and allows the management of water quality.

Scenario 3: ICT-enabled infrastructure improve the management of utilities for a city such as energy, water or electricity, e.g. smart power systems with intelligent management of energy mixes, smart grids, smart metering, heat storage, solar energy management systems, and surveillance management systems for resources such as clean tap water or wastewater or heating efficiency systems.

Interest in smart, energy-efficient building is growing, especially among those which mange large facilities, such as office buildings that traditionally use a lot of energy. Smart Buildings go far beyond saving energy. By creating a platform for accessible information and leveraging the connection between systems that until now have been entirely independent they address innovative objectives like minimizing energy cost, supporting a robust electric grid and mitigating environmental impact. Some examples:

[5] Source : Mapping Smart Cities in the EU, EU DG Internal Policies, Dept. A Economic ans scientific policy 2014

- All components inside a building will be linked by means of ICT and sensors. The majority of energy, ventilation, access and water devices will have embedded RFID chips or SIM cards and so become intelligent objects within a wirelessly connected environment.
- People can monitor and manage their energy (electricity, gas, heating and water) consumption with graphical user interface.
- Intelligent heating systems cover virtually all the households and commercial buildings in the appropriate high density areas of the city and an energy efficient district cooling system for its commercial customers. These systems make use of a range of excess heat sources all created within the city during the course of an average operational day, for example from various industrial and data centre activities, heat extracted from sewage and bio-based heating.

3.2.3 Smart Living[6]

3.2.3.1 Smart Living in a nutshell

By Smart Living we mean ICT-enabled life styles, behaviour and consumption. Smart Living is also healthy and safe living in a culturally vibrant city with diverse cultural facilities, and incorporates good quality housing and accommodation. Smart Living is also linked to high levels of social cohesion and social capital.

3.2.3.2 Visionary Smart Living Scenarios

Scenario 1: More human-centric embedded systems will continue to evolve. In the near future it will be possible to check vital health parameters in real time, monitor activities and administer drugs in an adaptive manner. The performance of the human body may even be improved by enhancing certain functions such as hearing, vision and even smell (e.g. by warning a person to the presence of toxic particles). The augmentation of the human body through intelligent technology is colloquially referred to as “human++”.

Scenario 2: ICT-enabled citizen participation platforms cover open data strategies and platforms, crowd sourcing and co-creation platforms and other forms of citizen participation and ideation. Most cities have data about a wide range of urban phenomena, such as living condition, employment, transport and economic that can be opened to the public. Using Open service platforms enables government to create an interface to open access to government data and services for third parties including entrepreneur and citizens. Open data can be the basis for new products and services in the information business, e.g. new apps that build on the analysis of new data sources. Some examples:

- Urban Operation System gather data from sensors buried in buildings and many other places to keep an eye on what is happening in an urban area. The sensors monitor everything from large scale events such as traffic flows across the entire city down to more local phenomena such as temperature sensors inside individual rooms”. The OS completely bypasses humans to manage communication between sensors and devices such as traffic lights, air conditioning or water pumps that influence the quality of city life.

[6] Source : Mapping Smart Cities in the EU, EU DG Internal Policies, Dept. A Economic ans scientific policy 2014

- Application on smart-phones could hook into the Urban Operation System to remotely control household appliances and energy systems.
- Regional information about population, urban services, economy and administration from public organisation will be easily accessible to the public. Opening up of public data make the society more functional and create better services.
- The citizens undertake most of their administrative procedures using online e-government services.

Scenario 3: Implementation of smart neighbourhood infrastructures. They are ICT-enabled carbon-neutral and sustainable and are designed to enhance resident's quality of life. Some examples:

- Bikes equipped with sensors to measure pollution and take action accordingly.
- Sharing platforms: to share cars, equipment, etc. between citizens in a neighbourhood.
- Smartphones and tablets increasing connectivity on the go and giving access to relevant data.
- Augmented reality solutions bringing support, assistance and information on the place of consumption, use, etc.
- Virtual guided neighbourhood tours: a virtual guide routing a tourist through a neighbourhood hereby taking into account personal preferences, weather forecasts, opening hours of museums, etc.

4 Technological Challenges

The studies listed at the beginning of each chapter do prominently mention the technological challenges described in the chapter.

The challenges are broken down into sub-challenges, detailing which challenging new technologies need to be mastered to overcome the Smart City demands.

4.1 Hardware and Communication

4.1.1 Manycore

[ITEAVision2030[7]], [DanishPosition[8]], [agendaCPS[9]]

The studies [ITEAVision2030], [DanishPosition] and [agendaCPS] specifically mention Multicore systems as key ingredient for networked embedded systems, which are essential for Smart Cities.

The [agendaCPS] goes into some detail, and lists advances that can provide solutions in the future:

- Optimising power consumption by hosting more functions on a single chip – including energy intensive I/O processing.
- Dedicated cores for specialised tasks will be directly integrated.
- Hardware-based virtualisation will enable consolidation of whole Systems.

[7] High Level Vision 2030 Opportunities for Europe, 2013
[8] ICT for Embedded Systems,2011
[9] Integrierte Forschungsagenda Cyber-Physical Systems

The study cautions that Multicore alone will not address the need for redundancy, since current multicore architectures are confined to a single substrate, and generally isolation mechanisms are lacking.

4.1.2 Sensor and Actuator Technology

[SmartHomeInterreg[10]], [agendaCPS[11]], [ArcadiaAligningAgendas[12]], [Ingutech[13]], [TelefonicaSmartCities[14]]

A cornerstone of Smart Cities, since data on the life in the city has to be collected (via sensors), and actions have to be accomplished via the actuators.

Challenges:

- Need to increase sensors' accuracy and speed, since these are currently often not sufficient to enable detailed real-time physical awareness.
- Sensors and actuators will be deployed in different and often extremely demanding environments, placing higher demands on their robustness and durability as well as on their size and energy consumption. In the most extreme cases, they may even have to be energy self-sufficient.
- The sensor systems by themselves will need certain intelligence and be able to act autonomously to provide certain services or parts of service without the need to connect to a central server. This requires increased processing power and memory (for example to capture the energy use of individual appliances).

[TelefonicaSmartCities] lists sensors that will be needed for Smart Cities: Security (e.g. smoke detectors), Lighting, Presence of persons, Weather, Transport, Movement (e.g. accelerometer, gyrometer) and Position (e.g. GPS).

4.1.3 Stable Distributed Controllers

[acatechSmartCities15], [agendaCPS]

Especially in the domain of Smart Grids, there is a need for concepts for stable, distributed controllers.

Distributed controllers are control systems or networks whose signal-processing components are geographically dispersed and may even be hierarchically structured, rather than being organised centrally.

Problems can arise as a result of connection failures, signal fluctuations caused by variations in communication latencies and packet loss, which typically has a major influence on controller behaviour and can easily result in controller instability. There is therefore a need for control concepts and the associated development and analysis processes and tools to enable the development of control algorithms (recognition, active grid control) that can counteract these

[10] Roadmap Smart Home, 2012
[11] Integrierte Forschungsagenda Cyber-Physical Systems, 2012
[12] Aligning Research Agendas in Embedded Systems (Arcadia)
[13] Ingutech Project Memory, 2012
[14] Smart Cities: un primer paso hacia la internet de las cosas (Telefonica), 2011
[15] Smart Cities – German Technology for the Cities of the Future

effects in a robust, scalable and hierarchical manner and that are adaptive or capable of reconfiguring themselves.

4.1.4 Communication

[agendaCPS[16]], [SmartHomeInterreg[17]], [ArcadiaAligningAgendas[18]], [TelefonicaSmartCities[19]], [MappingSmartCities[20]], [OutSmartActionPlan[21]]

The different parts of a Smart City have to communicate and exchange data to be able to provide meaningful services.

A system will consist of Personal Area Networks based e.g. on the Bluetooth and ZigBee short-range radio standards; Local Area Networks use e.g. wireless standards to enable nodes and systems to communicate with much higher data rates and over longer distances; and Wide Area Networks employing 3G, 4G and even 5G mobile communication technology cover much larger areas. Thus, both short range systems, in M2M language referred to as Capillary M2M, and long range system, in M2M referred to as Cellular M2M, will likely co-exist; some predict a full migration to cellular 4G/5G systems.

Challenges:

- The communication infrastructure will need to guarantee the most consistent and uniform service quality possible for all of the system's components.
- As the Smart City system is characterised by a high level of openness, it is necessary to constantly monitor and test the service quality of the connections in the system and make automatic adjustments in the event of any changes to the system.
- The smart city networks will be very heterogeneous; hence, interoperability and transparency will be essential.
- The data communication infrastructure is susceptible to blocking, interruption and eavesdropping, hence optimal data security must be guaranteed.
    - Lightweight cryptographic procedures and protocols that are tailored to the resource limitations.
    - The long service life of the components will require procedures, protocols and cryptographic keys that can either be replaced or that will remain secure throughout the duration of a prolonged service life.
- Sensor data needs to be submitted wirelessly in real time.

4.1.5 Non-Functional Requirements

4.1.5.1 Energy Efficiency

[CPSWorkshop[22]], [ArcadiaAligningAgendas], [HipeacComputing[23]], [OutSmartActionPlan], [ArtemisiaAgenda[24]]

[16] Integrierte Forschungsagenda Cyber-Physical Systems
[17] Roadmap Smart Home, 2012
[18] Aligning Research Agendas in Embedded Systems (Arcadia),2012
[19] Smart Cities: un primer paso hacia la internet de las cosas (Telefonica)
[20] Mapping Smart Cities in the EU, 2014
[21] Smart Cities: An Action Plan, 2011

In Smart Cities, the systems, sensors and actuators will be distributed all over town. Due to the sheer amount of systems, and the often limited access possibilities, the systems need to run as long as possible on their own energy supply. Energy harvesting typically only yields low energy volumes.

Challenges:

- Energy-aware algorithm design, for example using stochastic and approximate systems and algorithms.
- Dynamic adaptation/selection of heterogeneous multi/many core computing resources to application needs. Since the limits of power dissipation/consumption on a chip are already pushed, it will no longer be possible to power on all transistors on future chips simultaneously. Doing so will either dissipate too much heat or consume too much energy. This inability to turn on all of the transistors on a chip is known as “Dark Silicon”.
- Optimizing data movement, both for legacy applications and new computing modalities.
- Global system view for energy management.
- Reducing power consumption.

New hardware can offer solutions: Non-volatile memories, 2.5D and 2.3D integration techniques, new silicon technologies such as FinFETs (double- or triple-gate device) and FDSOI (Single-gate device)

4.1.5.2 Interoperability

[agendaCPS[25]], [SmartHomeInterreg[26]], [ArcadiaAligningAgendas[27]], [AutomotiveEmbedded[28]], [USSmartCities[29]], [Net!Works[30]], [MappingSmartCities[31]], [IntelligenteSystemer[32]], [DanishPosition[33]], [CPSWorkshop[34]]

The sheer number of studies pointing to interoperability and standards makes it a central challenge.

History shows that solutions to specific problems often are siloed, that is they are developed towards a specific problem or domain. On the contrary, solutions for Smart Cities have to be interoperable across the domains mentioned above. [USSmartCities] The most significant research challenge currently is thus the development of a European cross-domain approach to the design and implementation of embedded systems and the solid international standardization of the resulting architecture and tools. [ArcadiaAligningAgendas].

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22 CPS: Uplifting Europe’s Innovation Capacity, 2013
23 The HIPEAC vision for advanced computing in Horizon 2020, 2013
24 2014 MultiAnnual Strategic Research and Innovation Agenda for the ECSEL Joint,2014
25 Integrierte Forschungsagenda Cyber-Physical Systems, 2012
26 Roadmap Smart Home, 2012
27 Aligning Research Agendas in Embedded Systems (Arcadia)
28 Is Europe in the Driver's Seat? The Competitiveness of the European Automotive, 2010
29 Smart Cities Readiness Guide, 2013
30 Smart Cities Applications and Requirements., 2011
31 Mapping Smart Cities in the EU, 2014
32 Forslag til dansk program om: Teknologier til intelligente systemer, 2009
33 ICT for Embedded Systems, 2011
34 CPS: Uplifting Europe’s Innovation Capacity, 2013

Overall challenges:

- Standardisation (esp. open standards)
- Ensuring interoperability
- Common APIs

A drill-down on standardisation challenges:

- Domain models, ontologies and domain-specific languages (knowledge in a given application domain must be described in a domain model).
- Creating open Middleware, allowing simple integration of components (Plug and Play) and supporting new services.
- Interface specification technologies and interface management.
- Meta-level System-of-Systems coordination and cooperation, interconnectivity of subsystems

An example opportunity in Smart Buildings: Reconcile the standards for control and monitoring "inside the house" (KNX, LONWORKS EEBUS) with emerging standards for "outside building" energy data exchange (extensions of IEC61850, standard for the design of electrical substation automation) to support the integration of buildings in the smart grid.

4.1.5.3 Dependability

[HipeacComputing[35]], [agendaCPS[36]], [ArcadiaAligningAgendas[37]], [ArtemisiaAgenda[38]], [DanishPosition[39]], [CPSWorkshop[40]]

The Smart City systems need to be dependable and offer uninterrupted services – also during maintenance.

Challenges:

- Achieving higher levels of dependability.
- Secure run-time maintenance, care and development mechanisms.
    - Processes for testing the impact of changes on the safety and security goals.
    - Certified frameworks for safety relevant systems.
- Design for robustness.
- Platform for fault-tolerance.
- Design for Diagnosis.
- Self-reconfiguring systems, self-diagnosis.

4.1.5.4 Safety

[DanishPosition], [ITEAVision2030[41]], [agendaCPS].

Safety is related to dependability, but mentioned separately in studies.

[35] The HIPEAC vision for advanced computing in Horizon 2020, 2013
[36] Integrierte Forschungsagenda Cyber-Physical Systems, 2012
[37] Aligning Research Agendas in Embedded Systems (Arcadia), 2012
[38] 2014 MultiAnnual Strategic Research and Innovation Agenda for the ECSEL Joint,2014
[39] ICT for Embedded Systems, 2011
[40] CPS: Uplifting Europe's Innovation Capacity, 2013
[41] High Level Vision 2030 Opportunities for Europe, 2013

Special challenges:

- Component description and testing at run-time; Technologies for describing component safety make it possible to test key guaranteed characteristics such as maturity, permitted application contexts or operating status when components are integrated at run-time.
- Platforms with high-order integrated safety mechanisms; Most current platforms provide very few of the safety mechanisms required to implement safety functions. They are largely confined to hardware-oriented mechanisms such as memory integrity and fault containment or hardware-related mechanisms such as virtualisation.

4.1.5.5 Security

[Net!Works[42]], [ArcadiaAligningAgendas[43]], [DanishPosition[44]], [agendaCPS[45]]

The distributed nature of the Smart City systems makes it difficult to ensure the security of the services.

Challenges:

- Authentication of sensor data
- Intrusion detection in embedded systems infrastructures
- Trust management
- Development of lightweight cryptographic procedures and protocols
- Dedicated security hardware that can provide secure memory and secure execution environments. Currently, the majority of security hardware is deployed in conventional systems such as desktop PCs (e.g. under the name of Trusted Platform Modules).

4.1.5.6 Privacy

[Net!Works], [agendaCPS], [SmartHomeInterreg[46]]

Ensuring privacy for all city inhabitants is a prerequisite for the proliferation and accepted use of Smart City technologies. Despite realising this, few suggestions as to the concrete technical challenges are made in the studies (logging is cited as necessary to document data access).

[agendaCPS] proposes that the traditional information security goals have to be completed by three privacy goals: transparency, intervenability and unlinkability.

4.1.5.7 Certification

[ArcadiaAligningAgendas], [Net!Works], [ArtemisiaAgenda[47]], [CPSWorkshop[48]]

Embedded Systems must not only be constructed to work in a dependable way, but in most jurisdictions their traits must be officially certified before they may be implemented in Smart Cities. The studies stress that certification must already be supported in the design phase.

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[42] Smart Cities Applications and Requirements, 2011
[43] Aligning Research Agendas in Embedded Systems (Arcadia), 2012
[44] ICT for Embedded Systems, 2011
[45] Integrierte Forschungsagenda Cyber-Physical Systems, 2012
[46] Roadmap Smart Home, 2012
[47] MultiAnnual Strategic Research and Innovation Agenda for the ECSEL Joint Undertaking, 2014
[48] CPS: Uplifting Europe's Innovation Capacity2013

Challenges:

- Creating certified frameworks
- Auditing
- Affordable certification
- Modular and scalable approaches

4.1.6 Engineering Concepts

[Net!Works[49]], [AutomotiveEmbedded[50]], [ArcadiaAligningAgendas[51]], [ArtemisiaAgenda[52]], [DanishPosition[53]], [CPSWorkshop[54]]

From an engineering viewpoint, the exponential growth of complexity in increasingly networked embedded systems is the main challenge.

Challenges on the way to address this complexity:

- Platform thinking
- Tools for complex systems and environments
- Life cycle management
- Design methods and tools

Below, challenges in the engineering tools to address the complexity are more closely looked at.

4.1.6.1 Architectures

[IntelligenteSystemer[55]], [ArcadiaAligningAgendas], [AutomotiveEmbedded], [HipeacComputing[56]], [ArtemisiaAgenda], [DanishPosition]

A key tool to master Smart City complexity will be architectures.

Challenges:

- System design methods and tools to speed up the design process.
- Architecture-design, - exploration and -evaluation.
- Reference architectures and designs.
- Layered architectures.
- Model-based architectures.
- Components based on standard architecture.
- New architectures to support specific techniques like declarative programming and neural networks.

The [ArtemisiaAgenda] presents a timeline for solving Smart City architecture challenges:

[49] Smart Cities Applications and Requirements, 2011
[50] Is Europe in the Driver's Seat? The Competitiveness of the European Automotive,2010
[51] Aligning Research Agendas in Embedded Systems (Arcadia), 2012
[52] MultiAnnual Strategic Research and Innovation Agenda for the ECSEL Joint Undertaking
[53] ICT for Embedded Systems,2011
[54] CPS: Uplifting Europe’s Innovation Capacity, 2013
[55] Forslag til dansk program om: Teknologier til intelligente systemer,2009
[56] The HIPEAC vision for advanced computing in Horizon 2020, 2013

- Short term: Defining global architectures principles, programming paradigms and frameworks taking into account safe and secure operation in non-deterministic environment.
- Medium term: Translating these principles into modular and composable reference architectures and protocols including monitoring and diagnosis as well as application independent software.
- Longer term (see also chapter Higher Abstraction Layers): Adding cognitive users' model to the global Smart City architectural models (extension to novel application contexts).

4.1.6.2 Requirements Engineering

[ArcadiaAligningAgendas[57]], [ArtemisiaAgenda[58]], [agendaCPS[59]]

Challenges:

- The adequate understanding, analysis and accurate specification of the open application context, problem space, user goals, human-computer interaction and targeted specification of the functional and non-functional requirements in the shape of formal requirements models.
- The specification of non-functional requirements and quality models as well as the conversion of these requirements into architecture designs and models at the system integration (interoperability and semantic integration) and architecture design levels.
- Verification and validation methodology.
- Cooperative and distributed system debugging and validation.
- Environment modelling in the loop.

4.1.6.3 Requirements-oriented, Integrated Architectures

In order to integrate the various ontologies and modelling concepts, engineering needs standard requirements models and architecture concepts. The most important challenges are to combine basic system modelling concepts from the relevant domains, to develop an open Smart Cities platform with standard interoperability and Quality of Service services and come up with a way of managing autonomous and evolutionary systems.

4.1.6.4 Requirements Traceability

It is necessary to formalise the different user and stakeholder requirements and domain and context models, as well as possible ways of mapping these requirements onto the services that deliver them.

4.1.7 Domain Engineering of Open Applications and Platforms

[SmartHomeInterreg[60]], [agendaCPS]

Challenges:

- Specification and development of appropriate domain models including different user and stakeholder viewpoints and requirements.

[57] Aligning Research Agendas in Embedded Systems (Arcadia), 2012
[58] MultiAnnual Strategic Research and Innovation Agenda for the ECSEL Joint Undertaking, 2014
[59] Integrierte Forschungsagenda Cyber-Physical Systems, 2012
[60] Roadmap Smart Home, 2012

- Design of interoperable architectural and composition patterns for guaranteeing non-functional requirements.
- Flexible tailoring of the development processes and life cycle and integration management of different components and subsystems across different domains and companies, for example for remote maintenance or updating.

4.1.7.1 Quality Models and Integrated Validation and Verification Methods

[agendaCPS[61]], [ArtemisiaAgenda[62]], [ArcadiaAligningAgendas[63]]

Challenges:

- Comprehensive quality models, methods and end-to-end processes for the analysis, specification and guaranteeing of non-functional requirements .
- Formal quality models that precisely specify the quality in use requirements in open and networked contexts of use.
- Novel formal verification and validation techniques, including stochastic approaches.

4.1.8 Higher Abstraction Layers

From a technological viewpoint, the most mature stage of Smart Cities is that of tightly networked systems of systems consisting of embedded systems, that use a software-intensive backend to provide seamless real-world services to the citizens (such as modality-agnostic travel).

This level of integration and service provision poses a number of challenges on abstraction layers high above the hardware level.

4.1.8.1 Physical Awareness

[ArcadiaAligningAgendas], [SmartHomeInterreg[64]], [agendaCPS]

The ability to detect and recognise objects and the physical environment is called physical awareness. The Smart City services need to sense the physical situation before acting.

Challenges:

- Sensor fusion and data management: Fusion of data from several different sensors in order to obtain more accurate measurements or higher-order data.
- Pattern recognition: The use of algorithms and systems to recognise patterns in incoming data compare them against known patterns and assign the detected patterns to different categories.
- Situation maps: Combination of information from sensor fusion and pattern recognition to create a model of the physical situation.
- State-aware design.

[61] Integrierte Forschungsagenda Cyber-Physical Systems, 2012
[62] MultiAnnual Strategic Research and Innovation Agenda for the ECSEL Joint, 2014
[63] Aligning Research Agendas in Embedded Systems (Arcadia), 2012
[64] Roadmap Smart Home, 2012

4.1.8.2 Fully or Semi-autonomous Behaviour and Planning
[CPSWorkshop[65]] , [agendaCPS[66]], [SmartHomeInterreg[67]], [ArtemisiaAgenda[68]]

The Smart City will need to adapt autonomously to changes and need to act fully or semi-autonomously in order to fulfil goals that would typically either be set by the citizens or arise from their current situation. The systems must thus be able to plan ahead and predict the future.

Challenges:
- Decision making for automation.
- Creating bio-inspired Systems.
- Reliable and trustable decision making and planning.
- Distributed decision making.
- Rule-based system behaviour construction and “programming”.
- Multi-criteria situation assessment.
- Artificial intelligence.
- Cooperation and negotiation between systems, for example using multi-agent approaches.

4.1.8.3 Human-computer Interaction
[ArtemisiaAgenda], [ArcadiaAligningAgendas[69]], [CPSWorkshop], [agendaCPS]

If the Smart City services are to be easily used, the embedded systems must take into account the intentions and thinking models of the users – and they must provide a means for the users to understand the systems and their actions.

Challenges:
- Cross-sectorial usability
- Intuitive and enhanced accessibility for users
- Human centred design
- Availability of various human-computer interfaces and interaction modalities, such as touch screens, voice commands or body language. Should be modally independent.
- Intention and plan recognition, behaviour and routine capturing
- User and human modelling, to enable the diagnosis, simulation, prediction and support of human behaviour in interactions. Includes modelling complex interactions. Current research is focused on two applications: the "virtual test driver" and the "empathic virtual passenger".

4.1.8.4 Learning
[agendaCPS], [ArcadiaAligningAgendas]

Systems should adapt their behaviour and the way they cooperate to the requirements of their current context;

[65] CPS: Uplifting Europe’s Innovation Capacity,2013
[66] Integrierte Forschungsagenda Cyber-Physical Systems, 2012
[67] Roadmap Smart Home, 2012
[68] MultiAnnual Strategic Research and Innovation Agenda for the ECSEL Joint, 2014
[69] Aligning Research Agendas in Embedded Systems (Arcadia), 2012

One key challenge for this capability is the ability to build up knowledge, for example with regard to particular situations and the behaviour of human beings or based on experience from previous applications and interactions with different contexts.

Challenges for the machine learning and (big) data mining algorithms:

- Not stable enough to be used in safety critical environments.
- Not designed to handle the huge volumes of data involved.
- Relevant data are scattered across several distributed database systems.

4.1.8.5 Self-organisation

[ArcadiaAligningAgendas[70]], [agendaCPS[71]], [SmartHomeInterreg[72]], [DanishPosition[73]], [CPSWorkshop[74]], [ITEAVision2030[75]]

The Smart City technical systems becoming so complex, it will be required that they organise themselves, to integrate new resources, carry out new tasks, route around defective components, or adapt to changing environmental conditions. Especially in communication, self-organisation is required to ensure reliable communication.

Challenges:

- Self-adaptation.
- Emergence in self-organizing systems.
- Dynamic resource discovery and integration.
- Autonomous, Adaptive and Predictive Control

4.1.8.6 Connection to Business Software Backend / Cloud

[TelefonicaSmartCities[76]], [ITEAVision2030], [agendaCPS], [acatechSmartCities[77]], [Net!Works[78]]

Overall, system integration ultimately aims at an ICT-based integration of all urban infrastructures.

It is still open if the storage and analysis of data will be handled in a central facility (perhaps in the Cloud) or - more privacy friendly - in distributed nodes of the network.

For an ecosystem of providers of Smart City services, a service provisioning platform is required. Needed is a platform that facilitates the delivery of services in the scope of the Smart City. It consists of modules that allow for example to manage prices, agent negotiations, trust management, and service discovery.

The availability of Open Data is another key ingredient for useful Smart City services that will make sense economically.

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[70] Aligning Research Agendas in Embedded Systems (Arcadia), 2012
[71] Integrierte Forschungsagenda Cyber-Physical Systems, 2012
[72] Roadmap Smart Home, 2012
[73] ICT for Embedded Systems, 2011
[74] CPS: Uplifting Europe's Innovation Capacity, 2013
[75] High Level Vision 2030 Opportunities for Europe, 2013
[76] Smart Cities: un primer paso hacia la internet de las cosas (Telefonica), 2011
[77] Smart Cities – German Technology for the Cities of the Future, 2011
[78] Smart Cities Applications and Requirements, 2011

5 Business Opportunities

This section comprises an analysis of the sections concerning the business opportunities that arise in the implementation of the analysed scenarios and the capabilities that companies need in order to seize these opportunities. We have analysed the summarized data according to the Business Model Canvas (see Osterwalder et al. 2010, Business Model Generation, Wiley) in order to create an overview of the interplay between business opportunities and competences.

Companies that have relations to the area of Smart Cities can have different roles and therefore different Business Models depending on where and how they are located in the value chain. CPS[79] highlights different roles, which are both connected to the production and supply of components, operations of platforms, service and support in different aspects. This shows how companies can place themselves according to the whole value chain or to different parts of the value chain. Some companies might be suppliers of fully integrated systems or operate as specialized service providers for individual components, operating platforms or treat the collected data for different service purposes.

For these different areas of focus, different Business Models will arise. E.g. some companies have focus on the end-users (both companies and consumers), while other companies have other companies in the Smart Cities field as their customers. The review of the possible aspects of Business Models from the sources will be treated as one, which means that we will not differentiate between different parts of the value chain, and therefore it is up to the companies themselves to find their place in the value chain and from the inspiration of their own Business Model analysis. Lastly, many companies will probably think of their business in another way than that of a value chain, but rather in a business web, where a lot of different companies and customers collaborate, instead of in the form of suppliers and customers.

In the figure below the aspects from each source are put in to the Business Model Canvas. This gives an overview of all the different aspects on the Business Model within this sector. Each aspect will be elaborated upon below the figure. As it is seen in the figure some of the parts of the Business Model Canvas are blank, this is because it has not been possible to find information in these areas in the sources.

The cost structure is strongly related to the resources, activities and partnerships. While the channels are related to how the company reaches its customers. It is strongly highlighted in the sources and evident in the figure that Business Models to a high degree depend on collaboration, both between private and public companies in the Smart Cities business and with end-users. That is also why there is a red circle around the three building blocks; Strategic partners, Customers and Customer relations, because these three building blocks are strongly related in the business web and this relationship is concerned with collaboration between businesses. MSC [80]also highlights the creation of a central office that acts as go-between for Smart City ideas and initiatives.

[79] CPS - This is a Report of a Workshop on Cyber-Physical Systems held in October 2013 in Brussels (published December 2013), initiative by EC DG-CONNECT.

[80] Mapping Smart Cities in the EU

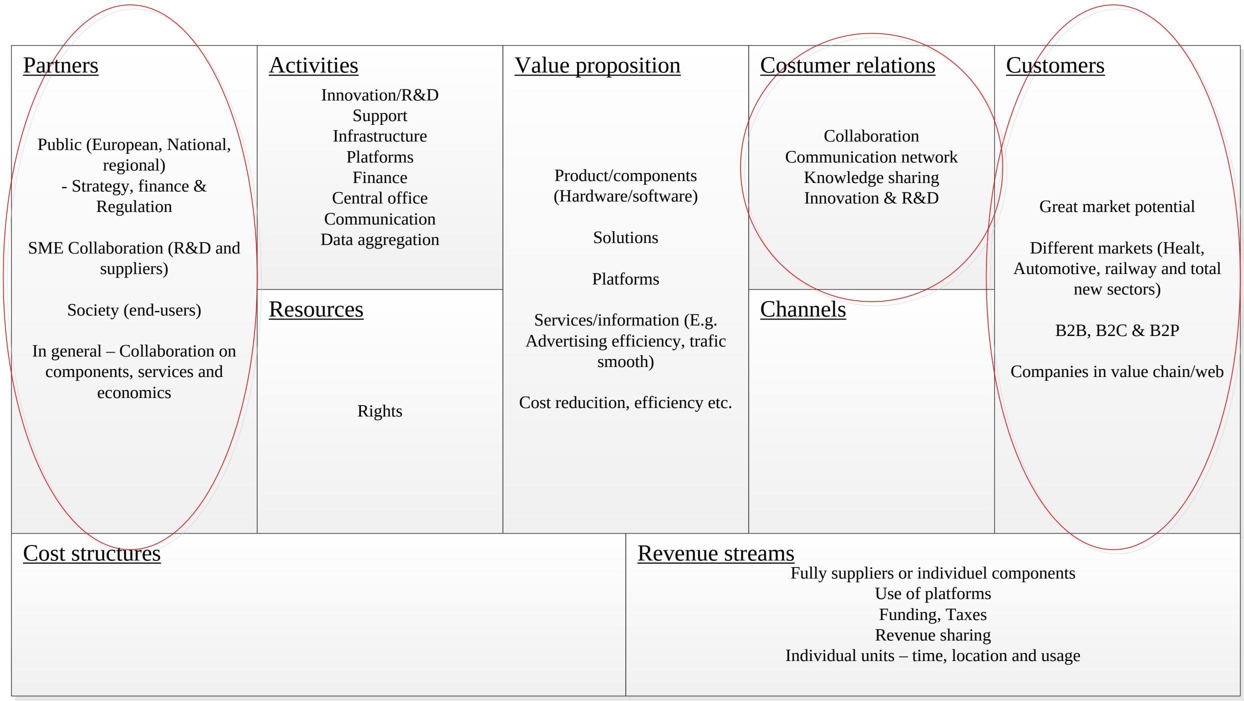

Figure 1: Business Model Canvas Structure

The elaboration will start with the customers:

5.1 Customers

The customer segment describes which customers there are in relation to the business and therefore it is focused on the potential business opportunities in the area of Smart Cities. Some of the sources focus on specific areas, while other has the overall view of Smart Cities. Generally there are good market opportunities in the area of Smart Cities. E.g. an estimate of more than 40 bn embedded applications until 2020 or 1.1 million jobs in embedded software in Europe in 2015. The opportunities for market growth can be seen in a lot of different areas. Artemisia81 highlights that there is almost no application area in which Embedded Systems have no direct or indirect impact. Arcadia82 highlights the market potential in different markets, where the biggest potentials are in medical devices and the automotive industry. Other areas are Railway, Manufacturing, security, Health and Mobility. But it can also be new other sectors such as food, energy and agriculture.

Customer segments will also depend on where a company places itself in the value chain/business web. Some customer segment will be other parties in the Smart Cities businesses, both private and public companies (B2B & B2P). Other customer segments will be the end-user of the product,

[81] *Artemisia – Aligning Research Agendas in Embedded Systems (Arcadia) (ArcadiaAligningAgendas).*

[82] *Arcadia Annex 2 (Part C) about embedded/cyberPhysical Systems of the 2014 MultiAnnual Strategic Research and Innovation Agenda for the ECSEL Joint Undertaking (ArtemisiaAgenda)*

platforms or services. These customers can again both be private and public companies, or consumers (B2C). Therefore, the customer segment highly depends on the placement in the value chain/business web.

5.2 Customer Relation

The customer relation describes the relationship between the customer and the company. Some of the sources highlight the importance of collaboration. This is both when the customers are the end-user and when they are other companies in the Smart Cities business. The collaboration is the innovation and R&D of the product and services, so that companies can learn and influence each other's technology developments and also to gain knowledge from the end costumer.

5.3 Value Proposition

The value proposition describes both the products and what value the products create for the customer. In the sources analysed the focus is mainly on the different products. By products, we mean physical products and single components, the platform and the services and information offered to the customers. This highlights again where the companies place themselves in the value chain. Some companies will focus on single component development, others focus on creating and administrating a platform and some again focus of the services that can be provided from the data. This also shows the tight relationship between the nine building blocks, where choices in one building block affect those of the other building blocks. The value the products create for the customer is not as much highlighted in the sources, but some of the presented value is in advertising, which can be done more efficiently, where you only reach out to the interesting customer based on the data, or in trafficking, where the data can be used to guide the traffic.

5.4 The Revenue Stream

The Revenue stream building block describes how the companies make money. Again the value chain plays a role in this block, because it will both determine what you are making money on (fully supplier, components or services, per unit) and how the company gets paid (funding, taxes, revenue sharing, direct payment). E.g. a collaboration with the public sector can ensure funding or payment through taxes.

5.5 Activities

Activities describe the key activities in relation to creating the value. From the sources analysed the main activities are both in relation to creating and developing products, both components and services. There are also some activities, which are strongly related to the business web and interaction with both partners and customers. These activities are just as important as the development and some of the activities are communication, data aggregation, infrastructure and finance (e.g. funding). MSC [83]also highlights a central office, which should act as centre of the business web and create and coordinate an overview between different ideas, data and stakeholders.

The resources describe the key resources in relation to the activities. The resources are not as much highlighted in the sources, besides platforms and rights in relation to the data. It is our view that the

[83] Mapping Smart Cities in the EU

focus on resources and competences and the companies' own understandings of their resources and competences needs to be analysed further moving forward. This seems a natural first step in helping the companies better understand how they can flourish in the smart city agenda.

5.6 Partner

Last but not least the Strategic partner building block describes the key partners in relation to creating value. From the sources analysed it is possible to conclude that partners are a key element in all the companies' business models in the Smart Cities businesses. Each company will have different partners, but some central partners are public, the EU, local and national governments and universities. The partnerships can be in different areas such as R&D, funding, strategy and regulation and can also be the central office of the web. Other partnerships could be between the SME's and also society or end-users. The partnerships can both be in relation to development and production of components, services or on the economic perspective. All in all the partnership building block is a central part of the business model.

Annex 1

List of Studies and Position Papers for Embedded Systems and Smart Cities

Name of study	Short Name	Year	Proposed by	Excerpt by
Roadmap Smart Home	SmartHomeInterreg	2012	DSP	AAU
Aligning Research Agendas in Embedded Systems (Arcadia)	ArcadiaAligningAgendas	2012	GAIA	TUM
Ingutech Project Memory	Ingutech	2012	GAIA	TecnGaia
Smart Cities: un primer paso hacia la internet de las cosas (Telefonica)	TelefonicaSmartCities	2011	GAIA	TecnGaia
Integrierte Forschungsagenda Cyber-Physical Systems	agendaCPS	2012	TUM	TUM
COSINE - Policies for Embedded Systems Research	COSINEPolicies	2010	DSP	AAU
Is Europe in the Driver's Seat? The Competitiveness of the European Automotive Embedded Systems Industry	AutomotiveEmbedded	2010	TUM	DSP
The HIPEAC vision for advanced computing in Horizon 2020	HipeacComputing	2013	TUM	AAU
Smart Cities Readiness Guide	USSmartCities	2013		Tecnalia/AAU
Smart Cities – German Technology for the Cities of the Future	acatechSmartCities	2011	TUM	TecnGaia
Smart Cities Applications and Requirements.	Net!Works	2011	TUM	DSP
Smart Cities Stakeholder Platform - 10 Year Rolling Agenda	RollingAgenda	2013	TUM	DSP
Mapping Smart Cities in the EU	MappingSmartCities	2014	DSP	TUM
Smart Cities: An Action Plan	OutSmartActionPlan	2011	AAU	TUM
Forslag til dansk program om: Teknologier til intelligente systemer	IntelligenteSystemer	2009	AAU	AAU
High Level Vision 2030 Opportunities for Europe	ITEAVision2030	2013	AAU	TecnGaia
2014 MultiAnnual Strategic Research and Innovation Agenda for the ECSEL Joint Undertaking	ArtemisiaAgenda	2014	AAU	DSP
ICT for Embedded Systems	DanishPosition	2011	AAU	DSP
CPS: Uplifting Europe's Innovation Capacity	CPSWorkshop	2013	DSP	DSP
Smart Cities Study: International study on the situation of ICT, innovation and Knowledge in cities	SmartCitiyIndicators	2012	GAIA	GAIA