Deliverable 1.3

Panorama of ICT landscape in EU and US: ICT, Policies, regulations, programmes and networks in the EU and US

Authors: Haydn Thompson, *THHINK – UK*
***Daniela Ramos-Hernandez**, THHINK - UK*

ICT Policy, Research and Innovation
for a Smart Society

May 2016

www.picasso-project.eu

PICASSO has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 687874.

Project Deliverable

Project Number:	Project Acronym:	Project Title:
687874	PICASSO	ICT Policy, Research and Innovation for a Smart Society: towards new avenues in EU-US ICT collaboration

Instrument:	Thematic Priority:
COORDINATION AND SUPPORT ACTION	H2020 ICT

Title:
D1.3 Panorama of ICT landscape in EU and US: ICT, Policies, regulations, programmes and networks in the EU and US

Contractual Delivery Date:	Actual Delivery Date:
May, 31st 2016	May, 27th 2016

Start date of project:	Duration:
January 1st, 2016	30 months

Organization name of lead contractor for this deliverable:	Document version:
THHINK	V1.3

Dissemination level (Project co-funded by the European Commission within the Horizon 2020 Programme)		
PU	Public	X
PP	Restricted to other programme participants (including the Commission)	
RE	Restricted to a group defined by the consortium (including the Commission)	
CO	Confidential, only for members of the consortium (including the Commission)	

Authors (Organizations):

Haydn Thompson (THHINK)

Daniela Ramos-Hernandez (THHINK)

Reviewers (Organization):

5G Expert Group, CPS/IoT Expert Group, Big Data Expert Group, Policy Expert Group and NIST.

Abstract: This report provides a panorama of ICT policies, regulations, programmes and networks in smart cities, smart transportation and smart energy and also an overview of industry-driven programs, priorities, networks, major projects in EU and US in the areas of 5G Networks, Big Data, Internet of Things and Cyber-Physical Systems. Additionally, these areas are also actively being pursued at the world level and relevant major programmes around the world have also been identified. Key work with respect to regulations and standards is highlighted for each of the domains. It is clear that there are many opportunities for joint collaborations between the EU and US. It would be possible to collaborate on research and policy, on regulations and on standards.

There are key opportunities in the areas of smart cities and IoT/CPS which are rapidly developing areas and where there are common research, regulatory and standardisation needs. There are also great opportunities in the areas of smart energy and smart transportation, however, here there is existing regulation and legislation which needs to be harmonised. For the underlying technologies, which are the basic building blocks of future applications: 5G, Big Data and IoT/CPS, there are many opportuntiies to work together which would allow bilateral access to EU and US markets and would allow technology and products to be sold on the world stage increasing the competitiveness of EU and US companies in existing and developing markets.

The report is live and will be updated in September 2016 with more material. Please contact the authors at Haydn.Thompson@thhink.com if there are key programmes, networks, regulations or policies that you think should also be included.

Keywords: Smart Cities, Smart Energy, Smart Transportation, 5G, Big Data, IoT, CPS

Disclaimer

Change History

Haydn Thompson 12/5/2016	Draft Circulated
Haydn Thompson 24/5/2016	V1.0 Updates to include 5G Expert Group and IoT/CPS Expert Group Comments
Haydn Thompson 25/5/2016	V1.1 Suggested collaboration opportunities tables for internal use removed from published deliverable
Haydn Thompson 27/5/2016	V1.2 Submitted to Commission
Haydn Thompson 31/5/2016	V1.3 Addition of information on document update plan and contact details for input

Table of Contents

List of Figures

Acronyms and Definitions

Acronyms	Defined as
ACER	Agency for the Cooperation of Energy Regulators
ADEME	Environment and Energy Management Agency
ADS-B	Automatic Dependent Surveillance - Broadcast
AID	Automatic Incident Detection
AIOTI	Alliance for the Internet of Things
AMI	Advanced Metering Infrastructure
ANPR	Automatic Number-Plate Recognition
ANR	National Research Agency
ANSI	American National Standards Institute
APAC	Asia Pacific
APEC	Asia Pacific Economic Cooperation
ARES	Aerial Reconfigurable Embedded System
ARIB	Association of Radio Industries and Businesses
ARMD	Aeronautics Research Mission Directorate
ARPA-E	Advanced Research Projects Agency–Energy
ARRA	American Recovery and Reinvestment Act
ARTEMIS-IA	Advanced Research and Technology for Embedded Intelligence and Systems Industry Association
ASC	Amsterdam Smart City
ASTRAEA	Autonomous Systems Technology Related Airborne Evaluation & Assessment
ATP	Automatic Train Protection system
AVI/AVL	Automatic Vehicle Identification and Location
BMBF	Federal Ministry of Education and Research (Germany)
BND	Federal Intelligence Service (Germany)
BSI	British Standards Institute
BUB	Bottom-UP Broadband
BuNGee	Beyond Next Generation project
BUTLER	uBiquitous, secUre inTernet-of-things with Location and contEx-awaReness project
CAA	Civil Aviation Authority
CAGR	Compound Annual Growth Rate
CAM	City Analysis Methodology
CCIT	California Center for Innovative Transportation
CEDS	Cyber-security for Energy Delivery Systems
CEER	Council of European Energy Regulators
CEF	Connecting Europe Facility
CEN	European Committee for Standardization (Comité Européen de Normalisation)
CENELEC	European Committee for Electrotechnical Standardization
CFM	Community Foundry Model
CIP PSP	Competitiveness and Innovation framework Programme, Policy Support Programme
CISE	Common Information Sharing Environment
CNAP	Cyber-security National Action Plan
C-ITS	Cooperative Intelligent Transport Systems

CML	Compass Modelling Language
COFRET	Carbon Footprint of Freight Transport
COMPASS	Comprehensive Modelling for Advanced System of Systems
CPS	Cyber-Physical Systems
CPSoS	Cyber-Physical Systems of Systems
CPS PWG	Cyber-Physical Systems Public Working Group
C-RAN	Cloud Radio Access Network
CRE	National Energy Regulator (France)
CRE	Comisión Reguladora de Energia (Mexico)
CRM	Citizen Relations Management
CROWD	Connectivity management for eneRgy Optimised Wireless Dense networks
CRYSTAL	CRitical sYSTem engineering AcceLeration project
CSA	Coordination and Support Actions
CSAAC	Cyber-Security Advanced Analytics Cloud
CSIA	Cyber-Security and Information Assurance
C2C	Car to Car
C2C-CC	CAR 2 CAR Communication Consortium
C2I	Car to Infrastructure
DANSE	Designing for Adaptation and evolutionN in System of systems Engineering project
DARPA	Defense Advanced Research Projects Agency
DCC	Dublin City Council
DCE	Digital City Exchange
DECC	Department of Energy and Climate Change
DHS	Department of Homeland Security
DISA	Defense Information Systems Agency
DITMAC	Defense Insider Threat Management and Analysis Center
DLR	German Aerospace Centre
DoD	Department of Defence
DOE	Department of Energy
DOT	Department of Transportation
DSM	Digital Single Market
EASA	European Aviation Safety Agency
EISA	Energy Independence and Security Act
EC	European Commission
ECHR	European Convention on Human Rights
ECSEL	Electronic Components and Systems for European Leadership
ECSEL-JU	Electronic Components and Systems for European Leadership programme
EEA	European Economic Area
EERA	European Energy Research Alliance
EFTA	European Free Trade Association
EIP	European Innovation Partnership
EIP – SCC	European Innovation Partnership on Smart Cities and Communities
EIT	European Institute of Innovation and Technology
EMC^2	Embedded Multi-Core systems for Mixed Criticality applications in dynamic and changeable real-time environments project
EMSA	European Maritime Safety Agency
ENSG	Electricity Networks Strategy Group
EPSRC	Engineering and Physical Sciences Research Council
ERA	European Railway Agency
ERTMS	European Railway Traffic Management System
ESOs	European Standards Organizations
ETCS	European Train Control System

ETI	Energy Technology Institute
ETNA	European Transport Network Alliance
ETP	European Technology Platforms
ETSI	European Telecommunications Standards Institute
EU	European Union
EV	Electric Vehicle
EV4SCC	Electric Vehicle for Smart Cities and Communities
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
FERC	Federal Energy Regulatory Commission
FHWA	Federal Highway Administration
FP7	7th Framework Programme
FTC	Federal Trade Commission
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GSM	Global System for Mobile
HEFCE	Higher Education Funding Council for England
HetNets	Heterogeneous Networks
HGV	Heavy Goods Vehicle
HIPAA	Health Information Portability and Accountability Act
HNDU	Heat Networks Delivery Unit
HPC	High Performance Computing
ICT	Information and communications technology
IEC	International Electrotechnical Commission
IEDs	Improvised Explosive Devices
IEEE	Institute of Electrical and Electronics Engineers
IERC	IoT European Research Cluster
IGERT	Integrative Graduate Education and Research Traineeship
IIC	Industrial Internet Consortium
IMO	International Maritime Organization
IOS	Interoperability Specification
IoT	Internet of Things and
IoTSF	Internet of Things Security Foundation
IREEN	ICT Roadmap for Energy Efficient Neighbourhoods
ISGAN	International Smart Grid Action Network
ISO	International Organization for Standardization
ISTAR	Intelligence, Surveillance, Target Acquisition and Reconnaissance
IT	Information Technology
ITA	International Trade Administration
ITDP	Institute for Transportation and Development Policy
ITL	Information Technology Laboratory
ITS	Intelligent Transport Systems
ITU	International Telecommunication Union
ITU-T	ITU Telecommunication Standardization Sector
I4MS	Innovation for Manufacturing SMEs Initiative
JMS	Joint Management System
JPO	Joint Program Office
JTC	Joint Technical Committee
KIC	Knowledge and Innovation Community
LA	Latin America
LCICG	Low Carbon Innovation Coordination Group
LCNF	Low Carbon Networks Fund
LeGSB	Local eGovernment Standards Body

LTE	Long Term Evolution
LTE-A	Long Term Evolution-Advanced
MEA	Middle East and Africa
MIF	Maritime Industries Forum
MIIT	Ministry of Industry and Information Technology
MIMO	Multiple Input, Multiple Output
MOST	Ministry of Science and Technology
MOU	Memorandum of Understanding
MSIP	Ministry of Science, ICT (information and communications technology) and Future Planning
M2M	Machine to Machine
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NCATS	National Center for Advancing Translational Sciences
NCCOE	National Cyber-security Center of Excellence
NCCP	NIST Cloud Computing Program
NCI	National Cancer Institute
NDRC	National Development and Reform Commission
NFV	Network Functions Virtualization
NGMN 5G	Next Generation Mobile Networks 5G
NGO	Non-Governmental Organization
NIBIB	National Institute of Biomedical Imaging and Bioengineering
NiCE	Networking Intelligent Cities for Energy Efficiency
NIH	National Institutes of Health
NIST	National Institute of Standards and Technology
NBD-PWG	NIST Big Data Public Working Group
NITRD	Networking and Information Technology Research and Development
NRC	Nokia Research Center
NSF	National Science Foundation
NSTC	National Science and Technology Council
OBSSR	Office of Behavioral and Social Sciences Research
OCF	Open Connectivity Foundation standard
ODI	Open Data Institute
OECD	Organisation for Economic Cooperation and Development
OEM	Original Equipment Manufacturer
OGD	Open Government Data
OIC	Open Interconnect Consortiums
OMG	Object Management Group
ON.Lab	Open Networking Laboratory
ONF	Open Networking Foundation
ONRC	Open Networking Research Center
ORION	On Road Integrated Optimisation and Navigation
OSNP	Open Sensor Network Platform
PDG	Public Data Group
PEB	Positive Energy Blocks
PFN	French Nuclear Platform
POSSE	Promotion of Open Specifications and Standards in Europe
PPP	Public-Private Partnership
PSCM	Public Service Concept Model
RANaaS	RAN-as-a-Service
RBC	Radio Block Centre
RDT&E	Defense Research, Development, Test, and Enhancement
RESS	Renewable Energy self-sufficiency

RFI	Request for Information
RFID	Radio Frequency Identification
RTOs	Research and Technology Organisations
RTP	Reference Technology Platform
RUS	Rural Utilities Service
RPAS	Remotely Piloted Air System
SAE	Smart Everything Everywhere initiative
SC	Sub-Committees
SCF	Smart City Framework
SDN	Software-Defined Networking
SERA	Single European Railway Area
SESAR	Single European Sky ATM Research programme
SETIS	Strategic Energy Technologies Information System
SGA	Smart Growth America
SGCC	Smart Grid Interoperability Panel (SGIP) Cyber-security Committee
SGDP	Smart Grid Demonstration Program
SGIG	Smart Grid Investment Grant
SGIP	Smart Grid Interoperability Panel
SMART	Sustainable Mobility & Accessibility Research & Transformation
SMEs	Small and Medium-sized Enterprises
SysML	Systems Modeling Language
SoS	System of systems
SRA	Strategic Research Agenda
SRRA	Strategic Rail Research Agenda
SSH	Smart Systems and Heat
SSI	Smart Systems Integration
SSTI	State Smart Transportation Initiative
STTP	Strategic Transport Technology Plan
Tbps	Terabit per second
TCAUP	Taubman College of Architecture and Urban Planning
TEN-T	Trans-European transport networks
TEPCO	Tokyo Electric Power Corporation
TERN	Trans European Road Network
TOD	Transit-Oriented Development
TRIP	Transport Research and Innovation Portal
TRKC	Transport Research Knowledge Centre
TRL	Technology Readiness Level
TSB	Technology Strategy Board
TWh	Terawatt hour
TX	Transformer program
UAS	Unmanned Aircraft Systems
UAV	Unmanned Aerial Vehicle
UC	University of California
UMTRI	University of Michigan Transportation Research Institute
US	United States of America
USDA-NIFA	U.S. Department of Agriculture-National Institute of Food and Agriculture
UTC	Urban Traffic Control
U-TacS	UAV Tactical Systems
VPPs	Virtual Power Plants
VSAT	Very-Small-Aperture Terminal
VSL	Variable Speed Limits
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
WeGO	World e-Governments

WG	Working Groups
WIVW	Wuerzburg Institute of Traffic Sciences
WNCG	Wireless Networking and Communications Group
WWRF	Wireless World Research Forum
W3C	World Wide Web Consortium
3GPP	3rd Generation Partnership Project
4G	Fourth Generation
5G	Fifth Generation
5GIC	5G Innovation Centre
5GMF	Fifth Generation Mobile Communications Promotion Forum
5G VIA	5G Vertical Industry Accelerator

1 Executive Summary

This deliverable provides a "Panorama of ICT landscape in EU and US: ICT, Policies, regulations, programmes and networks in the EU and US". Additionally, key activities in the rest of the world are also presented in order to put the work being performed within the EU and US in context. The intention of this document is to set the scene for the PICASSO project which has the intention to reinforce EU-US ICT collaboration in pre-competitive research and innovation related to key societal challenges: smart cities, smart energy and smart transportation, and in key enabling technologies: 5G Networks, Big Data, Internet of Things and Cyber-Physical Systems. These areas were chosen because they are key enablers for tackling the societal challenges mentioned above. Additionally, they are also an enabler for higher productivity and better service. Notably large ICT research and innovation efforts exist in both the EU and the US in these areas and they are also priority topics in various funding programmes in the EU and the US. As a consequence networks and critical mass in these subjects is present on both sides of the Atlantic which affords the opportunity for collaboration. The document provides:

- An overview of ICT policies, regulations, programmes and networks in the selected application domains (societal challenges): smart cities, smart transportation and smart energy.
- An overview of industry-driven programs, priorities, networks, major projects in EU and US related to 5G Networks, Big Data, Internet of Things and Cyber-Physical Systems
- An overview of ICT regulations in the selected domains.

The key aim of the document is to identify gaps and opportunities, the key challenges in the selected domains and open problems, and the needs for supporting policy measures and strategic EU-US initiatives (both policy and research related). Here potential areas where collaboration may be possible between the EU and US have been formulated as input for discussion within the PICASSO Expert Groups. These are not included in this document as they will be discussed and refined in future work. In total 15 potential areas have been identified where it may be possible to collaborate on research and policy, 16 areas where there is an opportunity to work together on regulations and 9 areas where it would be beneficial to work together on standards.

The most furtile areas for collabration are in smart cities and IoT/CPS where there are a range of research, regulatory and standardisation needs. However, there are also great opportunities in the areas of smart energy and smart transportation. In terms of the underlying technologies it is clear that a common approach and joint work on addressing 5G, Big Data and IoT/CPS would not only allow bilateral access to EU and US markets but would also allow technology and products to be sold on the world stage increasing the competitiveness of EU and US companies in existing and developing markets.

2 Introduction

Increased urbanisation is a key challenge for the future. It is predicted that by 2050, the world population will reach nine billion with a fundamental shift in demographic towards a more elderly population. The expectation is that 60% of the population will be older than 50 and that 75% of the population will live in cities. This will create great challenges to provide energy supply, logistics, health care, security, food and water. The growing rise in the use of ICT to provide interconnectivity, information and optimisation of services is leading to many "Smart" solutions being proposed. In this report we give a panorama of a number of the key projects which have been initiated in the EU, US, and around the world, to tackle these societal issues and also the underlying technologies. The key areas addressed in this report are:

Smart Cities: The area of smart cities includes many potential topics. In this domain ICT supports the efficient use of space, infrastructure and other resources in cities, e.g. integrated smart transportation concepts, lighting, smart garbage collection, optimising use of water and energy, monitoring for safety and the well-being of the inhabitants. It can also include governance, education and the monitoring of citizens health.

Smart Energy: ICT is exploited in many areas within energy supply and is used to provide availability of services, and management to reduce consumption and CO2 emissions. It is used for the stable operation of grids using secure communication systems with automatic load balancing and rejection of attacks, for incorporation of renewables within the main supply and also increasingly for interacting with grids for demand-side management. Smart energy usage is also being enabled within smart factories and smart homes to provide improved energy efficiency in buildings and production.

Smart Transportation: ICT is being used in smart transportation to provide an optimised use of infrastructure to increase capacity and also to improve the safety of road transport. This is being achieved through sophisticated traffic management systems that are relying on increased connectivity between cars and between cars and infrastructure. In the longer term the introduction of increased autonomy will lead to fundamental changes to traffic operation.

The key technologies addressed are:

5G: 5th generation wireless systems will be the next major phase of mobile telecommunications standards going beyond current 4G/IMT-Advanced standards offering data rates of 1 gigabits per second for several hundreds of thousands of simultaneous connections with extremely low latency of less than 1 ms. This coupled with reductions in energy consumption will enable massive sensor deployments in future.

Big Data: Big Data analytics covers the processing, analysis and use of very large data sets to extract value for data to provide trend detection, decision making, greater efficiency, cost reduction, risk reduction, crime and disease prevention, or to provide services to citizens.

IoT/CPS: The Internet of Things (IoT) is used to describe the network of physical objects, e.g. devices, vehicles, buildings, embedded electronics, software and sensors and network connectivity. Here objects can collect and exchange data allowing objects to be sensed and controlled remotely across network infrastructure to improve efficiency, accuracy and provide economic benefit. When feedback is introduced combining sensors with computing and actuators then Cyber-Physical Systems are created allowing control of smart cities, smart grids, intelligent transportation systems.

The social and economic challenges are common across the world and there are opportunities for the EU and the US to work together on these global challenges for mutual benefit, not only in allowing solutions from EU and US providers to be sold within each other's economic areas but also on a world-wide scale. In addition to economic benefits, there will be benefits to society and the end-users. The expectation is that by working together competitiveness on both sides will be improved leading to better products and services. Joint research and innovation will lead to a faster development of better solutions and will enable societal challenges to be addressed more efficiently. Alliances of industrial enterprises and academic institutions across Europe and the US and public-private partnerships will speed up the transfer of existing knowledge to applications and the development of new technologies for the benefit of all citizens.

Economic competition and differences in approaches and policies between the EU and the US have contributed to a number of projects and technologies being pursued on both sides of the Atlantic. The aim of the panorama report is to highlight the key initiatives that are ongoing as the basis for discussion for potential alignment of activities with a view towards pre-competitive research and innovation. Through collaboration it will be possible to enable faster development, provide opportunities to market new technologies, and better understand the cultures and markets that exist. Collaborative efforts will lead to addressing the global challenges more efficiently and will create market opportunities in the US and world-wide for European companies, who will also have advantages from new open innovation opportunities at a greater scale. In the other direction, EU citizens will profit from open competition.

2.1 Objectives and Scope of the Deliverable

PICASSO WP1 (EU and US Industrial drivers, societal needs and ICT collaboration landscape) aims to set the scene for the project execution. In order to achieve this, this deliverable as part of task 1.2 in particular provides a panorama of the EU and US ICT landscape focusing on ICT policies and regulations, programs, priorities, networks and projects.

The task objectives are to provide an:

- Overview of ICT policies, regulations, programmes and networks in the selected application domains (societal challenges): smart cities, smart transportation and smart energy.
- Overview of industry-driven programs, priorities, networks, major projects in EU and US related the expert group topics.
- Overview of ICT regulations in the selected domains.

These areas are consolidated in this report (D1.3) to provide a Panorama of ICT landscape in EU and US: ICT, Policies, regulations, programmes and networks in EU and US. The deliverable is organised in three main sections addressing the societal challenges, the thematic domains and identified opportunities for collaboration.

2.2 Panorama of ICT Landscape in the EU and US

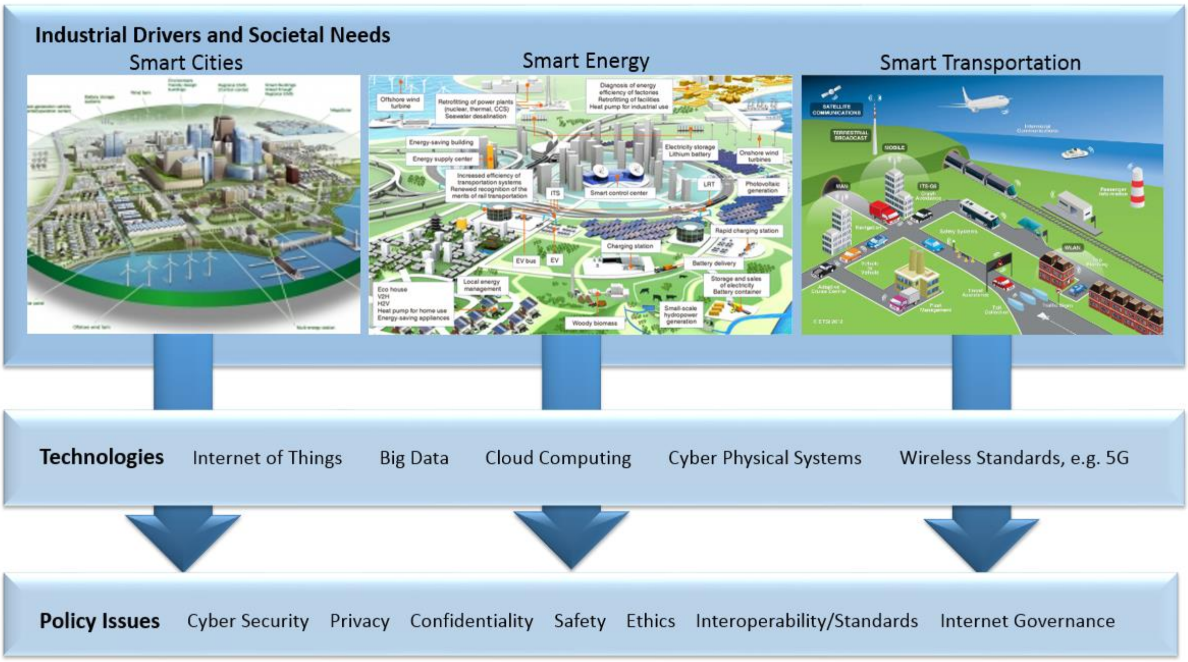


Figure 1. PICASSO Panorama

In this section the panorama of ICT landscape in EU and US is described. It should be noted that the area is huge and thousands of references have been found across the domains. It is not possible to include all of these references or describe all of the work that is going on in the area. Thus the report confines itself to the key programmes, projects or initiatives that are being undertaken within the EU and US. Additionally, where considered appropriate, references to other key work going on in the rest of the world is included to set the overall context of the work. The panorama covers the ICT, policies, regulations, programmes and networks in three societal challenges: Smart Cities, Smart Energy and Smart Transportation as depicted in Figure 1.

These societal needs as well as the industrial drivers will drive the future of key technologies such as Internet of Things, Big Data, Cloud Computing, Cyber-Physical Systems and Wireless Standards such as 5G. The successful deployment of these technologies is also dependent upon policy issues and introduction of standards. Here there needs to be harmonisation across Europe and also across the world. There are needs to consider cyber-security, privacy, confidentiality, safety, ethics, interoperability/standards, and internet governance. In many cases these are currently barriers to adoption of new solutions and so they need to be addressed at a fundamental level on a world-wide scale.

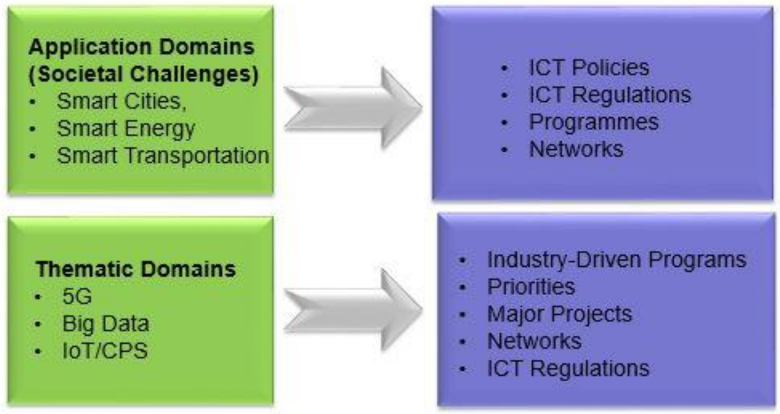


Figure 2. Panorama of ICT Landscape

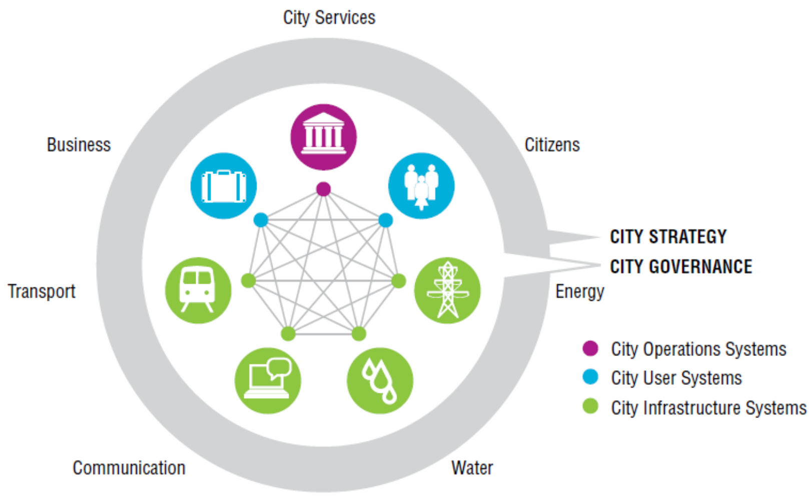
The structure of this report follows that shown in Figure 2. The application domains (societal challenges) of Smart Cities, Smart Energy and Smart Transportation are first considered, and for each of this, the main programmes, projects, networks and important ICT policies and ICT regulations within EU and US are highlighted. It should be noted that the topic of Smart Cities has a very wide remit and also covers Smart Energy and Smart Transportation to some extent. Here care has been taken to try and make a distinction between projects/programmes directly addressing Smart Cities and those that are focused on Smart Energy and Smart Transportation.

Following this, at the technological level, the main industry-driven programs, priorities, projects, networks and ICT regulations both in Europe and in the US for each of the selected thematic domains (5G, Big Data, IoT/CPS) are considered. This corresponds to the 3 main technical working groups set up within PICASSO. The intention of this is to provide input into the 3 main working groups, defining a baseline and starting point for discussions. In addition a 4th working group will consider the policy issues that need to be addressed providing input papers in a number of areas, e.g. privacy.

3 Smart Cities

3.1 European Smart City Drivers and Policy Activities

Increased urbanisation combined with increased instrumentation and interconnection is leading to cities having greater control and intelligence. Smartness allows cities to be sustainable and to provide public safety, health and education services and a good quality of life for their citizens. 100 years ago less than 20 cities had populations of more than 1 million people. Now there are 450 [1] and as they get larger they gain greater economic, political and technological power becoming the hubs of a globally integrated, services-based society. Operationally, cities are based on a number of core systems composed of different networks, infrastructures and environments related to their key functions: city services, citizens, business, transport, communication, water and energy. Service delivery is provided by the city authority which coordinates delivery across different agencies, allocating public funds and conducting physical planning activities. Cities also offer citizens and business the ability to move things around through their transport systems and to share ideas and information through their communication systems. Two core utilities necessary for all economic and social activity are also provided – water and energy. EC assessments have shown that resident engagement is one of the most critical conditions for the operating effectiveness of all smart city programmes/initiatives. Residents are both end-users and are at the front-end of energy use and energy services [2].



Source: IBM Center for Economic Development analysis.

Figure 3. Cities Systems and their Interrelationship with City Strategy and Governance

The various systems are interconnected to form a "system of systems" as shown in Figure 3. There is a need to balance the demands of each through service coordination, considering health, the needs of business, efficiency of transport, water leakage/quality and energy efficiency/security.

New technologies provide much greater scope for instrumentation, interconnection and intelligence of a city's core systems. However, it is necessary to carefully prepare and plan how to implement change and take into account the interrelationships between systems. For example, transport, business and energy systems are closely interrelated as they are all users of energy. Likewise a substantial amount of electricity is used in pumping and treating water. In Malta, for example, a new smart utility system will inform citizens and business about their use of both energy and water, enabling them to make better decisions about resource consumption. A reliable and efficient transport system reduces congestion, reduces carbon dioxide emissions improving health, and reduces stress and accidents. Less congestion also frees up more time for people to work or to relax.

The application of advanced information technology, analytics and systems thinking is also likely to attract, create, enable and retain citizens' skills, knowledge and creativity within cities [3]. With urbanisation cities contain an increasingly large number of the world's highly skilled, educated, creative and entrepreneurial population, giving rise to highly concentrated and diverse pools of knowledge and knowledge-creation networks. This coupled with the ability of cities to support large-scale business and investment networks is likely to see a shift towards cities for economic development. Thus strategic design of public services, building better transportation systems, supporting creative innovation and technological research and development, can be used to provide a supportive environment for delivering a higher quality of life, making a city more attractive to a knowledge-based population (See Figure 4).

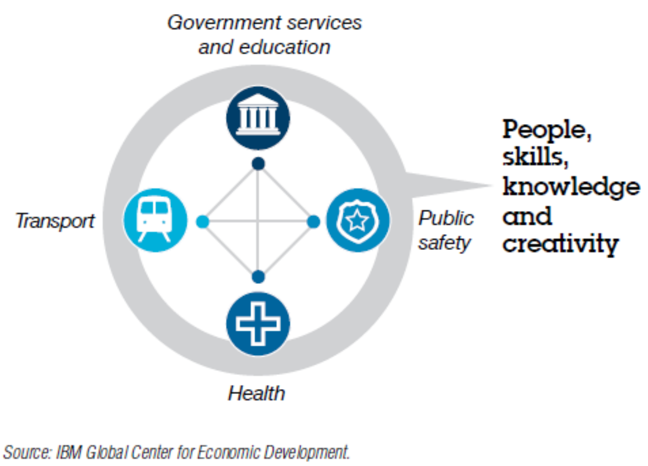


Figure 4. Interrelated Connections between a City's Core Systems

3.1.1 Scope of Smart Cities

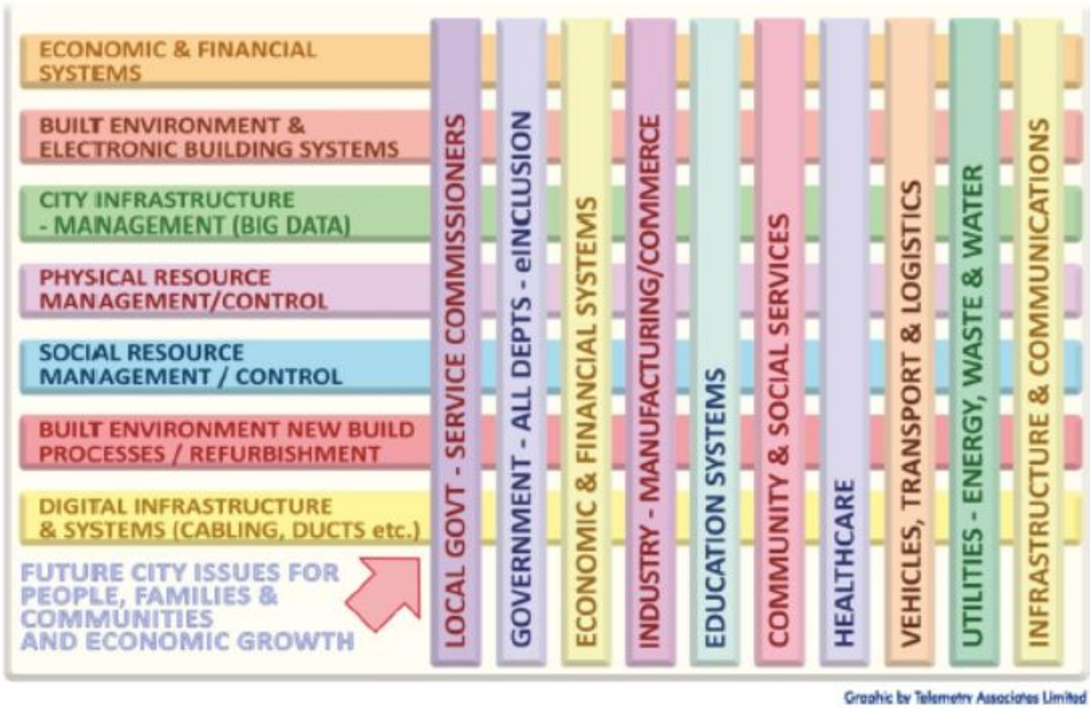
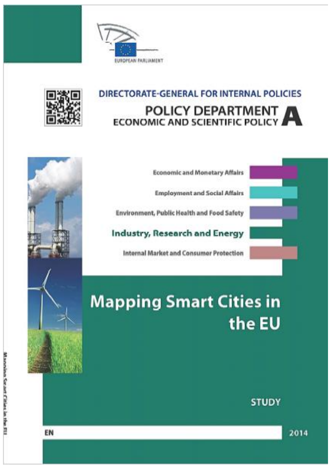


Figure 5. Areas that are Encompassed by Smart Cities

A challenge when considering the domain of Smart Cities is the shear breadth of different areas that are being affected by the use of ICT. In Figure 5 one can see that “smartness” can be utilised in a number of areas affecting government, economic and financial systems, building management, manufacturing, education, community and social services, healthcare, transportation, utilities and infrastructure and communications. In this report it is not possible to consider all of these domains as there are literally 1000’s of references covering all of these areas. The panorama report thus concentrates on the domains which are of particular interest to PICASSO.

3.1.2 Smart Cities within Europe

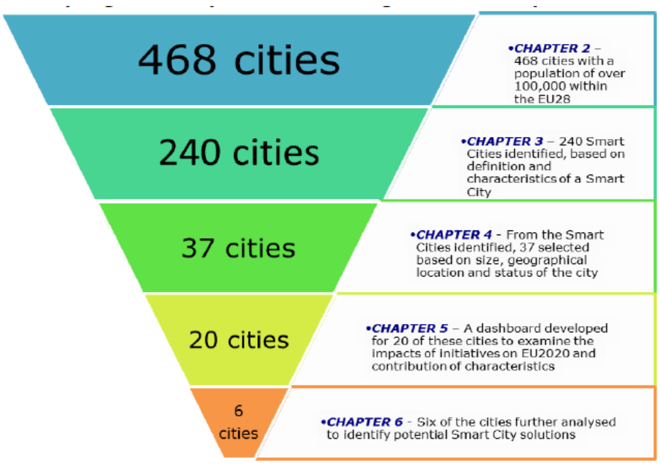


Recommendation	Intended for
Understanding Smart Cities: research and evaluation	
Detailed panel of longitudinal case studies with city-level funding and outcome data	DGCNECT, DG JRC
Standardised evaluation and assessment methods to measure success at internal, city and European level for impact assessment and benchmarking	The European Commission (EC) and Impact Assessment Board (IAB)
Develop methods and structures for a needs assay of the city's performance against relevant targets and presentation scorecards	Collective effort led by existing Smart City clusters[1]
Designing Smart City initiatives and strategies	
Mandate specialised impact assessment guidelines for Smart City strategies and initiatives to include: SMART objectives, issues of timing and uncertainty, and assessment of experimental variation	Funding bodies,[2] IAB, Smart City clusters
Promote local modularity for early-stage initiatives	Funding bodies, Smart City clusters; additional specific funding from EC, local government stakeholders
Facilitate exit and change of participation during the latter stages of an initiative	Funding bodies, Smart City clusters, local government stakeholders
Structural conditionality in funding for Smart City initiatives	Funding bodies
Specific design procedure for structuring Smart City initiative components	IAB, Smart City clusters, local government stakeholders (as monitoring hosts)
Smart City governance	
European-level Smart City platform with brokerage or intermediary functions	EC
Privileged or low-cost access to existing infrastructures	Local government stakeholders, infrastructure operators, national regulatory agencies
Mandatory multi-stakeholder governance with lay users represented and on integrated project teams	Funding bodies and government authorities and participants
Encourage industry-led public–private partnership consortia	Funding bodies and government authorities and participants

Recommendation	Intended for
Supporting the development of Smart Cities	
Use demand-side measures to stimulate demand for city-based 'Smart solutions'	Member State and local government procurement agencies, Horizon 2020, service users, standards bodies, national regulatory agencies
Selective use of regulatory forbearance and/or pro-competitive sourcing	Procurement agencies, national regulatory agencies, European Parliament
From Smart Cities to a Smarter Europe: replication, scaling and ecosystem seeding	
Periodic assessment of scalability potential and identification of instruments and activities to optimise pan-European dissemination of good practices and solutions	EC (platform), IAB (guidelines), local authority participants
Include Smart Cities as a future internet public–private partnership (PPP) use case or involve Smart City stakeholders in large-scale pilots, standards bodies, etc.	Future Internet Public–Private Partnership (FI-PPP), Horizon 2020, EC (supporting standards body engagement with additional specific funding)
Expand support for Smart Cities and Communities – European Innovation Partnership	EC
Additional resources for Smart City translation and transfer	EC, Member States
Create and encourage Smart City-specific new intellectual property ownership rights and contract forms	EC, Council, Parliament; possible WIPO

Figure 6. Mapping Smart Cities in EU

In [4] (See Figure 6) a study was performed within Europe to identify the key characteristics of smart cities and what the main areas of interest were. The report also makes recommendations on assessment of initiatives, how to design initiatives and strategies, on governance within smart cities, on how to support smart cities and how to replicate best practice across Europe and on creating a supporting ecosystem.



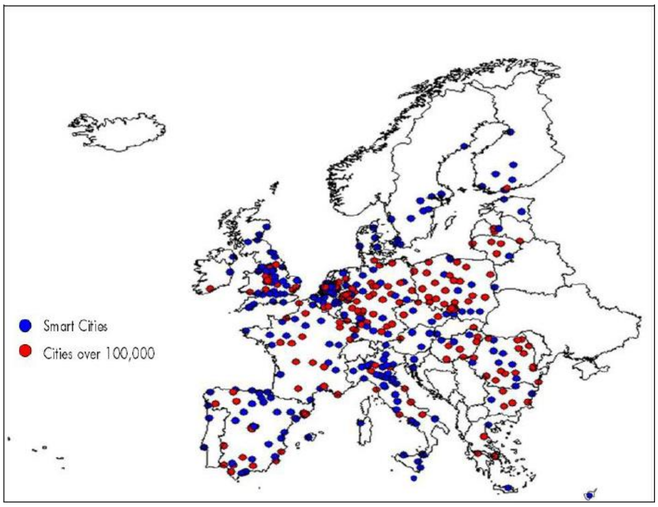
KEY FINDINGS

- There are many definitions of Smart Cities. Some focus on ICT as a technology driver and enabler, while broader definitions include socio-economic, governance and multi-stakeholder aspects such as the use of social participation to enhance sustainability, quality of life and urban welfare.
- In any case, a Smart City is quintessentially enabled by the use of technologies (especially ICT) to improve competitiveness and ensure a more sustainable future by symbiotic linkage of networks of people, businesses, technologies, infrastructures, consumption, energy and spaces.
- In this study, **a Smart City is a city seeking to address public issues via ICT-based solutions on the basis of a multi-stakeholder, municipally based partnership. These solutions are developed and refined through Smart City initiatives**, either as discrete projects or (more usually) as a network of overlapping activities.
- More concretely, the strategies and initiatives of a Smart City must include at least one of the following characteristics (objectives and/or modes of operation): Smart Governance, Smart People, Smart Living, Smart Mobility, Smart Economy and Smart Environment. These characteristics constitute the ends for which stakeholders participate in a Smart City initiative (e.g. to solve an environmental issue).
- The means by which those ends are achieved include a range of components: technologies; material, financial, organisational and knowledge inputs; processes; and norms or standards. These components may already be present or may be created specifically for use in Smart City initiatives.
- Components therefore provide the building blocks of Smart City initiatives and comprise three types: technological, human and institutional.

Figure 7. Key Findings

The report performs an analysis of 468 cities. These are considered with respect to roll out of different smart technologies and their use. From this there are a number of key findings as shown in Figure 7. These indicate that there is different emphasis across Europe in the areas that are being addressed within Smart Cities. In some areas, smart transport, and emissions are key drivers. In other areas smart governance is a key driver. It should also be noted that a city can be large or small and also be smart, indeed the majority of smart cities tend to be smaller, however larger cities display the use of more smart technologies as one might expect.

Finally, the report considers 6 smart cities in particular which display the highest number of smart features. These were Amsterdam (the Netherlands), Barcelona (Spain), Copenhagen (Denmark), Helsinki (Finland), Manchester (UK) and Vienna (Austria). Notably Amsterdam started work on its smart city initiative in 2009 and has 45 on-going projects in three geographic areas: Nieuw West, Zuidoost, and Ijburg. Barcelona launched the first smart city project in 2010. Other cities are also covered in the report, e.g. Tallinn and Santander, but these display less smart features.



	Smart Neighbour hoods	Testbed micro infrastructures	Intelligent traffic systems	Resource management systems	Participation platforms
	10	7	11	14	8
Smart Environment	+++	+++	++	+++	*
Smart Mobility	++	++	+++		*
Smart Governance				++	+++
Smart Economy	++	++		++	++
Smart Living	++			+	*
Smart People	++			+	++

50 Smart City Projects

Figure 8. Smart Cities in Europe

At a country level looking across Europe, the UK, Spain and Italy have the largest number of Smart Cities with more than 30 each as shown in Figure 8. Notably of the larger countries Germany and France have fewer Smart Cities. In general smaller countries have absolute lower numbers of Smart Cities. It can also be seen in Figure 8 that considering the top 50 smart cities the projects are concentrated in the areas of smart environment (12 projects), smart mobility (8 projects) and smart economy (8 projects).

3.1.3 European Commission Policy Actions and Strategy

The European Commission has been extremely active in trying to promote the concept of smart cities [5] and also in encouraging development of new technologies to enable smart features to be introduced into leading cities. Here the Commission has produced a number of strategic documents [6], communications [7], and also developed research strategies [8].

3.2 Key European Initiatives on Smart Cities

3.2.1 European Initiative on Smart Cities

The European Initiative on Smart Cities has been set up to support cities and regions. The key goal is to help cities take ambitious and pioneering measures to reduce greenhouse gas emissions by 40% through sustainable use and production of energy by the year 2020. This requires a systemic approach and organisational innovation to bring together measures on energy efficiency, adopt low carbon technologies and encourage smart management of supply and demand. The initiative particularly targets buildings, local energy networks and transport and builds upon existing EU and national policies and programmes, such as CIVITAS, CONCERTO and Intelligent Energy Europe.

This is also linked to the Strategic Energy Technologies Information System (see section on SETIS in Smart Energy section) which has an industrial initiative in the areas of Solar and Electricity Grid, as well as the EU public-private partnership for Buildings and Green Cars established under the European Economic Plan for Recovery. Notably this initiative is mobilising the Covenant of Mayors which involves local government from more than 4500 cities and has produced a strategic roadmap of activities covering building, heating and cooling, electricity and transport as shown in Figure 9.

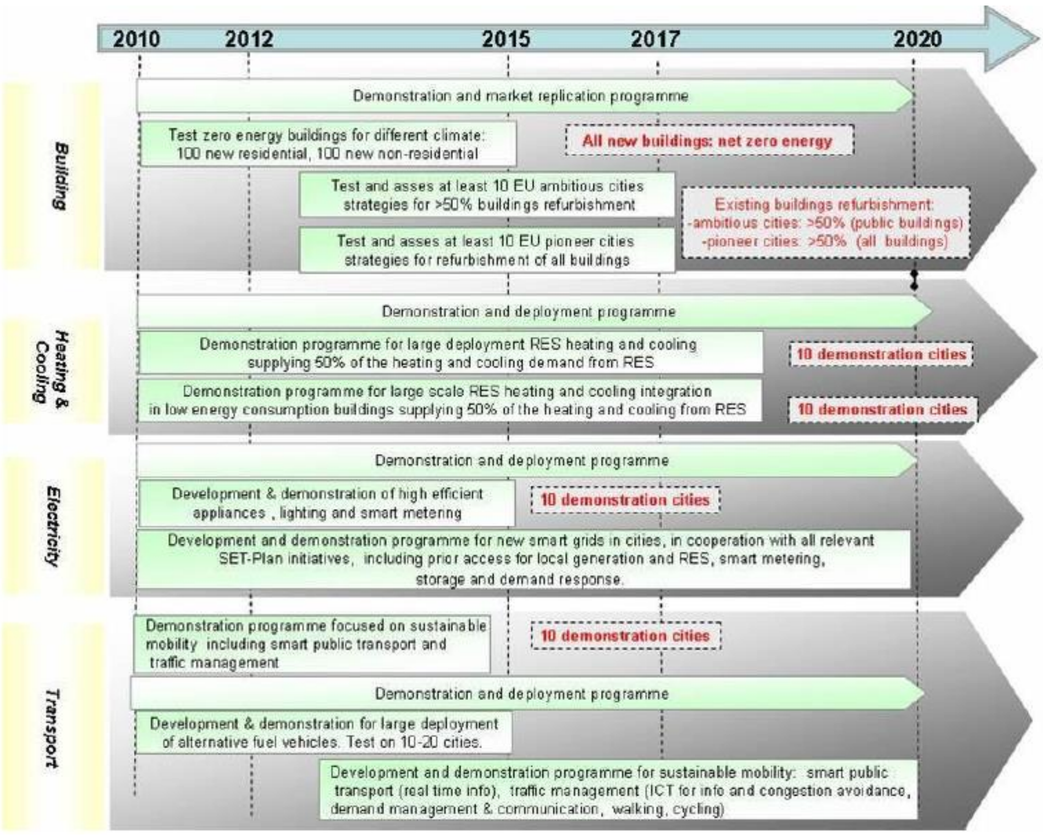


Figure 9. Smart Cities Technology Roadmap [9]

3.2.2 European Innovation Partnership for Smart Cities and Communities

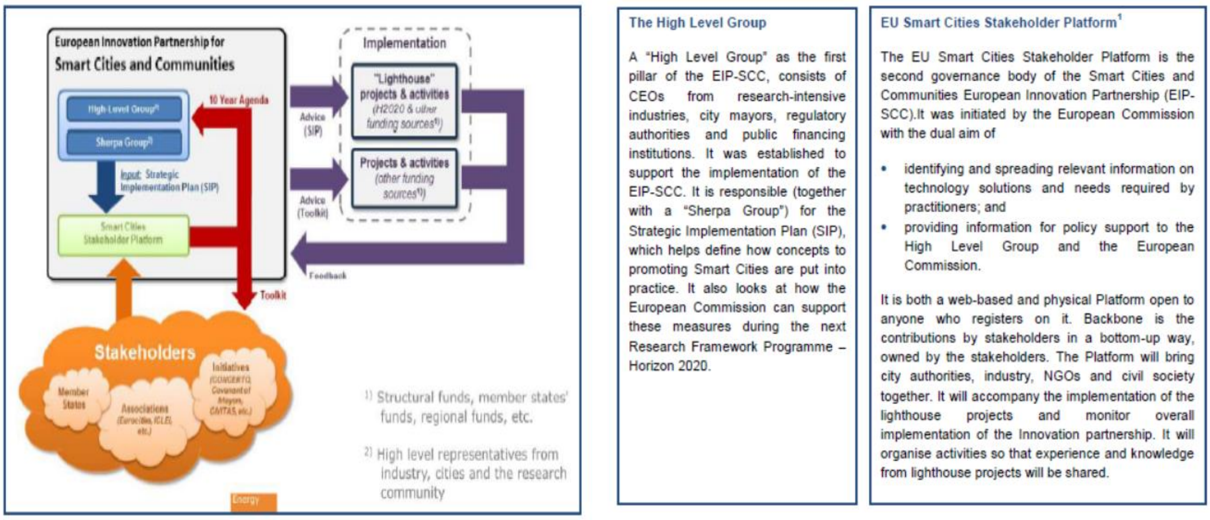


Figure 10. European Innovation Partnership for Smart Cities and Communities

The European Innovation Partnership for Smart Cities and Communities (EIP-SCC), as shown in Figure 10, is not a single initiative but actually part of a much broader effort by the EC to foster a new approach to EU research and innovation [10][11][12][13][14][15]. In total five European Innovation Partnerships have been launched. The European Innovation Partnership for Smart Cities and Communities is targeted at investing in sustainable development in as many cities as possible. The key word is "partnership" and the concept is to create equal partnerships between cities and companies based on synergies between ICT, energy and mobility. As highlighted by Günther H. Oettinger, then the EU Commissioner for Energy in November 2013, "This will lead to projects that make a real difference in our everyday lives."

Neelie Kroes, European Commissioner for the Digital Agenda in May 2013, stated that "By being geared towards addressing the energy and climate targets that we have set for ourselves for 2020, this Partnership will focus on our cities becoming more sustainable places to live and do business in. This translates into a greater quality of life for the individual citizen. It also provides tremendous market opportunities for local innovative businesses as well as our industries in the ICT, energy and mobility sectors."

The partnership is organised into a High Level Group made up of CEOs from large companies, city mayors, regulatory bodies and public financing institutions, and the Smart Cities Stakeholder Platform. This platform is used to engage with stakeholders who can sign up to the platform allowing development of an ecosystem in a bottom up fashion.

Supporting this is a need to create "Lighthouse Projects" which act as a model project with a signal effect for numerous follow-up projects in other cities. €81 Million of EU funds have been earmarked for these covering two sectors relevant to smart cities: transport and energy.

A Strategic Action Plan has also been created to promote Smart City concepts on a wider scale. This is shown in Figure 11.

Figure 11. European Innovation Partnership on Smart Cities and Communities Operational Implementation Plan (Sherpa Group Feb 2014)

The plan covers activities in sustainable mobility, sustainable districts and the built environment and also in integrated infrastructures and processes. Here a holistic approach is being adopted covering citizens and decision makers, knowledge and data gathering, funding and procurement.

3.2.3 Small Giants

In order to address smaller cities the Small Giants Initiative is targeted at small and medium-sized European cities that have less than 250,000 inhabitants. This has been set up by the EIP to strengthen the uptake of smart city solutions by facilitating networking, project building, fostering access to finance and ensuring up-scaling of solutions. Small Giants is project-driven and considers the fact that such cities have budget constraints and limited human resources [16].

3.3 National Initiatives

In addition to European-wide initiatives, there are a large number of national initiatives across Europe as indicated in section 3.1.2. It is not possible to include information on all initiatives in this document and thus a number of key initiatives are highlighted which are of interest.

3.3.1 UK

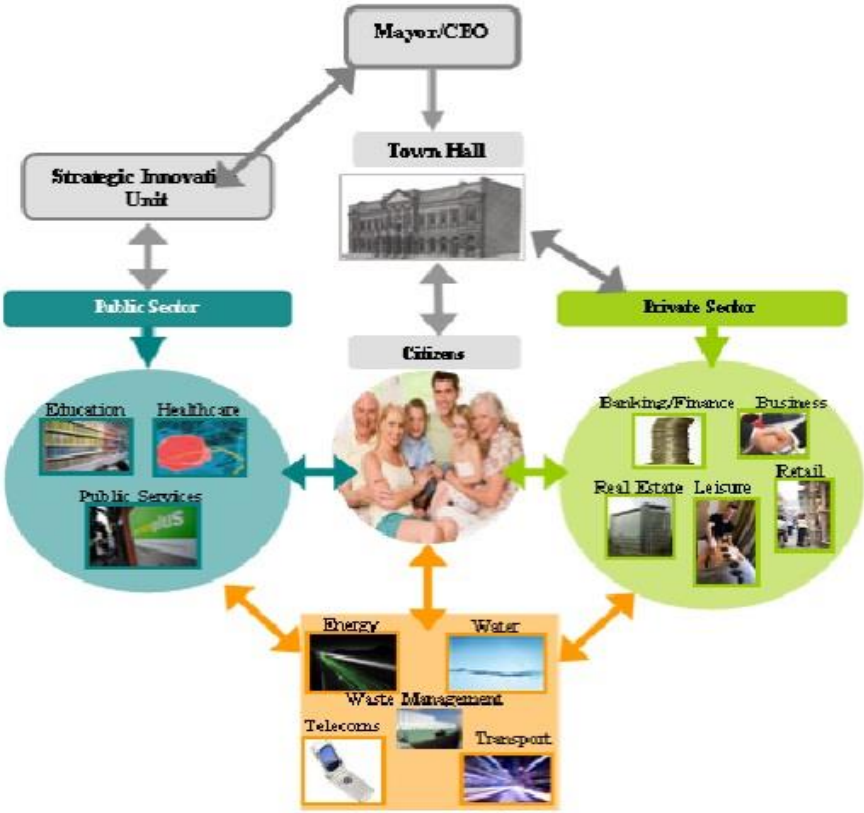


Figure 12. Smart City Model [17]

Smart Cities is a particularly active area in the UK with many initiatives. The UK does not want to only address the issues driving smart cities within the UK but also sees the area as a huge opportunity for UK businesses to develop new products and services that can be sold worldwide. The smart cities industry is valued at more than $400 billion globally by 2020, with the UK expected to gain a 10% share ($40 billion) [17] [18] [19] [20]. The area is thus being strongly driven by the UK Government via the Business, Innovation and Skills Department and over 100 opportunities for UK businesses have been identified. The UK Government has set up policies and programmes in five main areas:

- encouraging and empowering city authorities to develop the vision and leadership to provide solutions to their own problems;
- promoting open data and the capacity of organisations to improve access to open data, to share and to use it, including the development of open standards;
- programmes to develop underpinning technologies and to demonstrate their efficacy;
- Departmental programmes to encourage the adoption of new approaches and technologies, to transform both the service systems and consumer behaviour;
- participating actively in EU programmes.

A report [20] has been produced to highlight the economic opportunities from smart cities and also the impact on citizens (See Figure 12). Here the provision of real-time information will allow people to make more informed choices, e.g. for journey planning on buses and trains and for identifying car parking spaces. Supporting this a Smart Cities Forum has been established, chaired by Universities and by the Science and Cities Minister David Willetts and Cities Ministers with representatives from cities, business, and scientists.

The Technology Strategy Board (TSB) has also set out a strategy for future cities [21] which focuses on a more integrated and systemic approach to services. Two key initiatives have been launched to support UK businesses:

3.3.1.1 Future Cities Demonstrator Programme

The Future Cities Demonstrator Programme is a £33m TSB project which aims to demonstrate at scale the added value of integrating city systems [22][23]. 30 UK cities submitted proposals and Glasgow City Council won the funding with a project to integrate services across health, transport, energy and public safety. The city allows UK businesses to test new solutions that can be replicated around the globe. Additionally, Bristol, London and Peterborough also each received £3m and the four cities will work together to provide data into the Future Cities Laboratory and to the TSB DALLAS (Digital Assisted Living Lifestyles at Scale) project, already underway in Glasgow. This project is addressing smart applications of technology for transport and energy and it has recently announced Catapults in relation to Transport Systems and the Connected Digital Economy.

3.3.1.2 Future Cities Catapult UK

The other major initiative in the UK is the Future Cities Catapult. This has been set up to act as a global centre of excellence in urban innovation bringing together business, universities and city-administrations to develop solutions for future cities. Within the Catapult there are a number of activities. A Cities-Lab has been set up to integrate live data feeds with advanced modelling, simulation, analysis and visualisation with the aim to create new, commercialisable solutions to city challenges. The idea behind this is to allow cities, SMEs and businesses to plug in their data and ideas and use this as a test bed for improved solutions and new business models. There is also a “futures and best practice programme” to identify what future sustainable and future-proofed cities will look like and to showcase best practice. The idea behind this is to identify factors for success, risks and opportunities which can be used as input to decision makers and innovators. There is also work on addressing the barriers to city-integration, such as uneven procurement rules, inadequate templates for shared IP and lack of financing. It has been noted that the deployment of integrated city systems depends both on financial as well as technological innovation. A challenge here is to identify new financial models to create potential revenue streams and turn these into infrastructure investment. To address this, the UK’s financial sector is also engaged in the Catapult.

3.3.1.3 e-infrastructure Leadership Council

The UK government has also set up an e-infrastructure Leadership Council as a recommendation of the Tildesley Report “A strategic vision for the UK e-infrastructure” in 2011 [24]. The Leadership Council targets collaborative academic and industrial precompetitive research and development. Under this the Digital Economy Programme has been set up. This looks at how, in sustainable societies of the future, people will be able to make informed sustainable choices. Examples of this are the Urban Prototyping London project which is addressing how digital technologies, art, and design can be used as new tools by citizens to improve their urban environment. Here questions of citizen empowerment and engagement are being considered along with identification of the real barriers to entry for creating start-ups. A £5.9M five-year multi-disciplinary research programme, Digital City Exchange (DCE), has been set up to find innovative solutions to optimise the use and planning of cities and a 5 year EPSRC programme grant has been given to develop a method of designing and engineering UK cities called Liveable Cities. This will be achieved via the development of a City Analysis

Methodology (CAM) that will measure how cities operate and perform in terms of their people, environment and governance, taking account of wellbeing and resource security.

3.3.1.4 UK - HyperCatCity

Innovate UK has also provided £8 million of investment for the HyperCat project [25][26] to create common, secure standards and protocols to unlock the potential of the 'Internet of Things'. Under this HyperCatCity brings together London, Bristol and Milton Keynes working on better and more effective ways to deliver services.

3.3.2 Spain

The leading smart cities project in Spain is Smart Santander [27]. Smart Santander is a city-scale experimental research facility that supports typical applications and services for a smart city. The facility is large, open and flexible to enable horizontal and vertical federation with other experimental facilities. A key aim is to stimulate development of new applications including experimental advanced research on IoT technologies and provide realistic user acceptability tests for assessment. The project has a vision not only to deploy 12,000 sensors in Santander but also to deploy 20,000 sensors in Belgrade, Guildford and Lübeck.

The population of Santander is 180,000. 10,000 sensors have been installed around downtown Santander, in a 6 square kilometre (2.3 square miles) area hidden inside small grey boxes attached to street lamps, poles, building walls and buried beneath parking lots. The sensors measure light, pressure, temperature, humidity, and the movements of cars and people [28]. Every 2 minutes data is sent to the Muñoz's laboratory at the University of Cantabria where there is a central computer that builds a picture of the city. Buses, taxis and police transmit their position, mileage and speed, as well as environment data, such as ozone or nitric oxide pollution levels. Citizens can also download an app and become human sensors themselves. Using the data information can be provided on traffic jams, and exceedance of EU air quality and noise levels. The street lamps have also been made smart and are able to adjust their brightness according to weather conditions (or when no-one is on the street) and warn when a bulb has failed. Sensors are also being used to control the amount of watering done in parks to conserve water.

Citizens can access data via a "Pulse of the City" app which gives information on when the next bus is going to arrive at a bus stop, the program of events for the city's concert hall, tourist information and special offers at supermarkets. Citizens can also take photos of potholes and send it to city hall to request repair. The time for repair is made public which puts the onus on the city to repair the problem as soon as possible. The city mayor is making data available to encourage programmers to create more apps to make Santander even smarter.

3.3.2.1 Barcelona

Barcelona has established a number of projects that can be considered "smart city" applications within its "CityOS" strategy [29]. Sensor technology has been implemented in the irrigation system in Parc del Centre de Poblenou, where real-time data is transmitted to gardening crews about the level of water required for the plants. Barcelona has also designed a new bus network based on data analysis of the most common traffic flows in Barcelona utilising smart traffic lights to optimise the number of green lights. If there is an emergency the approximate route of the emergency vehicle is entered into the traffic light system and the traffic lights are set to green as the vehicle approaches using GPS data and traffic management software to minimise delay [30].

3.3.3 The Netherlands

Amsterdam Smart City (ASC) is a partnership between companies, governments, knowledge institutions and the people of Amsterdam to turn the city into a Smart City [31]. The aim is to use social and technological infrastructures and solutions to facilitate and accelerate sustainable economic growth. ASC believes in a habitable city where it is pleasant to both live and work. In six years ASC has grown into a platform with over 100 partners, which are involved in more than 90 innovative projects [32]. There are many different ideas that could be applied and the Amsterdam Smart City platform challenges parties to submit and execute innovative solutions to urban issues. ASC also addresses the possibilities to strengthen previous activities. This advances the development of new markets for innovative solutions. Where possible, these solutions are replicated elsewhere in the city. ASC works on a number of focus areas, in which projects, ideas and new business models are being developed: smart mobility, smart living, smart society, smart areas, smart economy, Big & open data, and Infrastructure (water/roads/energy/ICT).

3.3.4 Estonia - Tallinn

The Estonian capital Tallinn is one of the world's most technologically advanced cities. Notably it was the birthplace of Skype [33]. Tallinn residents are used to exploiting technology, with high levels of automation and use of connection to the Internet. Estonians are required to carry chip-embedded identification cards, without which they do not officially exist. The cards are used for voting, prescriptions and many other transactions. For example:

- Riding the bus is free with a smart card allowing the transit authorities to track your movements.
- Mailing a package requires a sender to use a cell phone to request a code from the electronic post office downtown. The code opens a locker where the package is posted.
- City parking utilises a text message with the car's number and code for the parking lot. The fee appears on the monthly cell phone bill, which is paid electronically.

Private sector Internet and communications technology is a priority in Estonia and a “Silicon Valley” called Technopolis has been set up near Tallinn airport that demonstrates the latest high-tech services and gadgets to visitors. This reliance on Internet technologies also means that Estonia has also had to deal with cyber-attacks. The country hosts routine cyber-attack drills in which government and private sector participants learn to spot and stop phishing attempts and viruses. NATO has set up a Cooperative Cyber Defence Centre of Excellence in Tallinn. International lawyers in Estonia have also recently completed the "Tallinn Manual," the world's first comprehensive guide on legally tackling cyber-warfare.

3.3.5 Sweden - Stockholm

Stockholm’s smart city technology is underpinned by the city owned Stokab dark fibre system which provides a universal fibre optic network across Stockholm [34]. A Green IT strategy is being pursued to reduce the environmental impact of Stockholm using IT to control energy efficient buildings (minimising heating costs), traffic monitoring (minimising the time spent on the road) and development of e-services (minimising paper usage). The e-Stockholm platform provides a number of e-services, including political announcements, parking space booking and snow clearance. Combining information with GPS data allows route planning in the city. This is further being developed through GPS analytics, allowing residents to plan their route through the city.

3.4 US Smart City Drivers and Policy

In the US the White House Smart Cities Initiative [35] plans to invest over $160 million in federal research. The aim is to set up more than 25 new technology collaborations to help local communities tackle key challenges such as reducing traffic congestion, fighting crime, fostering economic growth, managing the effects of a changing climate, and improving the delivery of city services. The President's 2017 budget proposal includes a focus on Cyber-Physical Systems and Smart Cities.

3.4.1 Smart and Connected Communities Framework

The NITRD Cyber-Physical Systems (CPS) Senior Steering Group (SSG) has set up a framework to help coordinate Federal Smart Cities activities and agency investments with outside collaborations. The aim is to guide foundational research and accelerate the transition into scalable and replicable Smart City approaches. The framework [36] outlines a vision and an approach agencies can use to move forward together in pursuing a vision of smart and connected communities. Activities within the framework include the entire pipeline from research and development to deployment of new tech-driven services and infrastructure in cities. The success of the framework requires federal interagency coordination, cooperation with external stakeholders, and next steps planning for Federal action.

3.4.1.1 National Institutes of Health (NIH)

One such action is the coordination, with the National Institutes of Health, of a programme to enhance collaboration between researchers, citizens, local cities and municipalities to evaluate the health-related benefits of networked sensors, infrastructure, and computing systems. This particularly addresses health-related Cyber-Physical Systems in smart cities considering security, privacy, health disparities and human factors. Key aims are to develop interoperable solutions and gain consensus on standards, and evidence that the technologies are safe, effective and sustainable.

3.4.1.2 National Institute of Standards and Technology (NIST)

A number of initiatives are being supported by NIST. The Global City Teams Challenge, brings together teams of cities and innovators working in partnership to use Internet of Things technologies for improving the safety, sustainability, livability, and workability of communities worldwide. NIST is also running open, consensus-based public working groups to develop a comprehensive framework for the design, evaluation, and operation of complex Cyber-Physical Systems, including smart city technologies at scale. Via the Smart Grid program and public-private Smart Grid Interoperability Panel, NIST is working with the private sector on smart grid interoperability and security standards. Security is a key concern and here NIST is working with the National

Cyber-security Center of Excellence (NCCOE) to provide real-world cyber-security solutions based on commercially available technologies for smart city applications. This is for a range of applications including energy, transportation, and finance. The NIST Big Data program also has a public working group and is driving standards effort to produce a reference architecture that is vendor-neutral, technology- and infrastructure-agnostic. Finally, the NIST Cloud Computing Program (NCCP) is providing a cloud architecture and metrics to enable secure storage, transmission and processing of data and services through collaborations with public working groups, industry and international standards efforts. The overall aim is to promote international standards for interoperable smart city solutions.

3.4.1.3 National Science Foundation (NSF)

The NSF is bringing together academic researchers, industrial and non-profit partners, and local cities, municipalities and regions to integrate data sources and networked computing systems with people, physical devices and infrastructure. Applications include health and wellness, energy efficiency, building automation, transportation, etc. The aim of NSF is to support foundational research that supports design and management of Smart and Connected Communities.

3.4.1.4 National Aeronautics and Space Administration (NASA)

NASA also has a role to play and here research is being performed on collaborative, planning, and scheduling applications to enhance multi-modal traffic flow in Smart Cities and also UAV operations. NASA are also developing and sharing verification and validation tools to enable smart city developers to assure high integrity, robust, and interoperable complex systems.

3.5 Smart City Activities within the US

There are a number of smart city initiatives in the US. In the following sections a number of key activities are highlighted.

3.5.1 Boston

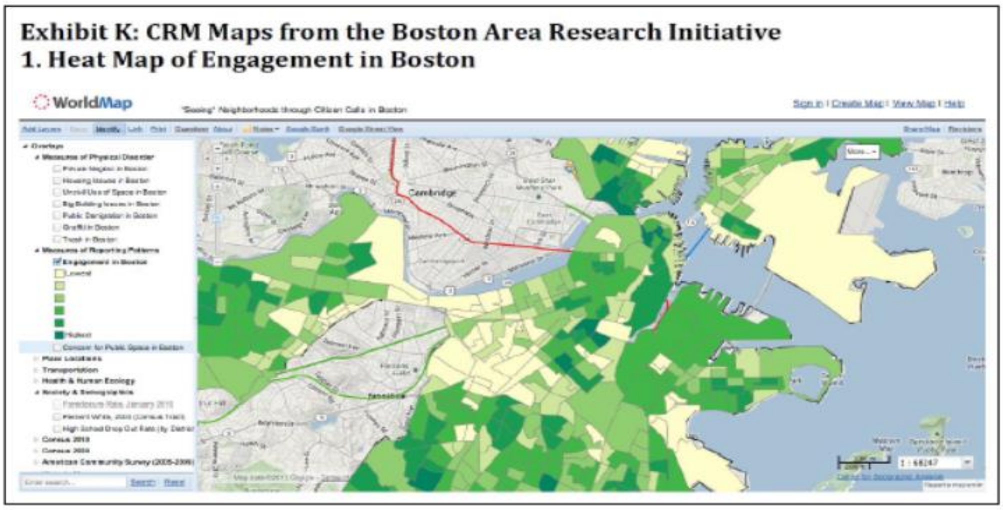


Figure 13. Boston “Heat Map” of Engagement [37]

One of the leading cities in the US with respect to implementation of smart cities ideas is Boston. Boston launched its first CRM system (Citizen Relations Management) in 2008 [38]. There are five city apps with a wide range of uses, from allowing citizens to report neighborhood problems to the government, to helping commuters find on-street parking in the Innovation District. Here there has been very good engagement with community. A heat map from an area in Boston showing the levels of engagement is shown in Figure 13. Here the darker the green, the higher the engagement [37].

The city has introduced Time to Destination message signs and Smart Parking Sensors to better manage traffic. Additionally, it is using smart technology to encourage children to walk to school and collects data from its Hubway rental bikes to reduce road congestion. The city has also introduced solar powered benches that can charge gadgets and monitor air quality and sound levels.

3.5.2 San Francisco

San Francisco is a global leader in smart-city projects providing a large number of free WiFi hotspots which cover downtown. Citizens are encouraged to participate in energy conservation through provision of web access to precise, near real-time energy use data and advice on how they can save energy. The city also has over 100 electric vehicle charging stations to promote the use of hybrid and electric cars.

3.5.3 New York

Figure 14. New York – Hudsons Yard (Artists Impression)

New York is a very densely populated city and it has initiated many smart and sustainable initiatives. City 24/7 [39] is an interactive platform that integrates information from government programs, local businesses and citizens to provide knowledge to anyone, anywhere, anytime, on any device. The city is also building the largest city-wide WiFi network [40] in the US by turning old phone booths into WiFi hotspots. The $20 billion Hudson Yard Project [41] (See Figure 14) is developing a 28-acre commercial and residential area on Manhattan's west side. Hudson Yards will digitally track traffic, energy consumption and air quality. It is being designed to provide the highest quality of life for those living, working, and visiting the area.

3.5.4 Seattle

Seattle is one of the greenest cities in the US. The city's electric meters are being upgraded to give more accurate readings of electricity consumption to allow management. Seattle has partnered with Microsoft to launch its High Performance Building Program [42] that allows real-time tracking of energy efficiency.

3.5.5 San Jose

In partnership with Intel San Jose has initiated a project, "Smart Cities USA", which is tracking real-time data on air quality, noise pollution, and traffic flow [43]. This is Intel's first smart city implementation in the United States with expectations to help the city to grow economically, create 25,000 clean-tech jobs, create environmental sustainability, and enhance life for residents. The data collected is expected to help citizens make decisions, e.g. if the air-quality is bad they may elect to use public transit, a bicycle, or carpool.

3.5.6 Washington, D.C.

The capital is one of the top cities in the U.S. for transit use and e-governance. Washington D.C. has been a pioneer in the adoption of new technology, including the launch of a private cloud in 2010 and the early use of mashups to become a GIS model city [44].

3.5.7 Chicago

Chicago has provided 851 open data sets and the Chicago's Digital Excellence Smart Communities Program [45] is working with local communities to close the digital divide for the elderly and lower-income residents of the city [46].

3.6 Rest of World

Around the world, there are many smart initiatives. It is not possible to list them all here but a number are of interest with linkages going beyond national borders.

3.6.1 IEEE Smart Cities Initiative

At a worldwide level the IEEE has launched the Smart Cities Initiative [47] which spans multiple IEEE Societies. The aim is to provide a trusted voice for the engineering, computing and technology communities around the world in the area of smart cities. Strategic and practical guidance can be obtained on management of essential services, the smooth operation of critical infrastructure and on providing a clean, economic and safe environment for inhabitants to live, work and play. Selected municipalities can join the active community of 10 cities that the IEEE aims to engage in developed and developing countries through 2016.

3.6.2 Brazil

Rio de Janeiro set up a smart city operation centre in 2010, using real data feeds from all data sources including cameras, sensors, actuators and vehicle GPS's. A key focus was on adopting smart technologies for hosting the World Cup in 2014 and the Summer Olympics in 2016.

3.6.3 China

Hong Kong is ranked 13th in the world in terms of the number of Internet of Things firms [48]. An example of smart city development in Hong Kong is the Octopus which is an electronic system that is widely used in public transport, retailing, online payments, parking facilities, self-services, access control systems, recreational facilities and schools, and public services [49]. There is also an EU-China Smart and Green City Cooperation. In this a comparative study has been performed into smart cities in Europe and China [50].

3.6.4 Australia

There are a number of smart city initiatives in Australia [51][52] notably in Adelaide, Brisbane and Melbourne.

3.6.4.1 Adelaide

The Connect Adelaide initiative [53] is providing free high-speed Wi-Fi across public spaces to support real-time transport information, enhanced CCTV coverage, interactive digital maps and live city event broadcasts. This is supported by a number of council smartphone apps, Splash Adelaide, Adelaide Street Eats and Adelaide Report It.

3.6.4.2 Brisbane

CitySmart [54] was created by Brisbane City Council to help make the city the nation's most sustainable city. CitySmart is currently delivering $25 million worth of projects, with a further $290 million in projects in development, all designed to contribute to Brisbane's economic growth and reduce environmental impact. This includes a district cooling energy system to provide cheaper/more efficient air conditioning. Queensland Watt Savers gave more than 300 SMEs easy-to-use tools and expertise to reduce energy consumption and related expenses. EzyGreen, a residential energy reduction program, engaged 61,000 Brisbane households to save over $10 million in annual energy costs.

3.6.4.3 Melbourne

Melbourne has many knowledge industries, a background in technical innovation, an emerging new media sector, and a focus on urban design and the quality of the urban environment [55][56]. The city is developing a number of initiatives based on open data and on providing wired and wireless access to urban spaces.

3.6.5 Japan

In Japan the Ministry of Economy, Trade and Industry has a program underway with companies, such as Panasonic, Hitachi, Toshiba and others, to develop smart city services that can be tested in four domestic pilot cities, and sold internationally. Japanese companies are actively participating in projects in the United States, France, Spain, India and China.

3.6.6 South Korea

The South Korean city of Songdo which is currently being built is expected to be one of the smartest cities on the planet. It will have sensors and cameras at every corner (monitoring temperature, traffic, electricity) that are all interconnected and linked to a central computer that will process information in real-time to optimise the management of the city. The city is attracting startups and companies like Cisco as it is a clean slate for developing technologies. A living lab was set up in November 2015. The lab is called the “IoT (Internet of Things) Cube” and gathers real-time data, and performs analytics [57].

3.6.5 Iceland

In Reykjavik, the city council implemented a Better Reykjavik website [58] where citizens can submit ideas. These are discussed and if there is sufficient political backing they are implemented. Interestingly, 60% of citizens have used the platform with the city spending €1.9 million on more than 200 projects based on ideas from citizens. Since 2008, the Citizens Foundation has used Your Priorities to promote online, democratic debate in Iceland and worldwide. The open source platform is available free of charge to any group, city or country around the world interested in using it to source ideas from citizens. Another prominent use of the platform has been in Estonia where 50,000 citizens used it to submit more than 2,000 proposals to government. Fifteen were taken forward to parliament, and seven have since become Estonian law.

3.7 Needs for Regulation

The very wide scope of smart cities which covers not only interactions with citizens and use of their data but also control of the energy, waste, transportation systems and social interactions with government, education and e-health leads to many areas were regulation may be required. Regulation with respect to energy and transportation systems is covered in the relevant sections in this report. Regulation with respect to gathering and use of data is considered in depth under the topic of Big Data. Safety is of underlying importance to citizens and is considered in the areas of energy, transport and IoT/Cyber-Physical Systems.

In this section, however, it is worthy to note that there is critical overarching need for regulation in the area of privacy and in allowing sharing of data to provide services. Smart cities rely on a myriad of sensors that constantly register and process private data from individuals. Some planned initiatives have failed because citizens have been worried about privacy. Privacy concerns must be handled sensitively, since smart cities rely on gathering large amounts of data that could be compromising or embarrassing if made public [59].

In some cases citizens reject surveillance which is necessary to bring convenience, efficiencies and energy savings to smart cities. There are now efforts under way to establish a legal framework in Europe on gathering data with consent, to reconcile the value of services with privacy, develop ways to use anonymous data and in providing protection through encryption. Full anonymisation is impossible so processing in encrypted domains may be the way forward [60].

Another key barrier to creation of services is the ability to access and utilise data. For data sharing there is a need for openness. This is discussed in detail in the section on Big Data and Open Data.

3.8 Smart City Standards

To help city government and developers provide new services there is a need for standardisation at many levels. This includes in defining reference models, planning guidelines, guides for sustainable development and standards for interoperability of data and communications. Again more detailed information is provided in specific sections on energy, transport, 5G, Big Data and IoT/CPS. In the following section a number of standards which specifically address smart cities are considered.

3.8.1 UK Standardisation Activities

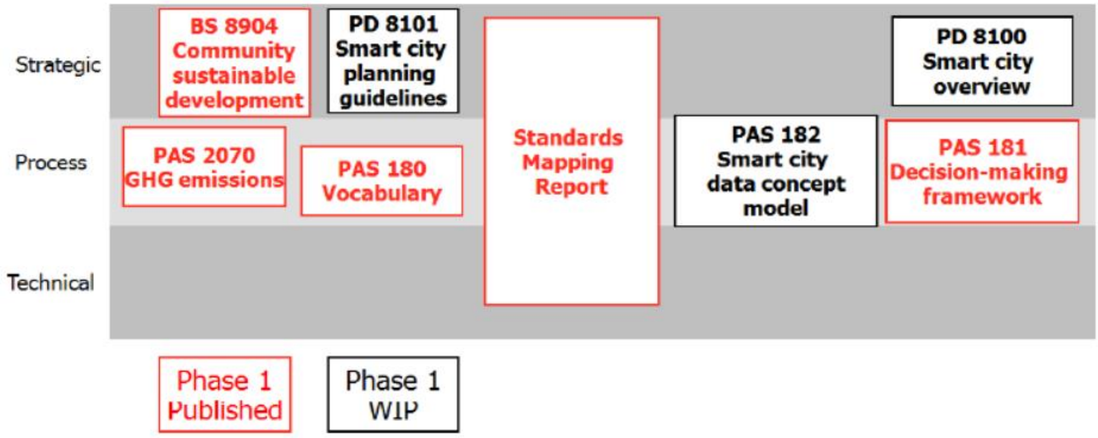


Figure 15. Standards

As an example of all the areas that need to be considered see Figure 15 which shows areas where standards are under development in the UK. The British Standards Institute (BSI) has established a Smart Cities Advisory Group, comprising representatives from cities, business, academia and NGOs. This has identified a number of areas where standards could reduce barriers to smart city implementation. Key aims are to share good practice on development and implementation of new service models, identify common solutions to technical problems and set out the preconditions for interoperability of data. A vision is being set out for the benefits of smart cities and the approaches that can be taken to improve city performance. This provides a smart city overview to communicate the benefits of smart cities to key decision makers. It is also necessary to create common terminology for smart cities to allow sharing of concepts (PAS 180) and provide smart city planning guidelines to set out how major new residential, retail and business developments can support the wider plans of that city to become smarter. Underlying this there is a need for guidelines for economic assessment and funding of smart city initiatives as well as highlighting potential business models and means of procurement. A standard (PAS 181) has also been produced to provide a decision-making framework for smart city leaders, setting out how to deliver a smart city project. Other documents describe data sharing, mapping across different international standards bodies, contributing to ISO standards on sustainable community development and metrics. Standards are being developed for:

- Good practice in provision of digital services, including sharing of open data, protection of privacy and inclusiveness of services
- Evaluating smart city performance, building on the current ISO programme to provide a means of evaluating the effectiveness of smart city products and services
- Procurement of smart city services, building on the initial economic assessment and funding model
- Practical approaches to collaboration between partners in delivery of smart city programmes
- Interoperability of systems, including a framework description of smart city systems building on the mapping work “Preparing the way for smart cities” performed by the BSI [61]

A BSI standards strategy for smart cities was also commissioned by the Department of Business Innovation and Skills to outline UK Department guidelines, metrics, management processes and technical specifications. The smart city framework (SCF) was published in 2014 [62]. This is a practical “how to” guide intended for use by leaders, at all levels and from all sectors, of smart city programmes.

The Institute for Transportation and Development Policy (ITDP) has also developed the Transit-Oriented Development (TOD) Standard, which was published in June 2013. This provides a common understanding of what constitutes urban development best practice from international experience in promoting sustainable urban transport. Key aims are to minimise the use of personal cars and reduce greenhouse gas emissions.

3.8.2 ETSI

Many technical activities of ETSI [63] standards are linked directly to the concept of “smart cities”, e.g. mobility, transportation, M2M, energy efficiency, security, etc. ETSI organised 2 events in 2013 gathering multiple players together involved in Smart Cities. The purpose of these events was to define the driving expectations from an ICT standards organization with regards to smart cities. In October 2013 the ETSI board agreed on a roadmap for Smart Cities to define a High Level Architecture for smart city from the ICT perspective, perform an initial in-house ETSI standards inventory of existing standards that may be applied in a smart city and identify National Standard Organisations outside of ETSI and plan for outreach.

3.8.3 ITU-T

ITU-T has established a new Focus Group on Smart Sustainable Cities to assess the standardisation requirements of cities aiming to boost their social, economic and environmental sustainability through the integration of ICTs in their infrastructures and operations.

3.8.4 China

In China, several national standardisation committees and consortia have started standardisation work on Smart Cities, including the China National IT Standardisation TC (NITS), the China National CT Standardization TC, the China National Intelligent Transportation System Standardization TC, the China National TC on Digital Technique of Intelligent Building and Residence Community of Standardization Administration and the China Strategic Alliance of Smart City Industrial Technology Innovation.

4 Smart Energy

4.1 European Smart Energy Drivers and Policy

The European power grid is highly complex spanning 29 countries over three continents with more than 10 million kilometres of power lines. It transfers over 3,500 TWh of electrical energy annually and this is expected to grow to 4,300 TWh by 2050. A significant proportion of this extra demand will be met by renewable sources which are expected to increase to 50-80% of the total generation capacity from the current value of approximately 14%. The use of electricity is also becoming more concentrated. Presently, 70% of the EU population lives in urban areas, and this figure is likely to increase over the next few decades.

Cities are the main centres for economic, social and cultural activities in Europe and create around 80% of the EU's gross domestic product. However, a consequence of this is that urban areas consume 70% of energy, and account for 75% of the EU's greenhouse gas emissions. Most of the energy consumption occurs within buildings, transportation systems, water supply and treatment, and sewage management. Cities are thus an area where most energy savings could be made and have an important role to play in achieving national and European green-growth strategies. Here innovations are needed in energy, transport and Information and Communications Technology (ICT). There is great interest in making buildings much more energy efficient [64] and a number of strategic priorities have been defined [65].

Notably across the five different priority areas of Europe 2020, environmental issues and green solutions are a key concern for the majority of European Smart City initiatives [66] with nearly 50% of the initiatives addressing environmental problems. This includes energy efficiency in buildings and smarter city transportation options. In Europe many initiatives in energy are transnational involving multiple cities, e.g. Networking Intelligent Cities for Energy Efficiency (NiCE). The NiCE initiative aims to decrease the direct carbon footprint of ICT by 30% per city, contributing to the Europe 2020 energy efficiency and CO2 targets [67].

4.2 European Smart Energy Initiatives

4.2.1 European Energy Research Alliance (EERA)

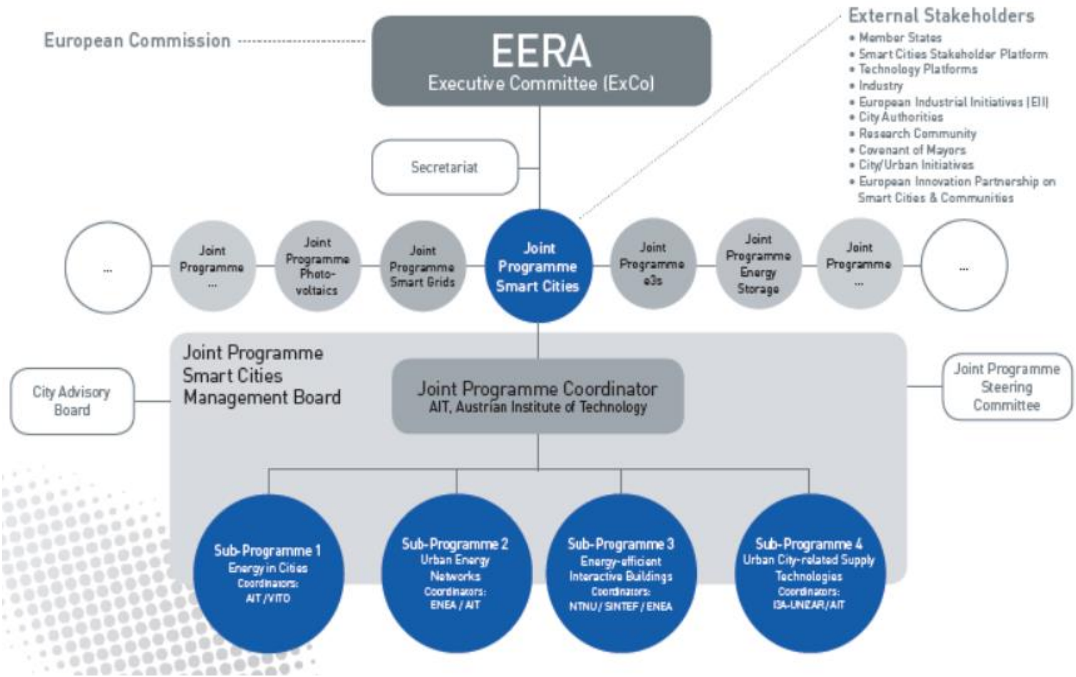


Figure 16. EERA Joint Programme on Smart Cities

The European Strategic Energy Technology Plan (SET Plan) has identified the need for development of energy technologies to combat climate change and the need for securing energy supply at the European and global level in the long term. Successful achievement of Europe's 2020 and 2050 targets for greenhouse gas emissions requires novel technologies designed to increase energy efficiency and enable large-scale integration of renewable energy. To support this, the European Energy Research Alliance (EERA) was set up by leading European research institutes. The aim of EERA is to streamline and coordinate national and European research activities and pool resources to maximise synergies and optimise European energy research capabilities and infrastructures. EERA brings together national facilities in Europe into a virtual centre of excellence and initiates joint research programmes. Currently, 3000 researchers from over 150 public research centres and universities are involved. The topics being addressed include photovoltaics, wind energy, fuel cells, hydrogen, smart grids and smart cities.

The Joint Programme on Smart Cities (See Figure 16), for instance, is developing new scientific methods, concepts and tools to support European cities in their transformation into smart cities. The key focus is on large-scale integration of renewable energy and enhanced energy efficiency using smart energy management at the city level. This requires an integrated systems view as well as innovative, intelligent approaches to the design and operation of urban energy systems. Four key areas are being addressed:

1. **Energy in Cities** is taking an integrated approach towards urban energy planning and transformation processes by understanding the energy performance characteristics and energy flows in urban areas and by providing new planning methods and best practice examples. Decision support and simulation tools will be developed to model economic scenarios and energy flows and thus support experts and authorities in developing urban energy roadmaps.
2. **Urban Energy Networks** concentrates on the intelligent planning, design and operation of thermal and electrical networks in cities through the use of smart energy grids which are able to communicate with each other to balance thermal and electrical loads depending on supply and demand. This requires comprehensive sensor networks feeding energy-related data into a multifunctional ICT platform.
3. **Energy-efficient Interactive Buildings**. Buildings account for around 40 per cent of European primary energy demand. In the work energy-efficient buildings will make use of energy conservation measures and on-site renewables to reduce their energy demand. For this innovative, competitive holistic concepts, tools and demonstration cases are being developed to coordinate the exchange of energy with thermal and electrical grids while providing a comfortable healthy indoor environment to their users.
4. **Urban City-related Supply Technologies** is investigating how on-site renewable supply technologies can be integrated into the urban infrastructure such as heat pumps, solar thermal, photovoltaics, energy storage units, etc.

4.2.2 SETIS (Strategic Energy Technologies Information System)

Figure 17. Strategic Energy Technologies Information System

The SETIS Initiative [68] aims to support cities and regions to taking ambitious and pioneering measures for the sustainable use and production of energy with the target to reduce greenhouse gas emissions by 40% by 2020. In particular, measures on buildings, local energy networks and transport are outlined (See Figure 17).

4.2.3 ICT Roadmap for Energy Efficient Neighbourhoods

Figure 18. Energy Efficient Neighbourhoods

The ICT Roadmap for Energy Efficient Neighbourhoods (IREEN) [69] (See Figure 18), was launched in September 2011 to encourage the development of energy-positive buildings, and eventually whole districts. Coordinated by Manchester City Council the IREEN roadmap was developed over a 2 year period taking input from over 200 experts from the ICT, energy and construction sectors across Europe. A number of recommendations are made. These include the needs for flexible and pay-per-use pricing schemes; “modular and configurable monitoring control systems” to manage neighbourhood energy services, such as LED public lighting; and using chargeable electric vehicles as storage for microgrids. The use of web and mobile applications is also recommended to engage with the local community with provision of e-learning and gamification to raise awareness of energy usage and encourage participation.

4.2.4 KIC InnoEnergy

KIC InnoEnergy is a Knowledge and Innovation Community (KIC) [70] created by the European Institute of Innovation and Technology (EIT). KIC InnoEnergy has been set up as a commercial company dedicated to promoting innovation, entrepreneurship and education in the sustainable energy field. It brings together 30 shareholders including industry, research centres and universities. The targets of KIC InnoEnergy are to reduce costs in the energy value chain, increase security and reduce CO2 and other greenhouse gas emissions.

4.2.5 Positive Energy Blocks

The aim of the Positive Energy Block initiative [71] is to build 100 Positive Energy Blocks (PEB) across the EU. There will be at least one PEB per EU Member State with 50% of these located in smaller cities (maximum 250.000 inhabitants, so called "Small Giants"). A Positive Energy Block is a group of connected buildings in a neighbourhood that produces more energy than it uses on a yearly basis. Here the contributions of heating, cooling, ventilation and lighting are considered. The buildings within a "block" must be a mix of housing, offices and commercial properties to demonstrate typical living environments and a block can also be made up of both new and old buildings (with suitable retrofit).

4.3 National Smart Energy Initiatives

4.3.1 Germany

Within Germany sustainable growth and energy supply has been a major public concern for the past 10 years driven by the federal government's 2010 plan to phase out nuclear power. This will require a fundamental transformation in the way existing infrastructure is operated and also in the exploitation of renewables. Many German municipalities/regions have Renewable Energy self-sufficiency (RESS) goals and the efficient use of energy is also being promoted with support for innovative research technologies and pilot projects.

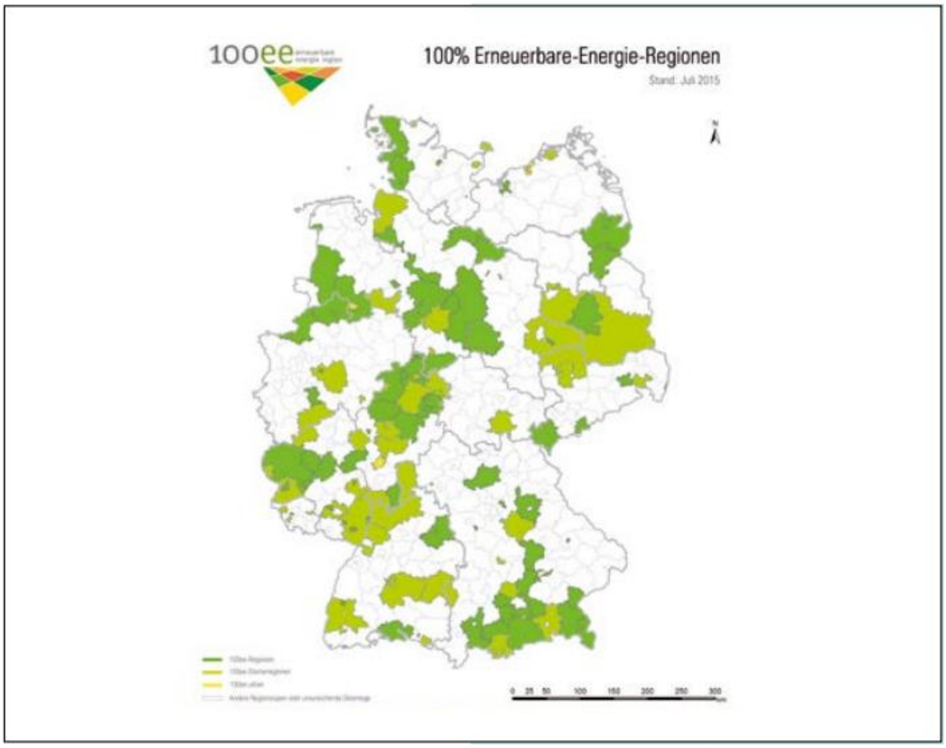


Figure 19. German Cities that are Becoming 100% Self-Sufficient in Renewable Energy

The map in Figure 19 shows the German cities that have been most active in their efforts to become 100% self-sufficient in renewable energy.

4.3.2 France

France derives about 75% of its electricity from nuclear energy, due to a long-standing policy based on energy security introduced after the “oil shock” in 1974 [72]. In mid-2010 the International Energy Agency adopted a strategic policy to make France a provider of low-cost, low-carbon base-load power for the whole of Europe. France is now the world's largest net exporter of electricity due to the very low cost of generation (nearly the lowest in Europe) and earns nearly €3 billion per year from this. Additionally France exports reactors, fuel products and services around the world. Nearly 17% of France's electricity is produced from recycled nuclear fuel. The CO2 emissions per capita from electricity generation is extremely low since over 90% of electricity is from nuclear or hydro sources. In 2013 French electricity prices for medium-size industrials were about 90% that of the EU-27 average, and those for medium-size households (at less than 8 c/kWh) were less than half of the EU-27 average. The national energy regulator (CRE) sets the price at which EdF’s electricity is sold to competing distributors.

President Francois Hollande called for a national debate on energy in 2013. 170,000 people took part in 1000 regional debates and 1200 submissions were received over the Internet. As a result in October 2014 an “Energy Transition for Green Growth” bill was passed by the National Assembly which aims to reduce the share of nuclear energy to 50% by 2025. The bill also sets long-term targets to reduce greenhouse gas emissions by 40% by 2030 compared with 1990 levels and by 75% by 2050. The bill also calls for energy consumption to be halved by 2050 compared with 2012 levels with reductions in fossil fuel consumption of 30% by 2030 and an increase of renewables to 32% by 2030. The bill also sets long-term targets for France's carbon tax: €14.50 per tonne CO2 currently, to €22 in 2016, then to €56 in 2020, rising to €100 in 2030. Areva, EdF and CEA announced the formation of the tripartite French Nuclear Platform (PFN) to improve the joint effectiveness of the three bodies and produce a shared vision of a medium- and long-term goal for the industry. In 2015 RTE started work on a new 1200 MWe HVDC connection to Turin in Italy supplying 10.5 TWh, costing about €1 billion which will be the longest subterranean high-voltage power line when it goes into service in 2019.

4.3.2.1 SmartGrids France

In 2012, nine French business and research clusters teamed up to create SmartGrids France. This aims to exchange experience to create a uniform grid architecture and standards across French SmartGrid initiatives. Several pilot projects have already been deployed in France, e.g. via funding programs managed by the ADEME (Environment and Energy Management Agency) and the ANR (National Research Agency). For example, in southern France, the Nice Grid project, supported by state-owned ERDF, has tested the integration of solar PV and energy storage with the national grid using networked smart meters to monitor usage. The project aims to develop a smart grid that integrates local produced photovoltaic electricity with a 1 MW battery energy storage system supplied by Alstom and Saft, and smart meters in residents' homes. In Toulouse, the Sogrid project will trial a next generation integrated chip to enable the transmission of digital information on the grid. One of the aims of the project is to develop a new international standard. The pilot forms part of a larger vision to create a smart electricity network that can integrate electric vehicles, renewable energy and provide demand management [73].

4.3.3 UK

4.3.3.1 The Energy Technology Institute (ETI) (UK)

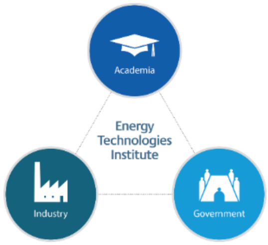


Figure 20. Energy Technology Institute

The ETI (See Figure 20) is a public private research partnership, involving six companies whose funding of projects is matched by the public sector, in particular EPSRC. Its Smart Systems and Heat (SSH) Programme aims to design and test a commercially viable Smart Energy System in the UK, facilitating improved heat management and low carbon energy services across the country. This involves the investigation of mass-market consumer behaviour and requirements to understand the likely future demand for heat and energy usage. The design methodology phase of the programme is under way, and work has begun on Enabling Component Technologies (identifying gaps in the potential range of smart systems technologies), Energy System Design Tool Development (assessing the impact of a Smart Energy System in a geographical area), Data Management and Architecture (fulfilling information and service requirements of a smart energy system), Value Management and Delivery (identifying how value can be delivered across the value chain) and a Consumer Behaviour Study (providing insight into consumer requirements for heat and energy both now and in the future). ETI has also started engagement work with local authorities, who will provide the demonstration locations for the second phase of the programme: a mass-market field trial of up to 10,000 homes to ensure any system design can be replicated geographically across the UK.

4.3.3.2 Low Carbon Economy

Work in the UK on energy is led by the low carbon economy. The Department of Energy and Climate Change (DECC) has defined the ambitious target of an 80% cut in greenhouse gas emissions by 2050. Currently the UK spends £32 billion a year on heating which accounts for around a third of UK's greenhouse gas emissions [74]. The UK is on track to meet its first carbon budgets and also the EU target for renewable energy. A Green Deal programme has been introduced to drive energy efficiency across the country. Every home will be supplied with a smart meter helping consumers to understand their energy consumption and make savings. At the same time this should reduce supplier costs, enable new services and facilitate demand-side management. Smart metering is seen as a key enabler of the future Smart Grid, as well as facilitating the deployment of renewables and electric vehicles. An Impact Assessment has been performed by DECC on the deployment of smart electricity and gas meters in domestic premises and in smaller non-domestic premises in Great Britain [75].

4.3.3.3 Low Carbon Pioneer Cities Heat Networks Initiative

The Low Carbon Pioneer Cities Heat Networks project began in March 2013 supporting five of England's core cities to move towards the deployment of low carbon heat networks, Leeds City Region, Greater Manchester (city region), Newcastle, Nottingham and Sheffield. Heat networks can be powered using a variety of fuels, including lower carbon sources such as biomass and energy from waste. Feasibility work was supported to investigate the potential for heat networks in each area with help from the Department of Energy and Climate Change (DECC). This led to the Heat Networks Delivery Unit (HNDU) scheme [76].

4.3.3.4 Low Carbon Innovation Coordination Group (LCICG)

The LCICG brings together the major public sector backed organisations that are supporting low carbon innovation in the UK. The LCICG aims to maximise the impact of UK public sector funding for low carbon technologies, in order to deliver affordable, secure, low carbon energy for the UK, encourage UK economic growth and increase the UK's capabilities, knowledge and skills. The LCICG have developed a Strategic Framework – Coordinating Low Carbon Technology Innovation [77]. The Strategic Framework sets out the LCICG's planned approach to collaboration and the prioritisation of future innovation support programmes. Building on the Technology Innovation Needs Assessment project (TINA) it highlights the key innovation needs up until 2020. LCICG have also highlighted the importance of energy storage systems to enable electricity generated at a time of low demand to be stored and used at a later time when electricity demand is high. This is being supported by a funding programme the DECC Energy Storage Innovation Competition [78].

4.3.3.5 Low Carbon Networks Fund (LCNF)

Ofgem [79] has made £500 million available to network operators over 5 years (2010-2015) to trial new technologies and approaches for efficiently connecting renewable generation, meeting the needs of small-scale and intermittent generation, addressing an increase in the use of electric vehicles, heat pumps, smart domestic appliances and other low-carbon technologies, using smart meter data to improve network performance and reduce costs and for incentivising customers to reduce their carbon footprint and cut bills, by managing their energy demand.

4.4 US Smart Energy Drivers and Policy

In the US there are a number of government initiatives and policies including investment grants, totalling $3.4 billion, dedicated to Smart Grid projects [80]. This includes funding to promote energy-saving choices for consumers, increasing efficiency, and fostering the growth of renewable energy sources such as wind and solar. The grants were part of the Reinvestment and Recovery Act that was a response to the global economic crisis. The grants follow an industry matching model, meaning that every private investment made is matched by federal grants. Development is driven by private companies. A key challenge in the US is that the grid infrastructure is largely outdated some parts being over 100 years old.

Category	$ Million
Integrated/Crosscutting	2,150
AMI	818
Distribution	254
Transmission	148
Customer Systems	32
Manufacturing	26
Total	3,429

18 million smart meters
1.2 million in-home display units
206,000 smart transformers
177,000 load control devices
170,000 smart thermostats
877 networked phasor measurement units
671 automated substations
100 PEV charging stations

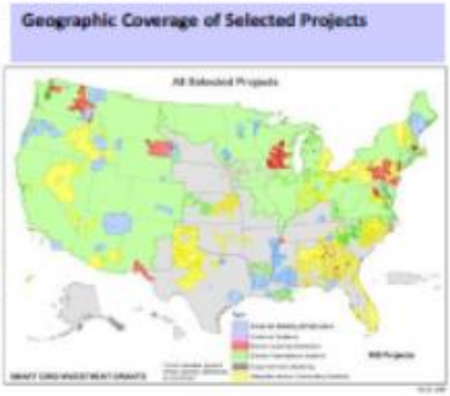


Figure 21. US Energy Programmes

Congress and the Administration have outlined a vision for a future Smart Grid and have also put forward policy to enable it to be built. The Energy Independence and Security Act of 2007 (EISA) [81] made it the policy of the United States to modernize the nation's electricity transmission and distribution system to create a smart electric grid. This coupled with the "The American Recovery and Reinvestment Act of 2009 (ARRA)" [82] is accelerating the development of Smart Grid technologies with $4.5 billion investment for electricity delivery and energy reliability activities (See Figure 21). This includes programmes to modernize the electric grid and implement demonstration programmes. This is supported by President Obama who has put forward a vision of a clean energy economy in a State of the Union Address and the Administration's commitment in the "Blueprint for a Secure Energy Future." The White House also released a report in 2011 by the Cabinet level National Science and Technology Council (NSTC) highlighting "A Policy Framework for the 21st Century Grid: Enabling Our Secure Energy Future."

4.4.1 Blueprint for a Secure Energy Future

The White House, "Blueprint for a Secure Energy Future" [83] outlines a three-part strategy:

- Develop and Secure America's Energy Supplies: We need to deploy American assets, innovation, and technology so that we can safely and responsibly develop more energy here at home and be a leader in the global energy economy.
- Provide Consumers With Choices to Reduce Costs and Save Energy: Volatile gasoline prices reinforce the need for innovation that will make it easier and more affordable for consumers to buy more advanced and fuel-efficient vehicles, use alternative means of transportation, weatherise their homes and workplaces, and in doing so, save money and protect the environment. These measures help families' pocketbooks, reduce our dependence on finite energy sources and help create jobs here in the United States.
- Innovate our Way to a Clean Energy Future: Leading the world in clean energy is critical to strengthening the American economy and winning the future. We can get there by creating markets for innovative clean technologies that are ready to deploy, and by funding cutting edge research to

produce the next generation of technologies. And as new, better, and more efficient technologies hit the market, the Federal government needs to put words into action and lead by example.

Standards for the Smart Grid have been identified as being critical in the EISA and 2011 NSTC report. Standards are needed to make sure that investment remains valuable in the future and help with innovation, highlight best practice, support consumer choice and open global markets for smart grid technologies and create economies of scale to reduce cost.

4.4.2 A Policy Framework for the 21st Century Grid: Enabling Our Secure Energy Future

The report “A Policy Framework for the 21st Century Grid: Enabling Our Secure Energy Future” [84] outlines policy recommendations that build upon the Energy Independence and Security Act of 2007 and the Obama Administration's smart grid investments. The report was prepared by the Subcommittee on Smart Grid of the National Science and Technology Council, Committee on Technology. It provides a policy framework that promotes cost-effective investment, fosters innovation to spur the development of new products and services, empowers consumers to make informed decisions with better energy information, and secures the grid against cyber-attacks. The framework has four pillars:

1. Enabling cost-effective smart grid investments
2. Unlocking the potential for innovation in the electric sector
3. Empowering consumers and enabling them to make informed decisions, and
4. Securing the grid.

Each pillar supports a set of policy recommendations that focus on how to facilitate a smarter and more secure grid [85].

4.5 US Smart Energy Initiatives

4.5.1 Department of Energy Smart Grid

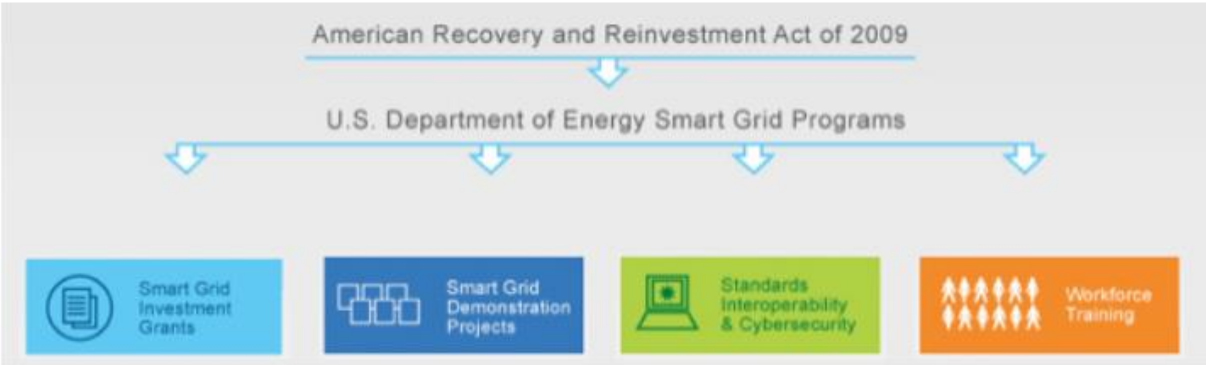


Figure 22. DoE Smart Grid

The American Recovery and Reinvestment Act of 2009 (Recovery Act) provided the U.S. Department of Energy with $4.5 billion to modernise the electric power grid and to implement Title XIII of the Energy Independence and Security Act (EISA) of 2007. The two largest initiatives within the US are the Smart Grid Investment Grant (SGIG) Program and the Smart Grid Demonstration Program (SGDP) (See Figure 22 and Figure 23). The DOE Office of Electricity Delivery and Energy Reliability (OE) is responsible for managing these five-year programs [85].

Figure 23. Smart Grid Initiatives

The DOE's Office of Electricity Delivery and Energy Reliability holds regional stakeholder meetings, to stimulate peer-to-peer dialogue on smart grid deployments, share lessons learned, and help replicate successes. The DOE is expanding cooperative relationships with the National Association of Regulatory Utility Commissioners and the National Association of State Utility Consumer Advocates, to provide technical assistance and share information on consumer empowerment from Recovery Act projects. A Smart Grid Innovation Hub has also been set up. Other initiatives include grid research and design investments by the Advanced Research Projects Agency–Energy (ARPA-E), a Home Energy Education Challenge, consumer behaviour studies funded by the

Recovery Act; and investment in smart grid technologies by the Department of Agriculture's Rural Utilities Service (RUS) [86]. The Department of Energy Office of Electricity Delivery and Energy Reliability is also launching a new Smart Grid Integration Challenge for Cities in 2016 to recognise US cities as "smart city leaders" in implementing sensing, data sharing, and data analytics to achieve energy consumption reduction targets set by individual cities. Each winning city will serve as a model for replication in other cities.

4.6 Smart Energy Initiatives in the Rest of the World

A worldwide study by DNV KEMA Energy & Sustainability [87] commissioned by the Netbeheer Netherlands made a global inventory of smart grid initiatives. This highlights lessons learned which can be used in the Netherlands. For instance, in America there is a strong focus on peak load reduction technology and dynamic pricing tariff pilots, whilst in Europe more emphasis is placed on improving energy efficiency and reducing emissions through the use of more decentralised means of production. In the Asia-Pacific region drivers vary country to country – from modernizing and improving grid reliability in China, to techniques for load management in Australia and New Zealand.

Notably there is a wide variety of technologies and services being demonstrated. This is affected by business drivers that are different in different regions and countries. Generally, smart meters and IT systems are being applied in most demonstration projects and demand response is being applied as a smart grid service to reduce peak loads rather than to 'fill' load gaps. To improve integration with renewable energy sources and apply smart devices and electric vehicles agent-based algorithms are being demonstrated. These algorithms are also being used for congestion management, critical operations, and load shedding. The PowerMatcher concept is being applied in several European countries and projects. Other decentralised controllers are being demonstrated for Virtual Power Plants (VPPs) by distribution network operators. For flexibility many demonstration projects also include energy storage. In some cases thermal storage devices have given storage capacity up to weeks.

Information Technology is a crucial part of a smart grid but introduces risk of communication failure and unwanted system errors. Interoperability and clear interface specifications are needed to allow integration. Other lessons learned are that there is a need for clear scoping and cost-benefit analyses prior to project commencement to prevent large project overruns. There is also a need to manage expectations to provide promised benefits to energy consumers and stakeholders. To deal with technical and financial risks it is important to perform demonstration projects at the correct scale.

Other countries investing heavily in smart grid infrastructure are Canada, Mexico, Brazil, many of the member states of the EU, Japan, South Korea, Australia, India, and China.

4.6.1 IEEE Smart GRID

The IEEE Smart Grid Initiative [88] brings together IEEE's broad array of technical societies and organizations to encourage the successful rollout of technologically advanced, environment-friendly and secure smart-grid networks around the world.

4.6.2 China

China is committed to reducing its carbon intensity for its GDP by 40 to 45 percent by 2020 relative to 2005. Here there is investment in renewable power transforming the nation’s energy landscape [89]. Equipment makers, communication device players, and integrated solutions providers from around the world see this as a major commercial opportunity. The Chinese government has announced plans to construct power grids in the north-west province of Xinjiang to allow interconnection with the country’s eastern provinces, Pakistan and other Asian countries. An Ultra High Voltage grid will be constructed to transmit power to the eastern coastal developed areas.

The State Grid Corporation of China has allocated US$31 billion to the Xinjiang Electric Power Company to perform grid integration of renewable energy and installation of power transmission lines by 2020. China also plans to construct a Global energy network by 2050 to meet global power demand using smart energy technology. This was announced by the Chinese President, Xi Jinping, to the UN Sustainable Development Summit. The aim is to create grid interconnectivity with neighbouring countries such as Russia, Mongolia, Kazakhstan, Pakistan, Myanmar, Laos, Nepal and Thailand. Since 1992 China has relied heavily on electricity it purchases from Russia.

China's annual predicted investment in smart grid development and related infrastructure from 2016 to 2030 is estimated to reach $128 billion and the Chinese National Development and Reform Commission has committed to producing 20% of the country’s energy needs from renewable and nuclear energy by 2030 [90].

4.6.3 Canada

In Canada, the state government of Ontario has a Smart Grid Fund [91]. The Smart Grid Fund supports projects that test, develop and bring to market the next generation of energy grid solutions. The aim is to help consumers and businesses manage energy costs, improve conservation efforts, and integrate new beneficial technologies like electric vehicles and storage.

4.6.4 Japan

The failure of the Daiichi nuclear power plant in Fukushima following the Great East earthquake in 2011 prompted the government to reform the power system to ensure a future stable supply [92]. Market liberalisation is also being introduced to provide lower costs to customers. This was launched in 2016 and will be complete by 2020. A driver to install smart grid infrastructure within the next five years is the Tokyo Olympic Games in 2020. The country's largest utility Tokyo Electric Power Corporation (TEPCO) has stated that it will have 27 million smart meters in the field by 2020.

4.6.5 South Korea

The South Korean government has imposed emission cuts on power plants. Here investment is being provided for clean and renewable power sources. Smart grids are seen as the way to integrated renewable sources so there is investment in smart meters, software and hardware, smart T&D equipment, communication and wireless network infrastructure and sensors. The market for smart grid equipment in South Korea is expected to grow by more than 20% during the five years to 2019 and home-grown smart grid equipment is being developed to support this with also a view to the export market [93]. As an example In June 2015, Kepco announced a $9.1 million contract to create a microgrid in Canada.

4.6.6 Brazil

Brazil suffers from frequent power outages [94]. This is driving interest in smart grid technology and the Mining and Energy Ministry is pushing for diversification in the energy mix to reduce reliance on hydro-power. Brazil's smart grid market is expected to grow by 21.17% over the period 2014-2019, according to market research company Tech Navio.

4.6.7 India

India's government has committed billions of dollars for smart grid infrastructure with cumulative spending forecasted to be US$21 billion over the period 2015-2025 [95]. They have also created a national smart grid organisation that will invest $210 million into planning, monitoring and implementing grid modernization up until 2017. There is a need in India to stop rampant electricity theft which is estimated to cost $16.2 billion a year.

4.6.8 Australia

In 2009 the Australian Government recognised the importance of investing in commercial-scale trials of promising smart grid technologies. $100 million was put into the Smart Grid, Smart City Program with further funding of $390 million by other contributors. The Program ran from 2010 to 2013 and determined the benefits of smart grid deployment [96].

4.6.9 Mexico

Mexico plans a 30.2 million smart meter deployment between 2015-2025 [97]. Mexico is the second largest consumer of smart grid technology behind Brazil in the Latin America. Regulatory momentum for smart grid infrastructure investment is being driven by a smart grid roadmap developed by the regulator Comisión Reguladora de Energia (CRE) which has a mandate to modernise the country’s power grid. A $10.9 billion smart grid infrastructure investment is planned with deployments across a number of market segments including smart metering, distribution automation, battery storage, home energy management, information technology and wide area measurement. This is supported by the PIDIREGAS program, which uses private company finance to carry out public works projects.

4.7 Needs for Regulation

The smart grid market is led by regulation. In many countries reductions in emissions, consumer choice and energy security are driving adoption of smart grid technologies. Grid regulation varies considerably per country, particularly across Europe which has a big impact on possibilities for smart grid investments. Advantages of innovation funding is therefore difficult to measure. As an example although Virtual Power Plants (VPPs) have been shown to have a high socio-economic value within the energy market it is difficult to copy results from field trials in one country to another country due to different regulations and ancillary services.

A key factor that influences consumer benefit is pricing structure used which can increase the value of smart grids (and smart appliances). Experience shows that tiered pricing rates are more effective at reducing load than a time-of-use pricing (off-peak/on-peak) schemes [98]. Tiered rate structures allow prices to reflect system capacity with super-peak price levels being applied when large load reduction is needed. More dynamic price levels are required but this has to be balanced against the increase in uncertainty for customers. Several pilots in the US, has shown that the use of “Critical Peak” prices is an effective technique to trigger load reduction. The use of rebates was found to be less effective indicating that "punishments" are more effective than "rewards".

4.7.1 European Regulation on Smart Grids

In order to get investors to commit there is a need for a regulatory framework for Smart Grids. Within Europe the Electricity Directive and the Energy Services Directive provide a mix of obligations and incentives to Member States to establish such a framework [99]. Regulation is being targeted to encourage network operators to earn revenue not from additional sales but from efficiency gains and lower peak investment needs. There are 3 key groups as outlined below:

4.7.1.1 Smart Grids Task Force

The Smart Grids Task Force [100] was set up by the European Commission in 2009 to advise on issues related to smart grid deployment and development. There are five Expert Groups who focus on specific areas and shape EU smart grid policies.

- Expert Group 1 – Smart grid standards. In 2015 this expert group performed an investigation on the interoperability, standards and functionalities applied in the large scale roll-out of smart metering in EU Member States.
- Expert Group 2 – This group addresses regulatory recommendations for privacy, data protection and cyber-security in the smart grid environment
- Expert Group 3 – This group gives regulatory recommendations for smart grid deployment
- Expert Group 4 – This group considered smart grid infrastructure deployment
- Expert Group 5 – This group considers implementation of smart grid industrial policy

4.7.1.2 Agency for the Cooperation of Energy Regulators (ACER)

The Agency for the Cooperation of Energy Regulators (ACER) [101] is a European Union Agency, based in Ljubljana, Slovenia that was set up to progress the completion of the internal electricity and gas energy markets. It is an independent body that fosters cooperation among European energy regulators to ensure market integration and the harmonisation of regulatory frameworks within the framework of the EU's energy policy objectives.

4.7.1.3 CEER

The Council of European Energy Regulators (CEER) [102] is the voice of Europe's national regulators for electricity and gas at the European and international level. CEER, is a non-profit association that allows national regulators to cooperate and exchange best practice, creating a single, competitive, efficient and sustainable EU internal energy market that works in the public interest.

4.7.1.4 Regulations in UK

Smart grids are being driven in the UK by energy and climate goals. Time varying electricity tariffs are Smart grid policy in the UK**.** Building a smarter grid is an incremental process of applying information and communications technologies to the electricity system, enabling more dynamic real time flows of information on the network and more interaction between suppliers and consumers. DECC published a vision document in December 2009 [103], and the Electricity Networks Strategy Group (ENSG) published a Smart Grid Routemap [104]. Smart electricity and gas meters are being rolled out to all UK homes by 2020 and Ofgem is providing £500 million through the Low Carbon Networks Fund [105] to support smart grid trials. A further £2.8 million has been given to 8 smaller smart grid demonstration projects. A framework for smart grid standards, focused on cyber-security issues has also been put in place [106].

In the UK the Smart Grid Forum was created by the Department of Energy and Climate Change (DECC) and the industry regulator, Ofgem, to bring together representatives from electricity network companies, consumer groups, energy suppliers and wider industry. The aim of the forum is to address technical, commercial and regulatory issues associated with developing smart grids in order to support the UK's transition to a secure, safe, low carbon, affordable energy system. The forum discusses new issues and questions that arise from smart grids with respect to the existing regulatory and commercial framework. Specific challenges are the increase in complexity, the need to balance supply and demand at local levels, the introduction of intelligent control networks and utilisation of energy storage. Investment is needed and existing regulatory and commercial frameworks need to evolve to incentivise this. The Ofgem Low Carbon Network Fund and DECC/Ofgem-chaired Smart Grid Forum have initiated some work, however, there is a need to remove regulatory barriers to storage and demand side response, deliver clearer price signals to allow more flexibility from consumers, e.g. time of use tariffs, and to catalyse innovation, so that new solutions can emerge [107]. The government is also assessing whether more fundamental changes are required to deliver a future smart system, including in the operation of the market and existing institutional arrangements [108].

4.7.1.5 Regulations in Germany

Regulation within Germany is leading to new roles, e.g. metering point operator and metering service provider, with new contracts and pricing models. Protection clauses are needed as well as changes in the regulation to allow for Balance Responsible Parties to take advantage of offering flexibility to consumers.

4.8 Smart Grid Standards

4.8.1 Smart Grid Standards in Europe

Within Europe standards in the sector are voluntary and are developed by industry and market actors following principles such as consensus, openness, transparency and non-discrimination. In the smart grid area there is a need for standards for interoperability and safety. The aim of standards is to reduce costs and to allow different vendors to integrate their equipment together. For the electricity sector standards are set by three European Standards Organizations (ESOs):

- the European Committee for Standardisation, CEN
- the European Committee for Electrotechnical Standardisation, CENELEC, and
- the European Telecommunications Standards Institute, ETSI and can be used to support EU legislation and policies.

The European Commission and EFTA issued the Smart Grid Mandate M/490 [109] in March 2011. This was accepted by the, CEN, CENELEC and ETSI in June 2011. The mandate highlights the need for speedy action, the need to accommodate a huge number of stakeholders and to work at an international level to develop a framework to enable the three ESOs to perform continuous standard enhancement and development in the smart grid field [110] [111].

4.8.2 Smart Grid Standards in US

Recognizing that standards play a critical role in the development of smart grids, EISA called for NIST and FERC to facilitate the development and adoption of interoperability standards (U.S. Congress 2007) [84]. The NIST led smart grid interoperability process, aims to develop flexible, uniform, and technology neutral standards that can enable innovation, improve consumer choice, and yield economies of scale.

4.8.2.1 NIST

NIST has been given the primary responsibility to coordinate development of a framework that includes protocols and model standards for information management to achieve interoperability of Smart Grid devices and systems. NIST has developed a three-phase plan to accelerate the identification and consensus on Smart Grid standards, establish a robust Smart Grid Interoperability Panel (SGIP) that sustains the development of the many additional standards that will be needed, and to create a conformity testing and certification infrastructure. The progress made in Phases II and III of the plan are described in [112]. This report also presents a reference model, standards, gaps, and action plans. The processes established by the SGIP are now guiding standardization efforts across more than 20 standards-setting organizations. NIST's standards for the Smart Grid [113] are targeted at industry utilities, vendors, academia, regulators, integrators and developers, and other Smart Grid stakeholders.

NIST and the International Trade Administration (ITA) have partnered with the Department of Energy to establish the International Smart Grid Action Network (ISGAN). This is a multi-national collaboration of 23 countries and the European Union. ISGAN is designed to complement the Global Smart Grid Federation which is a global stakeholder organization which serves as an "association of associations" to bring together leaders from Smart Grid stakeholder organizations around the world.

4.9 Cyber-Security

The deployment of networks of computers, intelligent electronic devices, software, and communication technologies presents greater infrastructure protection challenges than those of the traditional infrastructure. A smarter grid includes more devices and connections that lead to vulnerabilities which can be used for intrusions, error-caused disruptions, malicious attacks, destruction, and other threats. Smart grid technologies thus need open standards, specifications and requirements to assure interoperability but there is also need to protect consumer privacy and provide security to ensure resilience. As the electric grid network is key to the operation of a country cyber-security is a key topic on both sides of the Atlantic.

4.9.1 European Initiatives on Cyber-Security

Cyber-security is a highly important requirement for future smart grids. ICT infrastructures are an underpinning platform for critical infrastructure across Europe without which some services (e.g. in electricity transmission and distribution) could come to an abrupt halt. To tackle this challenge in 2010 the European Commission convened a multi-stakeholder and multidisciplinary group of experts to discuss and work on relevant matters regarding the security and resilience of communication networks and information systems for Smart Grids [114].

There is a drive to provide a high common level of network and information security across Europe. As a large system of distributed and interconnected systems, the smart grid offers an exceptionally large attack surface. Every asset of the smart grid (i.e., home gateways, smart meters, substations, control room) presents a potential target for a cyber-attack. A key concern is that an attack on a critical node may jeopardise grid security and lead a cascade effect and whole system blackout. The smart grid cyber-security challenge is thus to protect the ever-growing number of smart grid assets and their communication channels from fast-growing and continuously evolving cyber threats.

4.9.1.1 Cyber-Security Standards

Standards to develop smart grid cyber-security are already available, however, enhancements are needed to reflect the evolution of the smart grid, its technologies, and threats. A key challenge is to maintain these standards over time at an appropriate pace which requires considerable effort. In Europe Alstom Grid, Intel, and McAfee have joined their expertise to deliver a view on smart grid cyber-security in a white paper [115].

This initiative highlights challenges in migrating to the modern grid and different approaches to building it while addressing cyber-security risks.

4.9.2 US Initiatives on Cyber-Security

The U.S. White House has also expressed concern about cyber-security and protecting critical infrastructures. Cyber-security needs to address threats that are unique to electric grid technology which include long life expectancy of energy control systems, low-latency communications needed for real-time control, and differing requirements and regulatory frameworks among grid stakeholders. Although much has been done already in terms of processes for sharing information about risks and threats to the electricity sector the Administration has proposed specific cyber-security legislation. The Federal Government is seeking to ensure that grid operators have access to actionable threat information and provide support for research, development, and demonstration of cyber-security systems. Stakeholders (government agencies, industry, and utilities) are being encouraged to cooperate to identify and address cyber risks and open standards and guidelines for cyber-security will be developed through public-private cooperation. The aim is to identify and prioritise relevant cyber risks—including malware, compromised devices, insider threats, and hijacked systems—and develop standards and guidelines that enable the design of effective plans for mitigating those risks.

The overall goal is to develop policy and regulatory frameworks that ensure that effective and feasible security is appropriately implemented and that all stakeholders contribute to the security and reliability of the grid. A problem at present is that stakeholders have varying levels of awareness and understanding of current threats and specific vulnerabilities. It is necessary for Federal and industry partners to provide timely and actionable cyber threat and vulnerability information to state regulators, industry participants, and electric utilities. Already a number of threat warning bodies exist, e.g. Electricity Sector—Information Sharing and Analysis Center, the United States Computer Emergency Readiness Team, and the National Electric Sector Cyber-security Organization [116].

4.9.2.1 US Cyber-security Standard for Smart Grid Systems

Smart grid cyber-security must address not only deliberate attacks (from disgruntled employees, industrial espionage, and terrorists), but also inadvertent compromises due to user error, equipment failures and natural disasters. The NIST Information Technology Laboratory (ITL), Computer Security Division leads the Smart Grid Interoperability Panel (SGIP) Cyber-security Committee (SGCC), which was set up in response the Energy Independence and Security Act of 2007 to address cyber-security in the areas of Advanced Metering Infrastructure (AMI), cloud computing, supply chain, and privacy recommendations related to emerging standards. The primary goal of the SGCC is to develop a cyber-security risk management strategy for the Smart Grid to enable secure interoperability of solutions across different domains and components. It provides foundational cyber-security guidance, reviews of standards and requirements, outreach, and fosters collaborations in cyber-security within the smart grid. A key outcome from this are the NISTIR 7628 Guidelines for Cyber-Security (Volumes 1, 2, and 3). This publication is widely used by utilities, vendors, and regulators, and is also cited internationally. A first draft of (revised) NISTIR 7628 Guidelines for Smart Grid Cyber-Security, Revision 1 for SGCC review and comment has been published for comment [117].

The DOE/OE Cyber-security for Energy Delivery Systems (CEDS) programme is also working toward resilient energy delivery systems that are able to survive a cyber incident.

5 Smart Transportation

5.1 European Smart Transportation Drivers and Policy Activities

Transport is an essential component of the European economy accounting for about 7 % of GDP and for over 5 % of total employment in the EU.

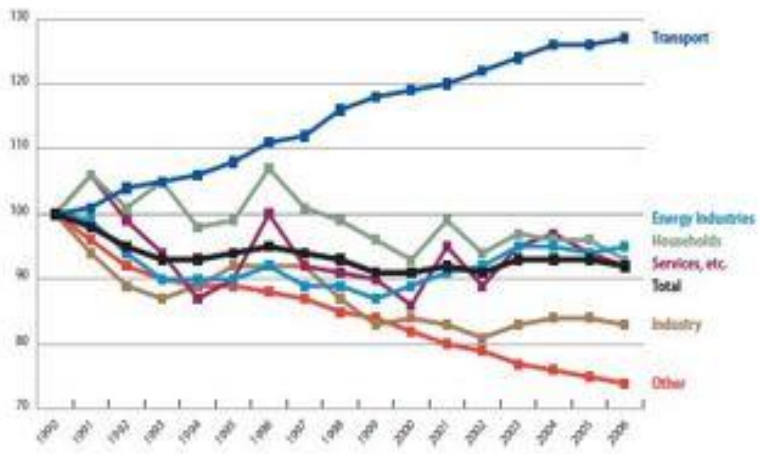


Figure 24. Contributions to CO2 Emissions

Sustainability is a key issue in Europe and there has been a dramatic increase in both freight (35%) and passenger transport (20%) between 1995 and 2006 and this is set to rise. Along with this increase in traffic there has been an increase in emissions. According to data from the European Environment Agency [119], transport accounted for close to a quarter (23.8%) of total greenhouse gas emissions and slightly more than a quarter (27.9%) of total CO_2 emissions in the EU-27 in 2006. No other sector has the growth rate of greenhouse gas emissions as high as in transport (See Figure 24). As the transport sector relies on fossil fuels for 97% of its needs, the fight against climate change in this sector is also synergistic with energy security of supply. The expectation is that traffic will increase further in all sectors and the infrastructure needs to support continuing increase in demand. Freight transport follows trade activity and in recent years this has grown more than GDP. Passenger transport, excepting aviation, has undergone a less dramatic rise. These trends can only be sustained, however, if transport radically improves its energy efficiency and reduces its greenhouse gas emissions.

Linked with this is a drive to improve safety. Europe’s roads have become safer in recent years: the number of road accidents involving personal injury fell by 12% between 1991 and 2007. More importantly, the number of road fatalities dropped by more than 44% over the same period. However, with still over 30 000 deaths in the EU in 2011, transport by road is still costly in terms of human lives. There is an objective in the 2001 European White Paper [120] to halve casualties with respect to 2001 levels in road transport. The increased use of ICT is seen as the answer to many problems to allow better scheduling of traffic flow to reduce congestion, enabling increased communication with infrastructure and between vehicles to reduce congestion and avoid accidents, and as a central element in introduction of more autonomy within systems to improve efficiency and increase safety.

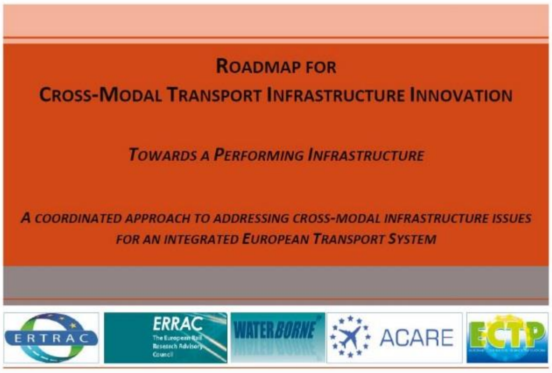
In the maritime sector, marine pollution and maritime accidents were considerably reduced and the EU has established one of the most advanced regulatory frameworks for safety and for pollution prevention (most recently with the third maritime safety package). In aviation, a comprehensive set of common, uniform and mandatory legislation has been adopted covering all the key elements affecting safety (aircraft, maintenance, airports, air traffic management systems, etc.). Safety agencies have been set up for aviation (EASA), maritime affairs (EMSA) and rail transport (ERA).

5.1.1 European Transport Technology Platforms

The European Commission supports a number of transport Technology Platforms that includes ERRAC [121], ERTRAC [122], ACARE [123] and WATERBORNE [124]. In 2001 the Commission issued a White Paper [120] setting a 10 year agenda for the European transport policy which was updated in the mid-term review of 2006 [125]. This highlighted that transport is a complex Systems of Systems that depend on multiple factors, including the pattern of human settlements, the organisation of production and the availability of infrastructure. Although the European transport system compares well in terms of efficiency and effectiveness with most advanced regions of the world, it is still not on a sustainable path. The open markets in Europe have led to more efficiency and lower costs which can be particularly seen in air transport, however, in other transportation areas there is a need to harmonise differences in taxation and subsidies.

5.1.2 TEN-T Guidelines

To coordinate the planning of infrastructure projects across Europe the Trans-European transport networks (TEN-T) policy has provided many benefits with an investment programme of EUR 400 billion. The TEN-T Guidelines [126] are the European Community's instrument for policy definition and network planning. Adopted in 1996 and amended in 2004, the guidelines include two planning layers: a comprehensive network layer including outline plans for rail, road, inland waterway, combined transport, airport and port networks and a second layer of 30 priority projects. The TENs have already gone a long way in linking EU markets and people. Progress has been achieved in reducing air pollution and road accidents. Air quality in European cities has significantly improved through the application of stricter Euro emission standards addressing fine particles (PM10) which are particularly damaging for human health. The guidelines are also addressing expansion of transport infrastructure which result in habitat loss and landscape fragmentation. To co-fund identified TEN-T projects in the EU Member States a Connecting Europe Facility (CEF) Fund has been set up with a budget of €24.05 billion.



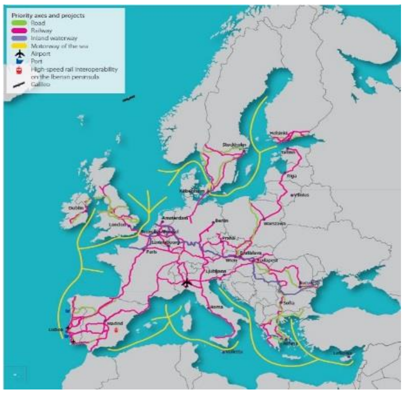
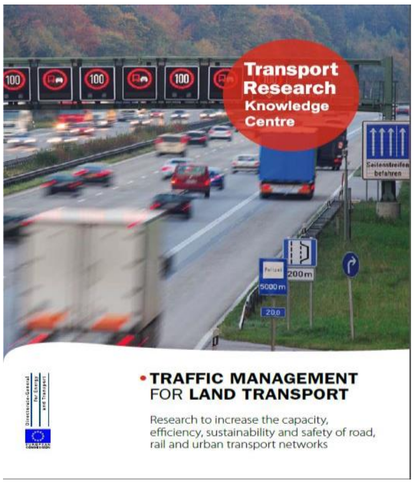


Figure 25. Cross-Modal Transport Infrastructure Innovation Roadmap [118] and Key Routes Identified [119]

Key transportation routes have been identified across Europe covering road, rail and marine transport [118] [[119] (See Figure 25). The European Parliament and Council introduced the Directive 2010/40/EU in July 2010 on the framework for the deployment of Intelligent Transport Systems (ITS) in the field of road transport and for interfaces with other modes of transport. The European Commission's aim is to accelerate and coordinate the deployment of ITS applications on the Trans European Road Network (TERN) across Member States in a consistent and harmonised way.

5.1.3 Traffic Flow and Integration with Infrastructure



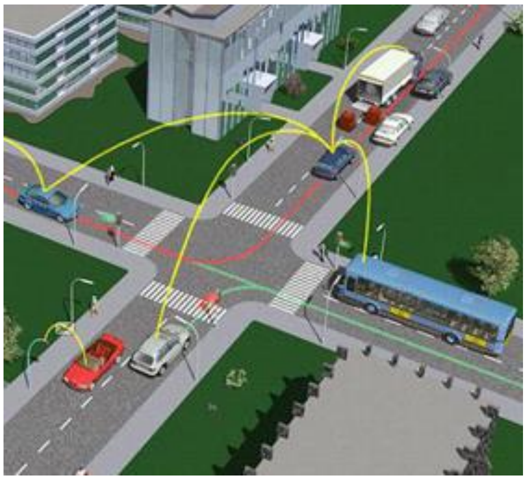


Figure 26. Policy Brochure on Traffic Management [126] and Intelligent Transport Systems [127]

The Transport Research Knowledge Centre (TRKC) consortium produced a Policy Brochure on "Traffic Management for Land Transport" [126] covering both road and rail on behalf of the European Commission's Directorate-General for Energy and Transport (See Figure 26). Although the use of railway signalling and traffic lights in cities have long been used for traffic management a key tenet of this brochure is the need for sophisticated integrated applications based on Intelligent Transport Systems. This is driven by realisation of the need to manage transport networks more effectively in order to maximise the use of existing infrastructure, provide a reliable service to the end user and increase safety, while reducing negative environmental effects. Urban and inter-urban traffic management research and applications are covered in this publication, including aspects such as network management, public transport priority, safety, punctuality and international traffic. Safety related to traffic management, e.g. speed management is also covered. The aim of traffic planning is to plan, monitor, control and influence traffic to maximise the effectiveness of the use of existing infrastructure, provide reliable and safe operation and address environmental goals. A further aim is to ensure fair allocation of infrastructure space (road space, rail slots, etc.) among competing users.

For road or rail transport the scope includes fleet management and timetabling, matching services and vehicles to meet demand and providing essential services while also fitting in with (or finding ways to improve) constraints caused by network capacity, driver shift patterns and technical aspects. For rail traffic the scope includes the bottom operational level of signalling systems and systems for train location; the intermediate level, consisting of the management of rail operations to enhance both the level of service to users and safety; and the higher strategic level, dealing with network access terms and capacity allocation. European policy has long promoted the use of rail in order to rebalance modal shift and encourage the use of this more environmentally friendly and safer transport mode. European rail policy has been developed in the last twenty years to open the competitive market for rail services, first in freight, then in passenger transport and to provide greater interoperability. This is expected to transfer more goods and passengers to rail, at a lower price and with better quality.

In the automotive domain the report highlights that research and deployment of ITS at the EU level is a key tool for traffic management and control to improve safety and user services and reduce the environmental impact of traffic, particularly at infrastructure bottlenecks. ITS applications for traffic management and control include rerouting, Variable Speed Limits (VSL) with automated enforcement, lane control, dynamic use of the hard shoulder on motorways or access control measures such as ramp metering, as well as specific measures for freight such as information on Heavy Goods Vehicle (HGV) parking and “stacking” of lorries in the case of disruption. Cooperative systems, whether vehicle-to-vehicle (V2V) or vehicle-to-infrastructure (V2I,) will play an increased role in traffic management and control in the future. To achieve this coordination across countries and regions, as well as with vehicle and equipment manufacturers, is required. Automatic Vehicle Identification and Location (AVI/AVL) and Automatic Number-plate Recognition (ANPR) is a prerequisite in order to ensure full use can be made of traffic management and enforcement strategies. Existing Automatic Incident Detection (AID) measures can be supplemented by linkage with “probe” (or “floating“) vehicle systems.

Additionally, in a report produced by Transport Research and Innovation Portal (TRIP) consortium for the European Commission’s Directorate-General for Mobility and Transport (DG MOVE) [128], it is highlighted that there is a need to manage conflicting factors, such as vehicles, loads and routes, to improve safety, and to reduce vehicle wear, transport times and fuel consumption. There are many challenges in relation to the increasing connectivity, amount of data (especially real-time), interoperability and integration of new and existing fragmented systems in multimodal and cross-border scenarios. New business models are needed and there is a need to promote behavioural change driven by policy. The challenges for policy-makers include data privacy and data sharing, regulation and planning of multimodal services, standardisation and cross border EU-wide trials. The Strategic Transport Technology Plan (STTP) is the long-term transport innovation policy to identify, in collaboration with all Research and Innovation actors, the most promising technologies. These objectives have been incorporated into the Horizon 2020 research and deployment focus, especially on the potential of ITS as a tool to link transport modes (promoting co-modality and inter-modality) with the services of different operators and infrastructure providers in a single transport mode. This cross modal perspective takes into account transport infrastructure, services and operations [129].

5.1.4 European Innovation Partnership on Smart Cities and Communities

The European Innovation Partnership on Smart Cities and Communities (EIP – SCC) was initiated in July 2012 (See section on Smart Cities). The Smart Cities concept was originally outlined in the digital agenda which contains 132 actions divided in 7 pillars to boost the EU economy and enable Europe's citizens and business to get the most out of digital technologies and infrastructures. Under the Priority Area "Sustainable Urban Mobility", 7 priority actions are being pursued:

- Improve clean power for transport: vehicles and infrastructure
- Foster seamless door-to-door multimodality in urban transport
- Further clean logistics
- Open up intelligence in urban transport systems
- Enable tools for seamless doors-to-door multi-modality
- Promote sustainable and integrated mobility planning
- Promote use of cleaner vehicles.

5.1.5 Smart Cities – Urban Mobility

Considering urban mobility POLIS has produced a policy paper [130] that highlights the needs to support the increased use of electric vehicles, introduce ITS and encourage behavioural change (sharing economy, focus on active travel) within smart cities. This advocates the use of governance with involvement of the Commissioner for Transport to raise the profile of sustainable urban mobility, include the Directorate Generals that govern EU legislation affecting Smart City objectives (DG Environment, DG Regio, DG Connect, DG Move, DG Energy) and engage with urban transport stakeholders.

5.2 Intelligent Transport Systems – European Activities

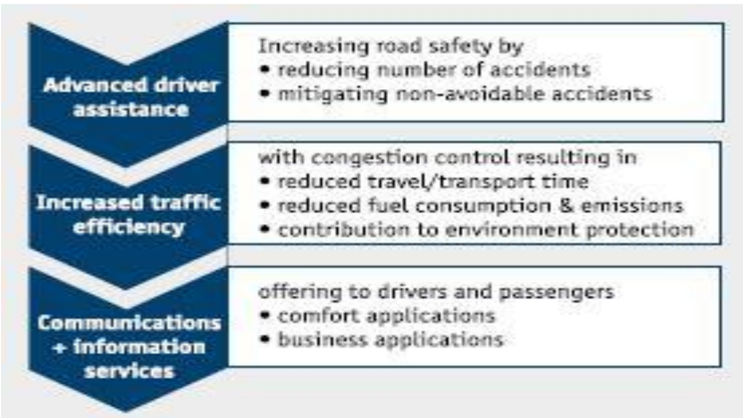


Figure 27. Intelligent Transport Systems [127]

Traffic management is a highly complex problem coming under increasing demands for additional capacity, greater safety and lower costs while meeting strict environmental regulations. At the same time the global car fleet is predicted to double from currently 800 million vehicles to over 1.6 billion vehicles by 2030. Without innovative thinking, integration of information and flow control systems severe congestion will be a major concern for mobility with long commutes and dramatic implications for road haulage of freight leading to logistical problems of late deliveries within highly complex scheduled systems. Already embedded intelligence, mobile phone, car-to-car and car-to-infrastructure communication are offering the opportunity for increased awareness, more efficient mobility and automated driver safety systems.

In the automotive sector Intelligent Transport Systems (ITS) [131] are being developed to provide innovative services relating to different modes of transport and traffic management (See Figure 27). These will enable various users to be better informed and make safer, more coordinated, and 'smarter' use of transport networks. The aims are to increase journey efficiency, reduce congestion, improve road safety and reduce air pollution. An EU Directive (2010/40/EU) was issued on the 7 July 2010 [132] defining the framework for deployment of intelligent transport systems in the field of road transport. Here ITS are defined as “systems in which information and communication technologies are applied in the field of road transport, including infrastructure, vehicles and users, and in traffic management and mobility management, as well as for interfaces with other modes of transport”. Air pollution and congestion are issues in areas of high population density and integrated approaches exploiting combinations of walking, bicycle, buses and trains are advocated.

Among the technologies being explored under ITS are car navigation, traffic signal control systems, vehicle message signs, automatic number plate recognition and speed cameras. Opportunities to link with parking guidance and with weather systems are also being considered. For congestion avoidance advanced modelling techniques are being explored against historical baselines to predict and redirect traffic. Already a lot of work is being performed on "floating car" or "probe" data collection for obtaining travel time and speed data for vehicles traveling along streets and motorways [131]. This can be done from triangulation from mobile phones (which periodically transmit their presence to the mobile phone network), vehicle re-identification using sets of detectors mounted along the road to track a unique vehicle serial number (provided by Bluetooth MAC addresses or RFID serial numbers, e.g. from toll tags) as it travels down a road to give travel times and speed, or from in-vehicle GPS (satellite navigation) systems that have two-way communication with a traffic data provider. A key advantage of floating car data technology is that it less expensive than sensors or cameras, it provides greater coverage, is faster to set up and maintain and works in all weather conditions including heavy rain.

Traffic control is not a new concept and inductive loops that detect magnetic field changes have been placed in road networks for many years to perform ramp metering in order to manage traffic congestion [131]. The simplest detectors simply count the number of vehicles during a unit of time that pass over the loop, while more sophisticated sensors estimate the speed, length, and weight of vehicles and the distance between them. Loops can be placed in a single lane or across multiple lanes, and they work with very slow or stopped vehicles as well as vehicles moving at high-speed. However, more recently advances in telecommunications and information technology, coupled with state-of-the-art microchip, (RFID Radio Frequency Identification), and inexpensive intelligent beacon sensing technologies, have enhanced the technical capabilities opening up new opportunities for more global control of traffic. Vehicle and infrastructure-based networked systems using infrastructure sensors installed or injected into the road or attached to buildings, posts, and signs, can be placed permanently or during road maintenance to provide better monitoring of vehicles operating in critical zones.

Cameras are a common sight on today’s roads and have been used for many years for traffic enforcement to detect and identify vehicles disobeying a speed limit (normally combined with radar detection), detect vehicles that cross red traffic lights, identify vehicles traveling in bus lanes, vehicles crossing railways, crossing double white lines or incorrectly utilising high occupancy vehicle lanes (reserved for car pooling). Number plate recognition systems can be used to automatically issue tickets to offenders. However, more recently cameras are also being used for traffic flow measurement and automatic incident detection.

Cameras are considered to be "non-intrusive" as there is no need to install components into the road surface but they do require some configuration, e.g. input of known measurements such as the distance between lane or the height of the camera above the roadway. The typical outputs from a video detection system are lane-by-lane vehicle speeds, counts, and lane occupancy readings. Some systems provide additional outputs including gap, headway, stopped-vehicle detection, and wrong-way vehicle alarms. These systems have been successfully combined with variable speed limits that change with road congestion and other factors such as weather conditions. One example is the M25 Motorway that circumnavigates London. On the most heavily travelled 14-mile (23 km) section (junction 10 to 16) of the M25 variable speed limits combined with automated enforcement have been in force since 1995 [131]. The results indicated savings in journey times, smoother-flowing traffic, and a fall in the number of accidents, so the implementation was made permanent in 1997.

5.2.1 ERTRAC Strategic Research Agenda for Road Transport

In Europe the ERTRAC Strategic Research Agenda [133] covers mobility, transport and infrastructure, safety and security, environment, energy and resources, design and production. It highlights a number of key research topics including traffic management, integration of vehicle and infrastructure systems, traffic management using ITS, data collection and processing, business models, optimisation of road space to ensure that vehicles (particularly HGVs) adopt routing systems that minimise adverse impacts, systems for segregating traffic with dedicated infrastructure and prioritised traffic management and methods to assist the booking of optimised slots for freight vehicles. The White Paper produced by ERTRAC [134] highlights a number of ongoing projects around Europe and also highlights the key role that exploitation of new ICT functionality will have on the future of ITS. In order to fulfill the aspirations of the Transport White Paper there is a need to coordinate the development of Systems of Systems for surface transport at an EU level with strong political commitment.

5.2.2 European Transport Network Alliance Plus (ETNA) Plus Project

The objective of ETNA Plus [135] is to foster innovation in trans-national cooperation in Transport. The aim is to encourage new actors and regions into EU research calls and projects. ETNA Plus targets transnational cooperation by raising awareness and giving support to national/regional research stakeholders to identify funding sources and partners, create coherence among research activities and transfer best practice via brokerage events, training and coaching.

5.2.3 New Mobility Services

The New Mobility Services project [136] is developing ways to better integrate and manage seamless multi-modal (door-to-door) mobility for urban transport. This is being achieved by providing open platforms and open data that allows public and private service providers to develop and test schemes that provide information, ticketing and planning of trips. The scheme targets large-scale roll out with involvement of 10 cities. A number of key challenges are being addressed, to overcome technological obstacles to deployment and target public investment, to reduce fragmentation and promote sharing of data to provide services, ensure quality of data, enable standardisation and interoperability, define business models and provide governance and reach a balance between private and public bodies.

5.2.4 DRIVE C2X

The DRIVE C2X project [137] has 34 partners, 13 support partners and an 18.6 million Euro budget. It aims to provide the foundations for cooperative systems in Europe with the aims of safer, more economical and more ecological driving. The project is carrying out field tests of systems leading on from the PRE-DRIVE C2X which implemented technologies in European test sites in Finland, France, Germany, Italy, Netherlands, Spain and Sweden. An aim is to raise public awareness, provide feedback for standard organizations and support for initiating public-private ventures. The work focuses on communication between vehicles (C2C) and the roadside and backend infrastructure system (C2I). Previous projects such as PReVENT [138], CVIS [139], SAFESPOT [140], COOPERS [141], and PRE-DRIVE C2X [142] have proven the feasibility of safety and traffic efficiency applications based on C2X communication. DRIVE C2X goes beyond the proof of concept and addresses large-scale field trials under real-world conditions at multiple national test sites across Europe. The systems being tested are built according to the common European architecture for cooperative driving systems defined by COMeSafety [143]. This guarantees compliance with the upcoming European ITS standards. This approach also ensures that the results of DRIVE C2X have long-term validity at a European level, giving system developers as well as decision maker’s confidence.

DRIVE C2X is also implementing and testing a concept for the integration of a data backend, enabling commercial services based on C2X communication data to be developed for private and commercial customers. Such services are expected to become a major revenue source for cooperative driving systems and are key for successful implementation of this technology on European roads.

5.2.5 Autonomous Cars - HAVEit – Highly Automated Vehicles for Intelligent Transport

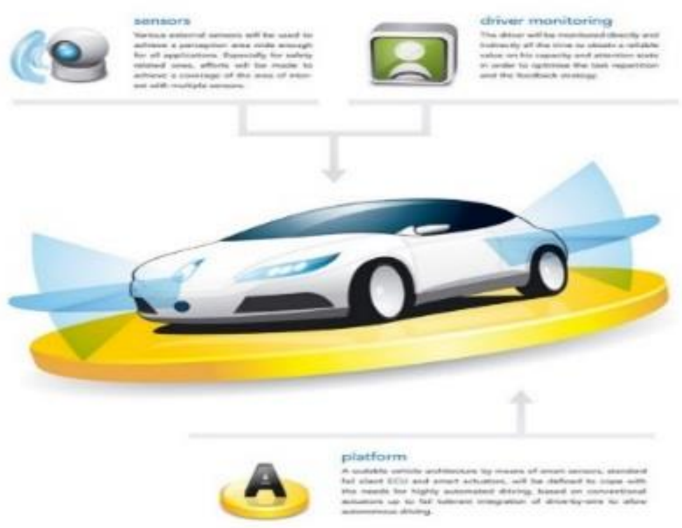


Figure 28. - HAVE-it Autonomous Car

There is great interest in the automotive industry in introducing autonomous driving features to improve safety. The EU funded HAVEit project [144] has developed concepts and technologies for highly automated driving (See Figure 28). The key drivers for automated driving are increasing traffic density, the growing flood of information available to drivers and the rising average age of the population. In Europe 1 in 3 people will be over the age of 60 in 10 years' time. Automation is needed to relieve drivers of some of the stress of driving guiding them through traffic more efficiently with a consequent environmental benefit. This will help reduce driver workload, prevent accidents, reduce environmental impact and make traffic safer. The HAVEit consortium (17 partners) consisted of vehicle manufacturers, Continental, Volvo Technology AB, Volkswagen AG, automotive suppliers and scientific institutes from Germany, Sweden, France, Austria, Switzerland, Greece and Hungary. In total, investments of 28 million Euro were made into HAVEit, 17 million Euro of which were EU grants and 11 million Euro were contributed by the 17 partners. Seven demonstration vehicles were produced.

Highly automated vehicles can take over three main driving functions: steering (lateral automation), path planning (longitudinal automation) and navigation. These make driving easier for people and create highly automated systems which can be used intuitively. As part of the HAVEit project, three automation modes which can be selected and activated by drivers were developed and implemented in all demonstration vehicles.

- Normal - Lane keep assist and emergency brake assist
- Longitudinal automation - no need to accelerate or brake
- Lateral automation - no need to steer

In the first mode, the driver steers the vehicle alone, assisted by already-available standard driver assistance systems, such as lane keep assist or an emergency brake assist. In partly or semi-automated mode, the vehicle drives with longitudinal automation, so drivers no longer have to accelerate or brake. At the level of high automation, lateral automation comes into play, meaning the driver no longer has to steer. Despite the level of automation selected, the driver is always fully responsible for manoeuvring the vehicle and can take control in place of the system at any time. The driver also has to monitor the vehicle's driving manoeuvers. In the partially and highly automated modes, the system observes the driver with the help of a camera located inside the vehicle. The moment the driver stops paying attention to the road, the assistant prompts them to take control of the wheel. The German Aerospace Centre (DLR) and the Wuerzburg Institute of Traffic Sciences (WIVW) developed the concepts of adaptive communication between the driver and the automated vehicle.

5.2.6 Drive Me

The Swedish Drive Me project [145] is a joint autonomous driving pilot project between the Volvo Car Group, the Swedish Transport Administration, the Swedish Transport Agency, Lindholmen Science Park and the City of Gothenburg with a vision for zero traffic fatalities. 100 self-driving Volvo cars will use 50 Km of selected public roads in everyday driving conditions around the Swedish city of Gothenburg to identify:

- How autonomous vehicles bring societal and economic benefits by improving traffic efficiency, the traffic environment and road safety
- Infrastructure requirements for autonomous driving
- Typical traffic situations suitable for autonomous vehicles
- Customers' confidence in autonomous vehicles
- How surrounding drivers interact smoothly with a self-driving car

The roads to be used are typical commuter arteries and include motorway conditions and frequent queues. The project started in 2014 with work on customer research and technology development, as well as the development of a user interface and cloud functionality. The first cars are expected to be on the roads in Gothenburg by 2017. An aim is that the Drive Me project will help define the role of self-driving vehicles in future city planning reducing infrastructure investments, lowering emissions and improving traffic safety. The driver will hand over responsibility to the vehicle, which can handle all driving functions at the driver's discretion, however, the driver is expected to be available for occasional control with a sufficiently comfortable transition time. For drivers autonomous driving is expected to provide more efficient time-management behind the wheel with the ability to interact safely via phone or tablets. The project will also investigate fully automated parking, without a driver in the car, such that the driver can walk away from the car at the parking entrance while the vehicle finds a vacant spot and parks by itself.

5.3 European Green Initiatives

In Europe there are a number of "green initiatives" to take up the use of electric vehicles and to reduce pollution across a range of transport modes.

5.3.1 Green Cars Initiative

Figure 29. Green Cars Initiative

The European Green Cars Initiative [146] (See Figure 29) provides funding for green technologies for cars, trucks and buses. Funding is via a combination of EC grants and loans from the European Investment Bank. Research is being funded on greener combustion engines for trucks, bio-methane, electric and hybrid vehicles and infrastructure.

5.3.2 Smart, Green and Integrated Transport European Programme

The Smart, Green and Integrated Transport programme [147] is targeted at boosting the competitiveness of the European transport industries. The aim is to create a European transport system that is "resource-efficient, climate-and-environmentally-friendly, safe and seamless for the benefit of all citizens, the economy and society". This is being supported with a budget of €6339 million (2014-2020) from Transport Challenge funding for cleaner and quieter aircraft, vehicles and vessels. The intention is to minimise impact of transport on the climate and the environment.

A number of areas are being funded including research on smart equipment, infrastructures, services and technology. The aim is to provide better mobility and reduce congestion in urban areas, improve safety by reducing accident rates, provide better security, and reduce traffic congestion generally to provide greater mobility of people and freight. There is also an aim is to support improved policy making to promote innovation and meet the challenges raised by transport and the societal needs related to it. Calls for this programme have been made under Mobility for Growth, Green Vehicles and Small Business and Fast Track Innovation for Transport.

5.3.3 Electromobility

The EV4SCC (Electric Vehicle for Smart Cities and Communities) project [148] brings together cities and regions with companies to showcase innovative electro-mobility solutions. The aim is to promote “replication at scale” in intelligent management of public and private fleets of electric-vehicles, smart urban logistics with light e-vehicles, smart electrification of public transport, innovative integrated infrastructure solutions and smart electro-mobility solutions that serve multi-modal mobility services [149].

5.4 Trucking and Logistics - Drivers and Initiatives

Figure 30. Logistics Issues – Traffic Jams [photo dpa-Zentralbild], Congestion from Deliveries [photo Abenblatt.de]

Information provided by modern ICT systems is available at all levels of the supply chain offering unprecedented opportunities for optimization. Transport volumes keep growing globally (See Figure 30) leading to congestion on roads, however, the sizes of individual shipments are not increasing and indeed there is a move towards shipments of smaller loads [150]. The move towards global sourcing has changed the dynamics of logistics. For example, 10 years ago 90% of the parts for a car would come from factories within a 200Km radius, now the parts are sourced from a world-wide supplier base. Customer service expectations are high with demands for fast and efficient on-time delivery. In order to execute transport tasks efficiently transport service networks play a vital role. These networks are dedicated, e.g. to parcel, express or less-than-truckload-shipments and related logistic services. Analysis and optimization of their structure can provide great benefits in terms of efficiency and also fuel cost and emissions reductions. More efficient operation of nodes (depots, hubs, terminals) provides greater throughput and lower latency. To support this operators are increasingly turning to simulation models to achieve robust solutions that improve their efficiency, reduce handling costs and increase the performance of their terminal operations. A key challenge is to link between material flow simulation and arriving and departing traffic.

The task of delivery in urban areas increasingly is leading to congestion (See Figure 30) and ways of bundling deliveries at local hubs to reduce the numbers of vehicles making deliveries is also challenge. Urbanisation is a key challenge and air quality directives such as Euro 6 [151] are driving new truck and powerplant design. Likewise stricter standards are being introduced in the USA and China for fuel economy and emissions.

The trucking community is familiar with the use of ICT and already automatic tolling systems are used across Europe, however, there is a lack of harmonisation of systems and to operate across all of Europe a lorry driver needs a myriad of different devices on the dashboard. For main routes across Europe drivers typically need 7 different tolling devices. The use of telematics and connectivity is seen as the future to make major improvements in management of freight efficiency, emissions, safety and personal effectiveness. Take up of telematics is, however, still low in the industry as the average fleet size in Europe is 10 trucks. Medium to large companies account for around 25% of the trucking companies in Europe and small companies for the remaining 75%. There is also driver resistance to being tracked. Typical experience shows that just by introducing a tracking device on a vehicle there is a 5-10% saving in fuel – indicating that drivers do not always use their vehicles for work.

There are a number of potential benefits from introducing tracking. These include monitoring of driving behaviour which can be fed back to the driver (highly fuel efficient trucks do not make a difference if the driving is bad), provision of routing to the cheapest petrol stations, and reductions in insurance claims (from providing proof of speed, etc. in court cases). Additionally, monitoring of key truck parameters can be used to optimise efficiency, e.g. truck tyre pressures have a big impact on efficiency, and there is a great interest in moving from remote diagnostics to prognostics as batteries and tyres account for 50% of breakdowns. Already companies such as Scania give away a free telematics system with all of their trucks and currently 800,000 vehicles are fitted with it. Services are provided based on this and customers have the option of buying them.

The key benefit of telematics is in gathering and exploiting data in fleet management. Customers want to know every minute where a delivery is and there is a move from reactive to proactive operations through data mining of Big Data. A major issue that contributes to unnecessary fuel consumption and emissions is the shipping of goods in half empty trucks and the return of empty trucks (where there is an immediate 40% penalty in fuel consumption). Means of co-ordinating and optimising deliveries across fleets of vehicles can thus bring huge savings.

5.4.1 DHL GOGREEN Initiative

The DHL GOGREEN initiative [152] is introducing optimised transport routes, alternative drive vehicles and energy-efficient warehouses to reduce CO_2 emissions and other environmental impacts in the transportation and storage of goods. By 2020 the company aims to increase the carbon efficiency of its operations by 30% compared with 2007 levels. Already the company has achieved a 10% reduction. Sustainability is seen as a competitive factor driven by consumer demands and also by investors who consult sustainability rankings when looking for viable investment options. To address this the GOGREEN initiative is considering a complete view of emissions with the aim to “burn less and burn clean” across all vehicles, buildings and aircraft. Already there are 11,500 green vehicles on test utilising a mix of electric and alternative fuels. A systems approach is being adopted and solar panels are used to charge electric vehicles at warehouses and a new rail link to China is being used as an alternative to flying goods. This allows goods to be shipped from China priority within 7 days by air or 28 days by rail depending on customer requirements. The company provides Carbon Reports and a Green Optimization service to identify ways to minimise greenhouse gas emissions and improve overall environmental performance. Carbon accounting has been integrated into financial accounting systems so that the emissions are automatically calculated from fuel and electricity consumption data. To compensate for unavoidable emissions a “climate neutral” approach is offered using energy provided by solar panels and wind turbine energy.

5.4.2 Carbon Footprint

The growing freight transport sector is a major contributor to greenhouse gas emissions. Several initiatives exist for the calculation of the carbon footprint of freight transport chains. However, there are problems in terms of comparability, transparency and accuracy since these initiatives are based on different starting points, approaches or intentions in development. The EU co-funded project COFRET (Carbon Footprint of Freight Transport) [153] is developing a unified approach to calculate logistics related carbon footprint emissions along complex supply chains. Likewise there are efforts in the logistics industry to harmonise the measurement of emissions from trucks for specific driving cycles and introduction of badging of truck CO_2 efficiency by Green Freight Europe [154].

5.5 National Smart Transportation Initiatives

5.5.1 The Netherlands

The Netherlands is one of the leading European countries with respect to the implementation of smart traffic systems. The government is making substantial investments in new forms of smart mobility allocating more than €70 million for intelligent transport systems (ITS) by 2018 [155]. Nine projects are being set up to deploy new services and gain practical experience in traffic management, to better distribute traffic on the roads to avoid congestion, and to provide services that give travellers real-time driving and travel advice during their journey. This includes:

- Tools to improve supermarket logistics by reducing 200 lorry trips per day in the Groningen-Assen, Arnhem-Nijmegen, Midden-Nederland regions and the Amsterdam Metropolitan Area.
- Improved sharing of information to reduce the build-up of traffic due to incidents in Brabant and Noord-Holland where more than 20,000 trucks and 150,000 passenger cars break down on the main road network. (It is predicted with national coverage, this could reduce congestion by 2.5%).
- Use of event apps to reduce congestion around festivals, congresses and concerts (festival goers account for five million rush-hour car trips in and around cities per year)

Collaborations on traffic management are also being performed with the Amsterdam Pilot, the ITS Corridor, the Innovation Traffic Centre and the policy theme Autonomous Vehicle Travel, among other initiatives. These and other efforts are part of the Road Map for Better In-transit Information (Routekaart Beter Geïnformeerd op Weg).

5.5.1.1 City region of Eindhoven Initiative

IBM and NXP Semiconductors N.V. conducted a 12 month smarter traffic pilot in Eindhoven demonstrating how a connected car can automatically share anonymous information on braking, acceleration and location that can be used by the central traffic authority to improve traffic flow, reduce congestion and resolve road network issues [156]. Eindhoven is located at the hub of several international transportation routes, where relatively small incidents can have major consequences for the system as a whole. In an earlier six-month road pricing trial conducted by the city in conjunction with IBM and NXP, advanced road pricing technology was successfully used to incentivise drivers to change their driving behaviour, reduce road congestion and contribute to a greener environment. Seventy percent of drivers changed their behaviour to avoid rush-hour travel when presented with the right incentives, demonstrating that road pricing systems can have a positive effect on driving habits and help alleviate traffic. Participating pilot cars were equipped with a device containing a telematics chip which gathers data from the central communication system of the car (CAN-bus) that gives indicators of potholes or icy roads which is transmitted to the cloud-enabled traffic centre.

5.5.1.2 Enschede Vehicle Inductive Profile

In Enschede the travel times of vehicles is collected by Smart detection loops at traffic lights [157]. Travel time savings are stored in a database, processed and shown on four dynamic route information panels on Highway 35 allowing drivers to choose the most favourable route in rush hour. The system is co-funded by Regio Twente.

5.5.2 Spain

5.5.2.1 Electric Barcelona

Barcelona has a growing fleet of electric vehicles, taxis, cars and motorcycles that benefit from the facilities offered by the city, such as its 300 public recharging points (See Figure 31) that are free to use and found at a number of stations across the city [158]. The city is also introducing a new way of renting cars, based on car sharing, using electric vehicles. The city also has the cleanest bus fleet in Europe, including hybrid and compressed-natural-gas vehicles.

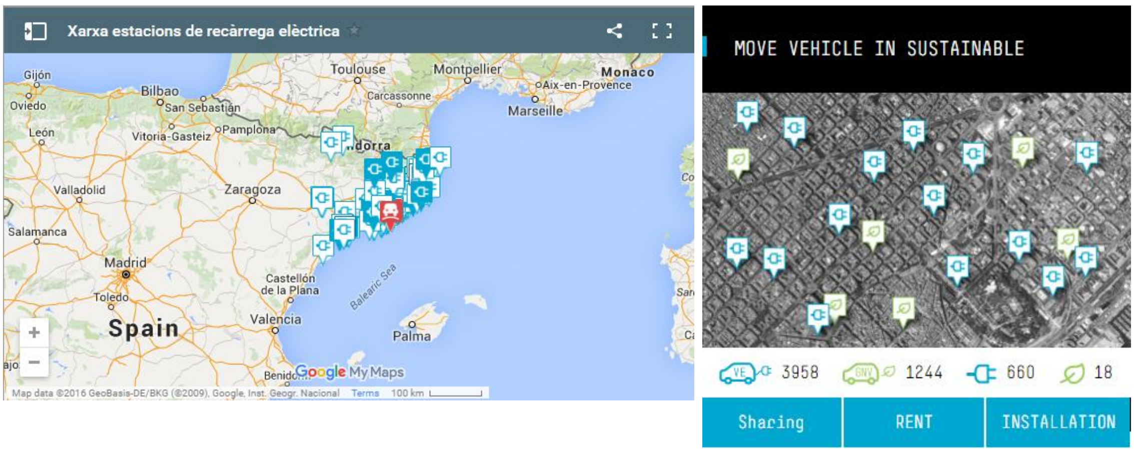


Figure 31. Barcelona Electric Charging Network [159]

A public-private partnership is being used to provide real time management of the city, an urban traffic sensor system, traffic management, mobile applications for public transport and fast ticketing. New business opportunities are being found in fleet management, pre-booking of parking slots and optimization of routes for emergency services [160].

5.5.2.2 Zaragoza traffic monitoring system (Spain)

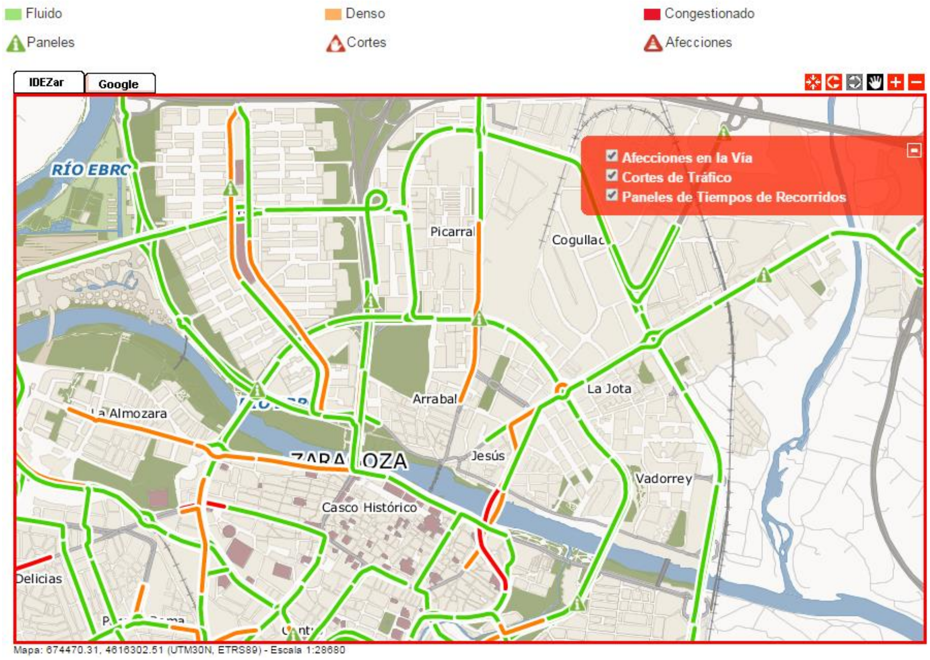


Figure 32. Zaragoza Municipal Traffic map

The Zaragoza City Council has installed 150 traffic sensors at traffic lights in 90% of the city's main thoroughfares which continuously send data to the Traffic Control Centre for traffic management. This is used to provide information to the public via mobile devices [161]. This gives information on the state of the main city roadways by means of a colour code, any incidents that have occurred, scheduled traffic diversions and serious traffic jams (See Figure 32).

Additionally, a metering infrastructure and vehicle passage sensors have been installed at numerous points in the city to allow traffic-light re-programming to cope with traffic conditions. Zaragoza has become Europe's least congested city with over 500,000 inhabitants according to TomTom [162].

5.5.3 Ireland

Dublin City Council (DCC) has made all of its data available to the IBM Smarter Cities Technology Centre in Dublin [163]. Big Data analytics is being used to gather insights from the data and this is being passed back to the council's roads and traffic department. As a result real-time geospatial data from 1,000 buses across Dublin and their timetables are integrated with a digital map of the city. Dublin's traffic controllers can use digital maps and dashboards to monitor the status of the entire bus network at a glance. It is also possible to see congestion forming in real time and instantly access CCTV feeds to identify the cause and apply appropriate traffic-calming measures. Data from rain and flood gauges is also being integrated to alert to potential hazards presented by extreme weather conditions. IBM is currently developing a predictive analytics solution combining data from the city's tram network with electronic docks for the city's free bicycle scheme to optimise the distribution of the city's free bicycles according to anticipated demand from tram passengers.

5.5.4 Greece

In Thessaloniki two different systems have been put into place [164]. The first, a new traffic control centre, manages incidents with real-time information, dynamically estimates traffic for the rest of the day, assesses and confirms estimated travel times, and dynamically manages traffic lights. The second system is a mobility planner that provides citizens with real-time traffic condition data, enabling them to choose between the shortest, most economical and most environmentally friendly route. This is funded 50% from Iceland, Liechtenstein and Norway through the 'European Economic Association' and 50% by National Funds. An aim is to promote the use of public transportation, walking and cycling. Finally, through special urban mobility training programmes, a new culture for urban mobility is being promoted.

5.5.5 UK Smart Transport Catapult

Figure 33. Intelligent Mobility

The Transport Systems Catapult [165] is one of seven elite technology and innovation centres established and overseen by the UK's innovation agency, Innovate UK. The centre promotes Intelligent Mobility (See Figure 33) using new and emerging technologies to transport people and goods more smartly and efficiently. The aim is to help UK businesses create products and service. The aim is to sell these at the world level and provide a test bed for the transportation industry. There is an emphasis on collaboration, bringing together diverse organisations across different modes of transport

5.5.5.1 MIRA

MIRA in the UK operates Europe’s most advanced ITS test track, innovITS-Advance [166] dedicated to research and development of intelligent transportation systems (ITS). This utilises modern communication technologies, private GSM and cellular networks, fully configurable wireless networks and state-of-the-art, vehicle-to-vehicle communications based on the draft 802.11p WAVE standard [167]. Work is investigating transport information, intelligent vehicles, and intelligent infrastructure, looking at a range of topics including OEM/aftermarket applications for congestion, hazards, tracking and fleet management, data management and modelling, real-time data sharing, integrated in-vehicle multimedia applications, aftermarket and integrated HMI solutions, secure communication networks, pedestrian safety, vehicle positioning and sensor systems, co-operative control systems and autonomous systems.

5.6 Rail Transport - Drivers and Policy

The European rail infrastructure is facing increasing congestion due to unprecedented numbers of passengers requiring innovative ways to increase capacity on existing infrastructure (faster scheduling of passengers through stations and shorter stopping times at stations) and demanding levels of punctuality never before seen with more people and improved journey times. Here management, control and sociological aspects need to be considered in unison.

The interoperability regulations and the 2011 Transport White Paper [168] require that the European railway system behaves as a single Systems of Systems. The commercial drivers in the industry are for 24/7 operation, high availability, low cost, safety, increased capacity, recovery from disturbance, low carbon emissions and customer satisfaction. Already trains are operating across the European continent and the Commission requires a level playing field without barriers to competition. The main competitors to the rail network are other modes of transport and in order for the railway to be the preferred transport mode, the industry must offer a guaranteed door-to-door or factory-to-point-of-sale service 24/7. To achieve this there is a drive towards Automatic Train Control and automated maintenance to increase capacity and reduce costs to the point where rail operations do not require subsidy from government.

Capacity is currently severely restricted due to controlling train movement through a system of blocks (sections of “reserved” track that no two trains can operate on). Moving blocks improve this but autonomous train-to-train communications and new infrastructure components could increase capacity by more than 100% with an asset value of billions. The 2011 Transport White Paper [168] requires the majority of medium to long distance journeys (freight and passenger) to be by rail. This is driven by congestion costs (1.5% of EU GDP) and the need for greatly reduced transport emissions. The EU is driving the railway industry towards a single system through interoperability requirements. The industry also aims for a more resilient infrastructure to route traffic in an optimal manner responding to an incident. Key improvements being sought:

- **Improved capacity** - Improved planning and operation with potentially more flexible timetables could deliver improvements in capacity, by optimising the timetables at peak periods to maximise traffic flow.
- **Reduced Emissions** - Improved timetable planning and operation, can lead to optimised driving to reduce stopping and starting to reduce emissions. A Systems of Systems approach may also provide the necessary planning that would allow hybrid rail vehicles to just run the combustion engine away from stations and urban areas, reducing noise and urban pollution.

5.6.1 ERRAC Strategic Research Agenda 2020 for Rail

ERRAC [121] was set up in 2001 with the goal of creating a single European body with both the competence and capability to help revitalise the European rail sector and make it more competitive, by fostering increased innovation and guiding research efforts at a European level. Within ERRAC, all major rail stakeholders are gathered, including 45 representatives from each of the major European rail research stakeholders: manufacturers, operators, infrastructure managers, the European Commission, EU Member States, academics and users' groups. ERRAC covers all forms of rail transport from conventional, high speed and freight applications, to urban and regional services. Since its launch in 2001, ERRAC has produced a number of important and influential documents, such as the Joint Strategy for European Rail Research – Vision 2020 [169], the SRRA – Strategic Rail Research Agenda [170] and its 2007 updated version, Suburban and Regional Railways Landscape in Europe [171], Light Rail and Metro Systems in Europe [172], Rail Research in Europe [173] and a comparison of the Member States public research programmes.

A set of roadmaps were developed in the EU funded (FP7) project ERRAC ROADMAP (2009-2012) and in 2012, an initial update of the ERRAC vision for the future of rail to support H2020 was released. This vision "Railroute 2050" [174], highlights the European effort required for research and innovation especially to meet the objectives of the European Commission 2011 Transport White paper "Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system". RailRoute 2050 offers a range of research opportunities for a competitive, resource-efficient and intelligent rail transport system that meets the future demands of European citizens, stipulates economic growth, creates European jobs, and strengthens the position of the European rail sector in global competition. The European vision for railway research and innovation outlined in RailRoute 2050 illustrates the research pillars that need to be supplemented by the corresponding investment pillar. Additionally, ERRAC launched FOSTER RAIL (2013-2016) [175] which will support development of a new full and complete vision, including the Rail Business Scenario and the Strategic Rail Research and Innovation Agenda.

5.6.2 European Rail Roadmap

Between 2009 and 2012, ERRAC carried out a 3 year rail research roadmapping project called ERRAC ROADMAP [176]. This highlighted the needs for intelligent mobility, competitiveness and enabling technologies and infrastructure as priority research areas related to traffic management. In the area of intelligent mobility, the main issues deal with the definition of new management techniques to enhance infrastructure use. These include timetable optimisation, new fleet management tools, and development of information systems, as well as harmonised information exchange between stakeholders in cross-border traffic. In the area of competitiveness and enabling technologies, priorities include the compatibility of on-board data collection systems and their integration with communication networks, as well as the analysis of passengers and traffic flows in order to reach a more efficient Europe-wide train path allocation. Finally, in the infrastructure area, priorities include the development of train control systems and new operational rules in order to optimise both capacity and service interchange.

5.6.3 European Rail Traffic Management System (ERTMS)

The European Railway Traffic Management System (ERTMS) [177] is a major industrial project developed by Alstom Transport, Ansaldo STS, AZD Praha, Bombardier Transportation, CAF, Mermec, Siemens Mobility and Thales in close cooperation with the European Union Railway stakeholders and the GSM-R industry. Currently there are more than 20 train control systems across the European Union. Each train used by a national railway company has to be equipped with at least one system but sometimes more are required to be able to run safely within one country. A problem is that each system is stand alone and non-interoperable. If traffic is cross border this leads to extensive integration and engineering effort with high associated costs. This restricts competition and also hampers competitiveness of the European rail sector versus road transport. As an example the Thalys trains running between Paris-Brussels-Cologne and Amsterdam have to be equipped with 7 different types of train control systems.

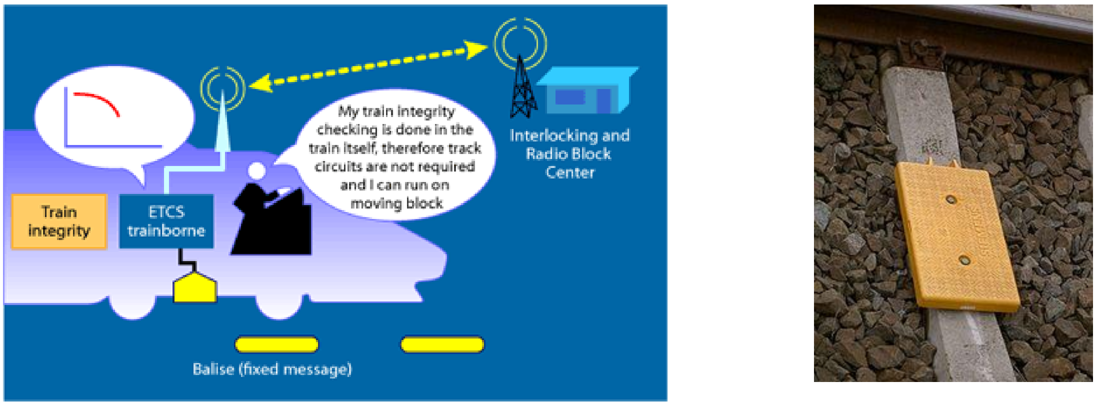


Figure 34. ERTMS Level 3 and Balise

To address this ERTMS aims to gradually replace the different national train control and command systems across Europe to create a seamless European railway system. Instead of lineside signals, a computer in the driver's cab controls the speed and movement of the train, whilst taking account of other trains on the railway (See Figure 34). Bringing the control system inside the train will allow more autonomous operation, so that drivers can always run at the optimum safe speed helping more trains run faster and recover from delays quicker. Each train will run at an appropriate safe speed, allowing more trains onto the tracks. This will increase passenger and freight capacity, reliability, reduce maintenance costs, improve punctuality and lead to safer trains and greater competitiveness for the supply market. By moving more people and freight onto trains and reducing delays there is also an expected reduction in pollution.

ERTMS has two basic components, the ETCS, the European Train Control System, which is an Automatic Train Protection system (ATP) to replace the existing national ATP-systems, and GSM-R, a radio system for providing voice and data communication between the track and the train. This uses standard GSM but on a reserved rail frequency. It should be noted that ERTMS is not a new concept and it has been successful outside Europe in countries such as China, India, Taiwan, South Korea and Saudi Arabia. The ERTMS/ETCS is split into a number of application “levels” which range from track to train communications (Level 1) to continuous communications between the train and the radio block centre (Level 2). Level 3, which is in a conceptual phase, will further increase ERTMS potential by introducing a “moving block” technology to increase capacity.

- ERTMS level 1 is used as an add-on to conventional lineside signals and train detectors. Communication between balises (See Figure 34) and the train ensures that it automatically brakes if exceeding maximum allowed speed.
- ERTMS level 2 does not use lineside signals (reducing maintenance costs by their removal). The movement authority is communicated directly from a Radio Block Centre (RBC) to the onboard unit using GSM-R. Balises are used to transmit “fix messages” such as location, gradient, speed limit, etc.
- ERTMS Level 3 is still in its conceptual phase but allows introduction of “moving block” technology. Removal of fixed blocks (sections of tracks where two trains cannot run at the same time) increases capacity greatly. The train itself becomes a “moving block” communicating accurate position data.

5.6.4 Foster Rail

FOSTER-RAIL is a European Level 1 Coordination and Support Action [175] driven by ERRAC aimed at supporting the land transport European Technology Platforms activities. The aim is to strengthen the research and innovation strategies of the transport industries in Europe. This will assist ERRAC and the other transport-related European technology platforms (ETP) in defining research needs for their strategies and programmes for H2020 in order to realise the objectives of the Europe-2020 strategy [169] and the White Paper 2011 vision for a competitive and resource-efficient future transport system [168]. An updated Strategic Rail Research and Innovation Agenda is being produced under Foster Rail. It is being performed in consultation with the European Commission and Member States and Associated States. FOSTER-RAIL will integrate the work of ERRACs Working Groups and progress this building upon the ERRAC ROADMAP project and RailRoute 2050 [174]. An aim is to support and enhance cooperation between stakeholders and decision-makers to provide an enhanced definition of strategic research and innovation needs and establishment of Business Scenarios. A key area is co-modality with other transport modes. The project will support the Strategic Rail Research and Innovation Agenda as well as a Rail Business Scenario for 2050. This Railway Business Scenario shall be the reference for future research agendas and technology roadmaps to be developed until 2050.

5.6.5 SHIFT^{2}RAIL

SHIFT^{2}RAIL [178] is a H2020 supported European rail joint technology initiative seeking focused research and innovation (R&I) and market-driven solutions by accelerating the integration of new and advanced technologies into innovative rail product solutions. The integration of systems is a core objective of the programme and it applies to all segments of the rail market: High Speed/Mainline, Regional, Urban/Metro & Suburban, and Freight. SHIFT^{2}RAIL aims to promote the competitiveness of the European Rail Industry and create a Single European Railway Area (SERA). SHIFT^{2}RAIL has set targets to double the capacity of the European rail system, increase its reliability and service quality by 50% and at the same time halve lifecycle costs.

The aim is to achieve this by introduction of better trains (more comfortable, quieter and more reliable), operating on an innovative rail network infrastructure in a reliable way from the first day of service introduction. This will be done at a lower life cycle cost, with more capacity to cope with growing passenger and freight mobility demand. SHIFT^{2}RAIL also aims to attract more users to rail. For passengers there will be more travel options, more comfort, and improved punctuality. For the freight forwarder/shippers rail freight will become more cost effective, punctual and traceable as a shipment option. There is an expectation of more job creation, less pollution and more efficient and optimised public investments.

5.7 Aerospace Transport - Drivers and Policy

Air passenger volume is predicted to double air traffic density over the next two decades in an already congested airspace. Movement of increasing numbers of passengers requires complex management and integration across the world of airport operations, baggage handling and air traffic control to maximise flow. Air traffic control systems by themselves integrate numerous functionalities which enable semi-automated operations in the en-route airspace. Tools and methods that partially automate some of what is manually performed by Air Traffic Controllers today is currently an active area of research. At the same time the need for unprecedented high levels of aircraft availability is driving the use of sophisticated information and communications technologies for predictive health monitoring, integrated with worldwide maintenance and logistics systems to ensure that aircraft are always fit to fly.

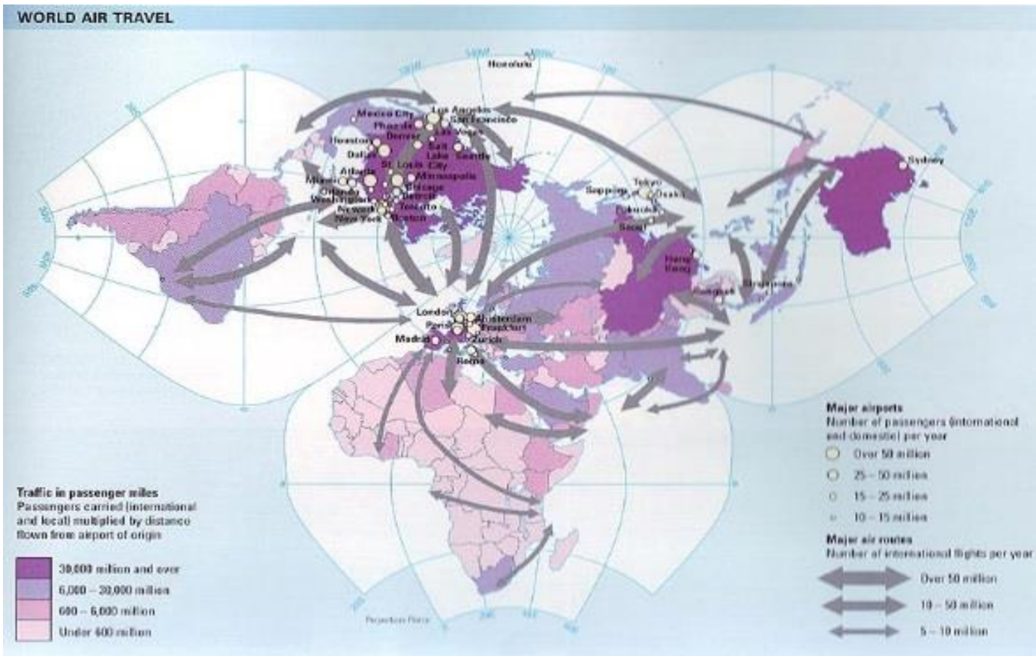


Figure 35. Major World Airports and Traffic Routes [179]

Figure 35 shows a map of major air traffic routes around the world [179]. On the key routes shown there are over 50 million passengers a year and on the majority of other routes there are 10-50 million passengers. Air traffic is increasing and the number of aircraft is expected to double by 2020 to meet demand. As a global aviation industry, the biggest and most important challenge is to continue to safely accommodate ever increasing air traffic in support of global economic growth and prosperity, whilst protecting the environment.

Air Traffic Management will be a major topic in the coming years, especially in Europe where separate systems will have to be integrated. The challenges here are not only technological, but also legislative/political and need to be tackled at a European (and even world-wide level). In the future Unmanned Aerial Vehicles will also be integrated with the normal ATM network presenting further technological, legislative and political challenges.

5.7.1 European Air Traffic Management - SESAR

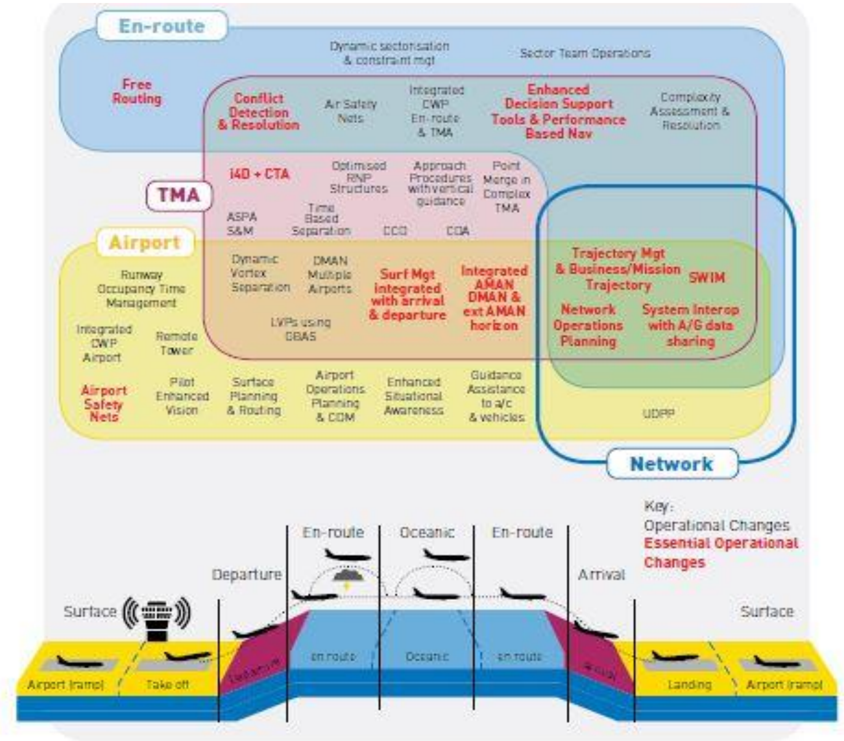


Figure 36. SESAR 4D Routing [180]

The Single European Sky programme [179][180] is reforming the architecture of European Air Traffic Control to meet future capacity and safety needs. Within Europe Eurocontrol predicts 20.4 million yearly flight movements by 2030 which is twice the current figure. In order to meet this need €2.1 billion is being invested in R&D to develop a new air traffic control system for Europe. This will exploit improved air traffic and aircraft positioning and communication technologies, such as GALILEO [181] to provide significant improvements in the efficiency and safety of air travel. The Single European Sky ATM Research programme (SESAR – formerly known as SESAME) is the name given to the collaborative project that will completely modernise the European Air Traffic Control infrastructure. SESAR (See Figure 36) aims at developing the new generation air traffic management system capable of ensuring the safety and fluidity of air transport worldwide over the next 30 years.

The first definition phase of SESAR ended in 2008, delivering an ATM master plan [182][183][184] defining the content, the development and deployment plans of the next generation of ATM systems. This activity was led by Eurocontrol, and co-funded by the European Commission under the Trans-European Network Transport programme. Work was executed by a consortium with representatives of all air transport stakeholders and included non-European members reflecting the global nature of ATM. The development phase (2007-2013) provided a new generation of technological systems and components. For this phase the Commission created the SESAR joint undertaking, based on the GALILEO model, supported by public and private funds from the European Community, Eurocontrol, industry and third countries. The current deployment phase (2013-2020) is seeking to build the new infrastructure necessary for the future within Europe and in partner countries. This is being carried out under the responsibility of industry without further public funding. Additionally, there has been some activities performed under the Clean Sky EU programme [185] looking at ATM and related issues to reduce emissions and fuel cost such as work by Thales on innovative Flight Management Systems.

5.7.2 Unmanned Aerial Vehicles (UAVs)

There are numerous UAV activities being undertaken within Europe with several major large programmes and many smaller programmes investigating and developing UAV technology for military and civilian use. It is not possible to cover all of these in a report but in this section a few key large programmes are highlighted.

Figure 37. Watchkeeper UAV [186]

The Thales Watchkeeper WK450 [186] (See Figure 37) is a remotely piloted air system (RPAS) for all weather, Intelligence, Surveillance, Target Acquisition and Reconnaissance (ISTAR) which has been developed for use by the British Army, in a €1bn contract awarded to UAV Tactical Systems (U-TacS) in 2005, a joint venture between Thales UK and Israeli Elbit Systems.

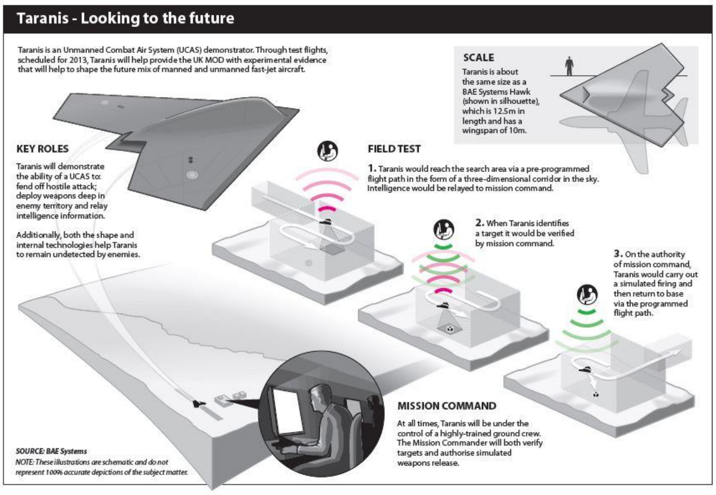


Figure 38. TARANIS UK Military Programme [187]

Named after the Celtic god of thunder, the £185 million Taranis concept aircraft [187] (See Figure 38) is jointly funded by the UK MOD and UK industry. The Taranis demonstrator aircraft was formally unveiled in July 2010. It is about the size of a BAE Systems Hawk aircraft and has been built by BAE Systems, Rolls-Royce, the Systems division of GE Aviation (formerly Smiths Aerospace) and QinetiQ working alongside UK MOD military staff, scientists and other smaller companies. The Taranis demonstrator is the result of one-and-a-half-million man hours of work by scientists, aerodynamicists and systems engineers from 250 UK companies. The aircraft was designed to create an unmanned air system which is capable of undertaking sustained surveillance, marking targets, gathering intelligence, deterring adversaries and carrying out strikes in hostile territory. The aircraft has low observability, high levels of systems integration, supporting control infrastructure and full autonomy elements. The aim of TARANIS was to help the UK MOD and Royal Air Force make decisions on the future mix of manned and unmanned fast jet aircraft and how they will operate together in a safe and effective manner.

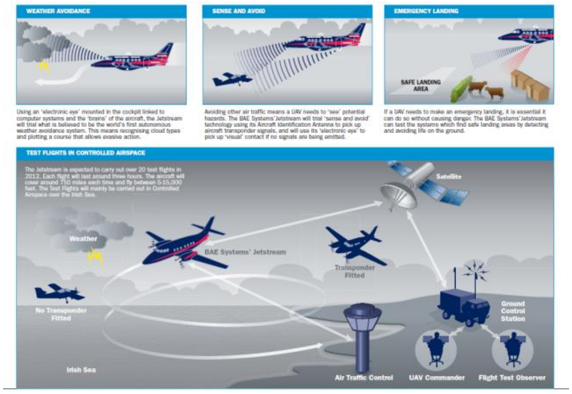


Figure 39. ASTRAEA UK Civil UAV Programme [188]

The ASTRAEA (Autonomous Systems Technology Related Airborne Evaluation & Assessment) programme [188] (See Figure 39) is a UK industry-led consortium focusing on the technologies, systems, facilities, procedures and regulations that will allow autonomous vehicles to operate safely and routinely in civil airspace over the UK. The aim of the ASTRAEA programme is to enable the routine use of UAS (Unmanned Aircraft Systems) in all classes of airspace without the need for restrictive or specialised conditions of operation. This will be achieved through the coordinated development and demonstration of key technologies and operating procedures required to open up the airspace to UAS. The programme is a £62 million effort led by seven companies: Autonomous Decision Making SOftware (AOS), BAE Systems, Cassidian, Cobham, Qinetiq, Rolls-Royce and Thales. The programme consists of two separate projects, one addressing *Separation Assurance & Control* that covers the particular technologies required to control the flying vehicle in the airspace considering the ground control station, the spectrum, security and integrity of the communication system and the vehicle's sense and avoid sensor system, and the second addressing *Autonomy & Decision Making*, providing the intelligence within the vehicle through a variable autonomy system that shares decision making for the mission and contingency management with the human operator.

5.8 Marine Transport – Drivers and Initiatives

By far the most efficient mode of transport for the movement of goods, the shipping sector is expected to grow by 150-250% over the next 30 years. Here integrated world-wide ship management systems are being linked with ship fouling efficiency metrics and navigation systems to optimise performance to reduce fuel consumption and emissions. The introduction of emissions monitoring [189] has led to new operational approaches such as “slow steaming” to reduce emissions for products that are not time critical. Logistically there are complex interactions in the movements of containers around the world to ensure that shipping and handling costs are minimised with tight linkage into the appropriate rail or road haulage network to move the goods onwards as quickly and efficiently as possible.

European shipbuilders are world market leaders by turnover [124]. In particular Europe produces nearly all the high value cruise ships in the world, around 50% of all equipment suppliers' products are exported outside Europe and almost 100% of the dredging technology and know-how is European. From a fleet management perspective around 40% of the world merchant fleet is controlled by European companies and approximately 25% are flying the European EEA flag. Of the top 5 world ports, 3 are European and the European Oil & Gas Service Industry is also a world technology leader, exporting 70% of products. The European maritime industry is spearheading environmentally friendly technologies, e.g. European equipment suppliers have provided on-board total waste management systems ahead of future environmental regulations.

A key driver in the maritime industry is improving safety of waterborne operations. This is because recent maritime disasters and accidents in inland navigation have shown that accidents come with high costs in terms of loss of life, environmental damage and with high economic impact. Additionally, high profile accidents have tarnished the overall image and public perception of the waterborne sector. With the increase in cargo traffic in busy North Sea lanes there is a need to maintain safe operations of cargo vessels. At the same time passenger cruise ships have also got bigger and are now operating in non-traditional, remote and difficult regions such as the artic with new and increasing risks. Passengers have high expectations for comfort and a wide range of on-board amenities. The current research drivers are to develop and demonstrate innovative solutions for ship design and waterborne operations to avoid and mitigate passenger risks and ensure high levels of safety.

The industry believes that new technologies for maritime traffic management will be key for safer and more secure operations. In the marine sector there is great interest in optimised shipping operations and voyage optimisation, condition based maintenance, reducing costs and reducing emissions. Local legislation has resulted in emissions monitoring being introduced in ports and local governments have introduced their own requirements. The drivers are for reduced maintenance, enhanced asset life, reduction in crewing levels through increased automation and fleet optimisation via shore based decisions. Key enablers in the industry are the introduction of VSAT systems [190] that allow much greater data rates for data transfer.

There is also a drive for a more integrated transport chain. To reduce congestion in ports and port fairways, port traffic guidance systems need to be at the same time cost efficient and easily deployable. Synergies with existing systems should be ensured, with the aim of integrating the use of port traffic guidance tools by all relevant authorities and ensuring the full interoperability between Information and Communication Technologies (ICT) systems, which monitor vessels, freight and port services.

5.8.1 Waterborne

Figure 40. WATERBORNE European Technology Platform Research Summary [192]

In Europe the marine industry has come together with the aim of providing sustainable waterborne transport for the future. To support this the WATERBORNE European Technology Platform [191] has been created with the aims highlighted in Figure 40 [192]. The WATERBORNE initiative was driven by the Maritime Industries Forum (MIF) and its R&D Committee in 2005. Waterborne identifies R&D requirements for European competitiveness in the industry and the innovation and research needs to meet new regulations for safety and environmental goals. The programme is very wide with stakeholder coverage from deep and short sea shipping, inland waterways, ship yards, equipment manufacturers, the marine leisure industry, research and university institutions and classification societies. In addition to a stakeholder Support Group, there is a Mirror Group of government appointed delegates. The WATERBORNE TP published a Vision 2020 paper in 2012 [193], a Strategic Research Agenda in 2011 [194] and an Implementation Plan in 2011 [195]. These documents are being used by the European Commission to direct calls under the R&D workprogrammes and also national R&D programmes. They are also being used by industry to guide research and development.

5.8.2 Marine Vision 2020 and Strategic Research Agenda

Although waterborne transport is the most sustainable, fuel-efficient and environmentally friendly transport mode, special consideration is required of the consequences of accidents, particularly in sensitive coastal areas. As a mode of transport ships have the capacity to transport very large quantities of cargo or large numbers of passengers, consequently there must be a strong focus on safety and also environmental protection. The development and expansion of port capacity is required but care must be taken to preserve natural habitats in surrounding areas. Additionally, security is increasingly an issue and operations must be protected against threats. The EU shipping industry working with public authorities has progressively enhanced safety at sea and introduced greater measures to protect the environment and is actively promoting this on an international basis. The Vision 2020 paper [193] produced by the industry highlights the needs for effective designs, systems, procedures and techniques to increase the level and reliability of the ship system's performance, with the goal of a "zero accident" record. To do this there is a need for research into:

- Effective means to avoid accidents
- Robust ships and reliable equipment
- Improved survival in extreme conditions (ice, freak, waves, etc.)
- Competent crew, ship management and shore operations

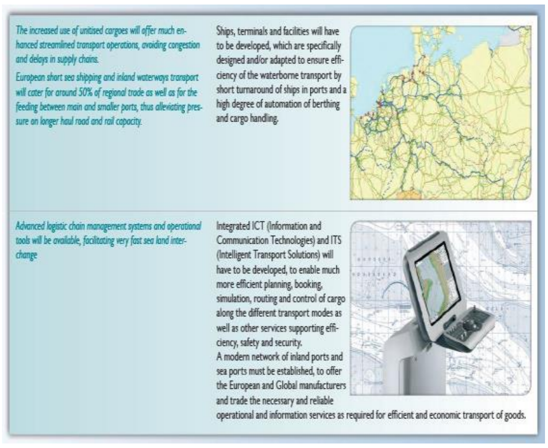


Figure 41. Innovation Challenges: Traffic Management, Integrated Supply Chains, Port Efficiency [193]

Supporting this there is a drive to improve man-machine interfaces and decision support systems to minimise impact of human error. Ships built in Europe will be equipped with on board systems for performance monitoring (See Figure 41) with the aim of reducing life cycle maintenance and also providing safer operation. This will include monitoring and failure prevention strategies and systems for corrosion and wear monitoring. This requires the development of predictive maintenance and inspection capabilities to support the whole life cycle. For safer operations cheap, fool-proof and safe communication and identification equipment needs to be developed to support smaller coastal craft (e.g. fishing and recreational craft, craft with amateur crew) that can be integrated within traffic management systems. This is required if a political decision driven by safety is made to include all small coastal craft in traffic management systems. Additionally, safe and efficient data models and algorithms will be required to cope with the expected huge numbers of traffic participants. If no political decision is made safety is still a concern and so alternative safe and user friendly strategies to traffic management also need to be developed.

Emissions are another key issue and a 'zero emission' approach, to SOx, NOx, CO_2, PM, VOCs presents a technological and economic challenge particularly as approaches to reducing one pollutant tend to increase the emissions of other pollutants with different options being needed for a variety of ships. The Waterborne Strategic Research Agenda [195] focuses on three themes:

- Safe, sustainable and efficient waterborne operations
- Maintaining a competitive European maritime industry
- Managing and facilitating growth and changing trade patterns

These are subdivided into topic area such as short-sea shipping, inland waterways, ship design, operation, and maintenance, maritime safety and ports and port operations.

Under Horizon 2020 a major call was made [196] supporting innovation actions to develop safer and more efficient waterborne operations through new technologies and smarter traffic management. The key areas related to ICT and Systems of Systems are:

- New and improved systems for the surveillance, monitoring and integrated management of waterborne transport and other activities (commercial and non-commercial).
- New and cost effective European Global Navigation Satellite System (European GNSS)-based procedures for port approach, pilotage and guidance, ICT-enabled shipping lanes and maritime services that will reduce the risk of accidents and incidents in port approaches and dense traffic lanes, and minimise both delays and turn-around times.
- For traffic management, solutions that support the extension, integration and optimisation of waterborne transport information and communication systems with the aim of contributing to build a comprehensive "e-maritime" environment (including e-Navigation components that are compatible with existing or emerging international standards). The objective here is to build a “European Maritime Transport Space without Barriers” allowing waterborne transport (including inland navigation) to be used to the full potential within an integrated intermodal logistic chain.

Of particular note is that the call is asking for solutions that will also provide the foundation for the deployment of autonomous and actively guided ships as well as the possibility to verify all related safety certificates before a vessel enters the port. This is to support the future long term goal to reduce crew numbers still further and move towards autonomous and actively guided ships. In parallel with the research activities there is a need to also provide inputs into EU and international regulatory regimes. An aim is to promote standardisation and international research co-operation particularly in the areas of safety devices and e-Navigation solutions.

5.8.3 e-Maritime

The EU e-Maritime initiative [197] aims to foster the use of advanced information technologies for working and doing business in the maritime transport sector. Maritime transport administrative procedures are complex, time-consuming and, even today, are quite often done on paper so there is a need to embrace modern ICT technologies and ways of doing business. Major European ports have deployed advanced information systems. These deliver considerable quality and efficiency gains, however, currently there is no interoperability between port information systems. This limits the potential for new services and economies of scale. Small ports may not have any electronic data transmission capabilities at all. The usual practice is that shipping companies at each port manually enter the same data repeatedly, resulting in duplication and errors.

For the next generation of sailors (the "Internet" generation) access to cyber-space is a must. e-Maritime aims to stimulate coherent, transparent, efficient and simplified solutions in support of cooperation, interoperability and consistency between Member States and transport operators.

Going beyond e-Maritime there is also an activity to provide a mechanism for a Common Information Sharing Environment (CISE). This is currently being developed jointly by the European Commission and EU/EEA member states [198]. It will integrate existing surveillance systems and networks and give all concerned authorities access to the information they need for their missions at sea. CISE will make different systems interoperable so that data and other information can be exchanged easily.

5.8.4 Unmanned Ships

Figure 42. Rolls-Royce Unmanned Ships Concept [199]

Modern ships are operated with much lower numbers of crew than in the past. This has been achieved by introducing much greater levels of automation and also through more advanced on-ship monitoring systems. Rolls-Royce's Blue Ocean development team has set up a virtual-reality prototype that simulates 360-degree views from a vessel's bridge [199]. The idea is that eventually captains on dry land will be able to use similar control centres to command hundreds of crewless ships. Drone ships would be safer, cheaper and less polluting for the shipping industry (See Figure 42). The European Union is funding a €3.5 million study called the "Maritime Unmanned Navigation through Intelligence in Network" project which will produce a prototype for simulated sea trials to assess costs and benefits. The Rolls-Royce design for an autonomous ship (See Figure 42) has no bridge with just containers from front to back. By replacing the bridge and the systems that support the crew, e.g. electricity, air conditioning, water and sewage, the ships can be 5 percent lighter before loading cargo and would burn 12% to 15% less fuel. Additionally, from a financial perspective figures show that a crew costs $3,299 a day and account for about 44 percent of total operating expenses for a large container ship.

There are considerable hurdles to adoption of unmanned ships coming from regulators who are concerned about safety and unions who are concerned about job losses. In fact current regulations dictate minimum crew levels by international conventions. The country where a ship is registered is responsible for regulating vessels within its own waters and for enforcing the international rules. The international IMO regulations apply to seagoing vessels trading internationally and exceeding 500 gross tons, except warships and fishing boats. If drone ships do not comply with the IMO rules, they would be considered unseaworthy and ineligible for insurance. There is, however, interest in deployment of unmanned ships in the Baltic Sea. The expectation is that computers will gradually increase their role in navigation and operations reducing crew levels further. Container ships and dry-bulk carriers are the most likely first candidates for total autonomy as tankers carrying hazardous materials such as oil and liquefied natural gas will probably remain manned longer because of the perception that having a crew on board is safer.

To successfully replace crews unmanned ships will need constant and comprehensive computer monitoring to anticipate failures in advance and "redundant" systems to maintain availability. Computer systems can also be used to analyse ship information and optimise performance. Cameras and sensors can already detect obstacles in the water far better than the human eye. Of particular note is that human error causes most maritime accidents which are often related to fatigue. Unmanned ships would also reduce risks such as piracy, since there would be no hostages to capture, however, ships would become vulnerable to a different kind of piracy from computer hackers.

5.9 US Transportation Drivers and Policy Initiatives

The drivers in the US for intelligent transportation are similar to those in Europe, however, another key driver is homeland security. There is a desire to provide surveillance of roadways and also a means for mass evacuation of people in urban areas as a result of natural disaster or threat. Each state has an Intelligent Transportation Systems chapter that holds a yearly conference to promote and showcase ITS technologies and ideas. Representatives from each Department of Transportation (state, cities, towns, and counties) within the state attend this conference. The Department of Transportation (DOT) has defined a set of goals for the US transportation system:

- Reduce or eliminate deaths and serious injuries among all users of the transportation system – drivers, passengers, cyclists, and pedestrians
- Increase the reliability and efficiency of the transportation system – for the movement of both people and goods
- Drive innovation in the development of safe, affordable mobility options for all Americans
- Increase the service life and optimise the maintenance of transportation structures in a state of good repair
- Reduce the environmental and energy impacts in the development, operation, and maintenance and use of the transportation system
- Increase the resilience of the transportation system to withstand severe weather and climate change impacts.

5.9.1 Intelligent Transport Systems Joint Program Office (US)

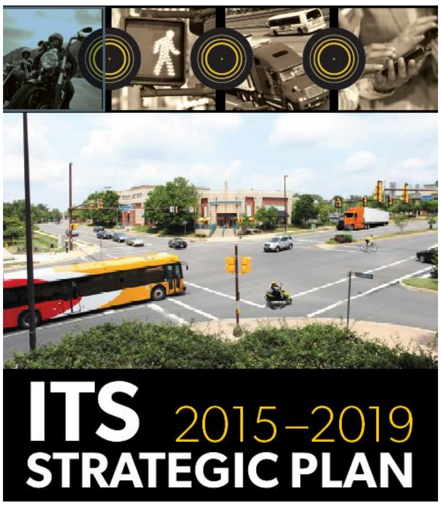


Figure 43. Intelligent Transportation Systems

The ITS Joint Program Office (ITS JPO) [200], within the Office of the Assistance Secretary for Research and Technology (OST-R) has responsibility for executing the "Subtitle C- Intelligent Transportation System Research of Public Law 109-59 Safe Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users, enacted August 10, 2005". Specifically the ITS-JPO will:

"Conduct an ongoing intelligent transportation system program to research, develop, and operationally test intelligent transportation systems and to provide technical assistance in the nationwide application of those systems as a component of the surface transportation systems of the United States"

The office works with the Federal Highway Administration, Federal Motor Carrier Safety Administration, Federal Railroad Administration, Federal Transit Administration, Maritime Administration, and the National Highway Traffic Safety Administration to plan, programme, and execute the ITS Research Program (See Figure 43). The focus of the programme is on vehicle-to-vehicle and vehicle-to-infrastructure connectivity through the application of advanced wireless technologies. The ITS Research Program specifically develops and tests the underlying technology and applications.

5.9.2 State Smart Transportation Initiative (SSTI)

The State Smart Transportation Initiative [201] promotes transportation practices that "advance environmental sustainability and equitable economic development, while maintaining high standards of governmental efficiency and transparency". The SSTI, housed at the University of Wisconsin, operates in three ways:

- As a community of practice, where participating agencies can learn together and share experiences as they implement innovative smart transportation policies.
- As a source of direct technical assistance to the agencies on transformative and replicable smart transportation reform efforts.
- As a resource to the wider transportation community, including local, state, and federal agencies, in their efforts to reorient practice to changing social and financial demands.

The SSTI and Smart Growth America (SGA) has produced a handbook [202] that provides 34 specific recommendations to help state transportation officials position their agencies for success.

5.9.3 Smart Growth America

Smart Growth America [203] is a national organization dedicated to researching, advocating for and leading coalitions to bring smart growth practices to communities nationwide. The aim is to use smart growth strategies to create transportation systems for businesses and communities. This includes coverage of transit options like buses, trolleys, subways, light rail, street cars and ferries. It is driven by the need to accommodate more travellers in the same space and create better options for travel between home, jobs and stores. There is also an aim to make neighbourhoods safer and more appealing. Notably there is a drive to avoid new construction, cut expenses and improve the environment. Communities can provide travel choices by making it easy for residents and visitors to drive, walk, bike, or take public transport.

5.9.4 Smart City Challenge

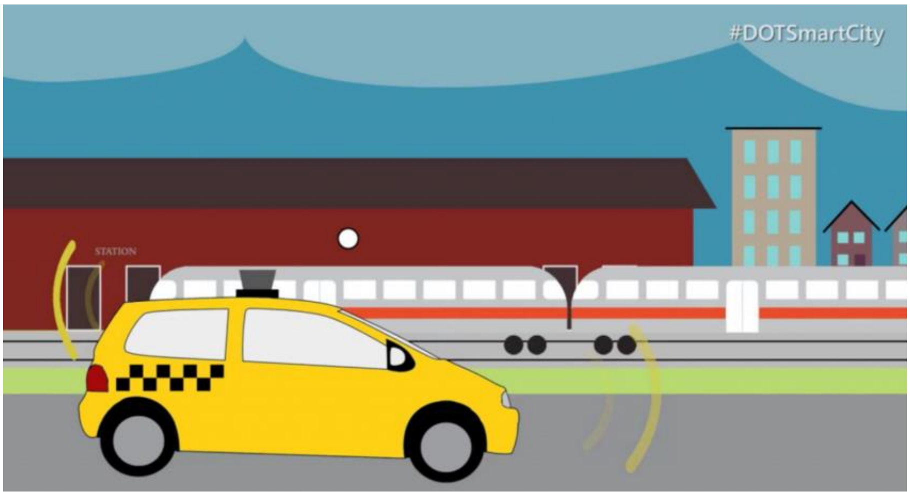


Figure 44. Smart City Challenge

The United States Department of Transportation (DOT) has launched a Smart City Challenge [204] (See Figure 44). This is targeted at mid-sized American cities (200,000 and 850,000 residents). The DOT will award the winning city with $50 million of funding to implement proposed ideas and create a model for other cities to follow. The winner will be announced in June 2016. The funding will come from a public-private partnership between the DOT ($40m) and Vulcan ($10m) which is an investment vehicle founded by Microsoft co-founder Paul Allen [205]. The aim is to promote Intelligent Transportation Systems, connected vehicles and automated vehicles.

5.9.5 Beyond Traffic

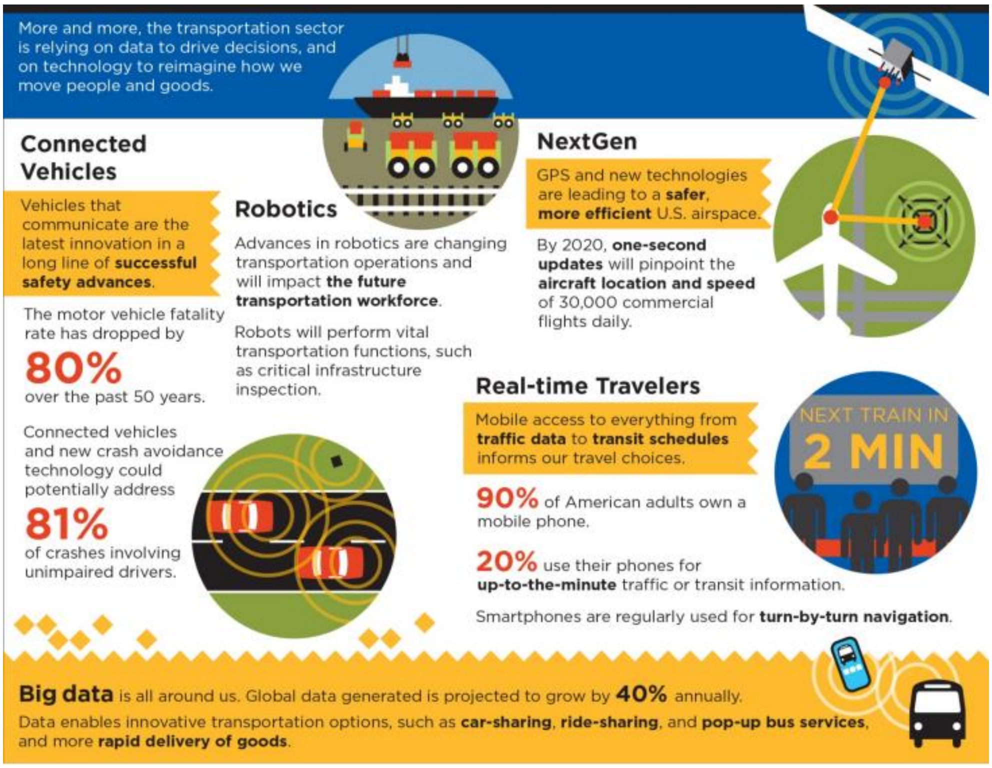


Figure 45. Technology Applications for Transportation

Beyond Traffic [206] is a new forward-looking analysis from the U.S. Department of Transportation outlining the expected trends in the transportation system over the next three decades (See Figure 45). The aim is to promote a national conversation about the future of the U.S. transportation system and objectively frame critical policy choices that need to be made. Beyond Traffic is structured into three parts. The first part discusses the major trends in the transportation system. The second part discusses the implications of these trends for each mode of transportation: highways, transit, pedestrian and bicycle, aviation, intercity and freight rail, maritime and pipeline. The final part presents a future scenario and highlights policy options based on the implications of the trends.

5.9.6 Mobile Millennium

Mobile Millennium [207] was developed by the California Center for Innovative Transportation (CCIT), the Nokia Research Center (NRC), and the University of California (UC) at Berkeley. The partnership began in 2006 when the National Science Foundation co-funded a joint US/European Union workshop in Helsinki. The aim of the work is to use mobile phone and navigation technologies to monitor real-time traffic flow. In 2008 the Mobile Century project performed proof of concept work to test traffic data collection from GPS-equipped cell phones in one hundred vehicles driven on a 10-mile stretch of a highway located in the San Francisco Bay Area. The phones, which effectively served as vehicle probes, stored vehicle speed and position information every three seconds. These measurements were sent wirelessly to a server for real-time processing. The Mobile Century experiment enabled the design and development of algorithms and data collection systems to assemble traffic data from GPS-equipped mobile phones.

The aim of the Mobile Millennium project was to demonstrate the potential of GPS in cell phones to alter the way traffic data is collected, by using the existing cell phone infrastructure to collect data and transmit it directly back to drivers as a 24/7 consumer service. This was demonstrated in the Bay Area and New York City in November 2008 and remained operational until June 2010 with 2000 registered users. Mobile Millennium highlighted some future challenges that need to be addressed by transportation agencies and businesses before similar systems become more commonplace. These challenges include new procurement approaches that are focused on purchasing information rather than equipment, defining the respective roles (and business models) of the public and private sectors in provided traffic information to consumers, and trade-offs between individualised information delivered to a smart phone and distracted driving.

5.9.7 SMART

SMART (Sustainable Mobility & Accessibility Research & Transformation) [208], is a project of UMTRI, the University of Michigan Transportation Research Institute and TCAUP, the Taubman College of Architecture and Urban Planning, in Ann Arbor. The US SMART programme is working with Ford to undertake research and demonstration projects related to the sustainable future of transportation in an urbanizing world. This is driven by the need for sustainable transportation to cope with accelerating urbanization, population growth, globalization, and demographic shifts. Key issues are the environment, energy security, social equity, productivity, urban economies and livability. Recognizing the complexity of the challenge and the sophistication of the innovation required, SMART takes a systems approach to urban mobility. It is a university-wide initiative, working on new theoretical perspectives and practical, innovative, systems solutions.

5.9.8 ITS Deployment – Sensys Networks

Sensys Networks is an American SME developing wireless sensor technologies for ITS. They are working on control of intersections and within the PATH project [209] on “connected corridors” which is concerned with coordinated control of freeways and adjacent urban streets. The timeline for implantation of these systems is 2-3 years with drivers for 24/7 operation, low cost, safety and mobility. A key aim is to provide the ability to get a layered view of operations from network level to individual intersections and compare real time and historical performance of road networks. The expectations are that this will reduce traffic congestion and the associated costs and emissions.

5.9.9 Google and Apple

In general telematics in the automotive sector, even for fleet and insurance operations, has a low uptake because of the cost of retrofitting it to vehicles which is far higher than for factory installed equipment. Customers are not currently asking for connectivity, however, presently there is interest is in providing in-car WiFi so that passengers can connect to services such as Apple CarPlay [210] and those being provided by the Android Open Automotive Alliance [211]. Going one step further Apple is producing wearable computing that connects with cars. The future could well be a “Google Dashboard” and Google are very interested in the automotive industry as collecting information from cars gives free mapping information.

5.9.10 INRIX

Founded in 2005 in Kirkland, Washington and with offices in the UK and Germany INRIX [212] combines data from 1 million miles of roads in North America and 1 million kilometres in 28 European countries to provide services in the car, online and on mobile devices for personal navigation, mapping, telematics and other location-based services. The company has 200 customers and industry partners worldwide including the Ford Motor Company, MapQuest, Microsoft, NAVIGON AG, TeleNav, I-95 Corridor Coalition, Tele Atlas, deCarta, TCS, Telmap, ANWB and ADAC.

Using the services drivers get information on the fastest routes and travel journey times that save time, money and reduce fuel consumption. The traffic data services include accurate real-time and predictive information, real-time incident and weather safety alerts, personalised traffic reports and route advice as well as historical traffic information. For fleet operators the company provides traffic congestion information which can be used to reduce fuel costs and optimise schedule planning. The company also provides information to media broadcasters on traffic congestion and estate agents on actual drive time to and from home and work based on traffic conditions.

5.9.11 Electric Vehicles

Transportation is responsible for 70% of petrol consumption in the US and is the second costliest expense for most American households [213]. President Obama has made historic investments in advanced vehicle and fuel technologies, public transit, and high speed rail under the Recovery Act. One goal was to have one million electric cars on America’s roads by 2015 which was incentivised by tax credits. New fuel economy standards are also being introduced for cars and trucks to raise average fuel economy to 35.5 miles per gallon by 2016. This is predicted to save 1.8 billion barrels of oil over the lifetime of the vehicles subject to the standard. The aim is to lower transportation costs, reduce dependence on oil, revitalise the U.S. manufacturing sector and provide more transportation choices to the American people. Steps have been proposed to improve the efficiency of all modes of transportation, air, road, rail and marine and to develop alternative biofuels

5.9.12 Google Car

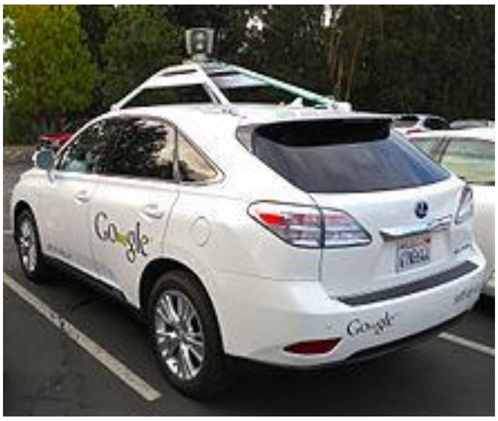



Figure 46. Google Equipped Lexus Autonomous Car and Google Prototype Driverless Car

Google has been working on a Self-Driving Car project [214] for several years to develop autonomous car technologies. This has resulted in the Google Chauffeur software. The company has equipped 6 Toyota PRIUS, 3 Lexus RX450h (as shown in Figure 46) and an Audi TT with $150,000 of equipment to allow autonomous operation. Google has also been active lobbying American states to allow operation of autonomous cars and has been successful in Nevada, Florida and California. By April 2014, the 10 cars had logged nearly 700,000 autonomous miles (1.1 million km). Google have also announced their own driverless car that has no steering wheel or pedals (See Figure 46). Google is not planning on commercial development of the system but they are interested in selling the system and the data behind it to automobile manufacturers.

5.10 Trucking and Logistics - United Parcel Service

UPS perform 17 million shipments per day and are moving from being a trucking company to being a “technology company with trucks” with extensive use of package routing technology and telematics. All road, rail, air and shipping hubs are connected by a private IT system to provide a single network for all categories of service. They have obtained huge savings from network efficiency through development of the ORION (On Road Integrated Optimisation and Navigation) system [215] for predictive and prescriptive operations. This provides an in-cab computer that performs highly complex optimisation of deliveries to minimise miles driven and minutes vehicles spend idling while at the same time maximizing the number of pickups and deliveries made per litre of fuel used. It also gathers information on driving behaviours (which can be used to identify and improve driving performance to reduce fuel consumption) and collects information on mechanical variables from the engine and drive train that can be used for on-condition maintenance saving money and reducing waste (parts, oil, etc.).

Vehicles are used as rolling laboratories and data has been collected for 185 million miles since 2000. Small adjustments to operations can be made with large payoffs over 100,000 drivers around the world. For example, the most efficient vehicles can be matched to routes, the number of stops and starts performed can be minimised and safety can be improved by minimising backing up required in residential areas (which are full of other vehicles, fixed objects, people and pets).

In 2010 telematics-equipped vehicles eliminated more than 15.4 million minutes of idling time saving 103,000 gallons of fuel (and avoiding of 1,045 metric tonnes of CO_2). Additionally, the number of stops per mile were reduced delivering more packages with fewer engine restarts that consume fuel. The use of telematics saved 1.7 million miles of driving in 2010, equating to more than 183,000 gallons of fuel or 1,857 metric tonnes of CO_2. The company is also increasingly using electrification for local deliveries and biomethane as an alternative fuel for larger trucks to further reduce emissions.

5.11 US RAIL

The US lags behind Europe and China in terms of it rail network [216]. The introduction of High-speed rail was one of President Obama's signature transport projects and $11 billion has been spent since 2009 on development of faster passenger trains. However, implementation has been slowed down by Republican and community opposition. The money provided went into upgrading the existing Amtrak service, however, this will only allow trains to go 110 miles per hour and not provide high speed rail services (See Figure 47). Also none of the money went into services in the Northeast Corridor which is the most likely place for a high-speed rail line. Congress has been subsequently asked for a further $10 billion to support high-speed initiatives.

Figure 47. Amtrak's Acela Near Baltimore. The 150 mph Acela Averages Only 80 mph on the New York to Washington Corridor. (Credit Luke Sharrett: The New York Times)

Notably there is opposition from republican governors in Florida, Ohio and Wisconsin, who all canceled high-speed rail projects and returned federal funds after deeming the projects too expensive and unnecessary. The most likely and controversial high speed rail project to be implemented is the 520-mile route between Los Angeles and San Francisco which has begun track construction and put out bids to build the trains. The project will be partly supported by the states cap-and-trade programme which requires business to pay for excess pollution.

In Florida, a 125 mph train will be introduced by a private company, All Aboard Florida, but this will operate at much slower speeds between Miami and West Palm Beach, with a stop in Fort Lauderdale. An extension to Orlando is also planned. Although private, the builders have applied for a $1.5 billion loan from the Federal Railroad Administration which must be paid back with interest over 25 years. Several counties along the route, however, are opposing the project.

In Texas, the private Texas Central Railway company, has proposed a high-speed rail line by 2021 with trains that could reach speeds of up to 205 mph using Japanese bullet trains. This would cut the trip between Houston and Dallas to 90 minutes.

5.12 US Aerospace

5.12.1 NEXTGEN – Air Traffic Control USA

The equivalent of SESAR in the US is NEXTGEN [217]. The National Airspace System (NAS) is the collection of all the components (airspace, facilities, equipment, services, workforce, procedures, etc.) that enable the US air transportation system. Within the United States one organization, the FAA, operates 350,000 airplanes and 18,000 landing facilities. NEXTGEN, is short for the "Next Generation Air Transportation System," and is a programme to comprehensively transform the NAS into a system to meet future needs that will be safer, more reliable, more efficient and which will reduce the impact of aviation on the environment. The system is due for implementation across the United States in stages between 2012 and 2025.

There are some fundamental differences in the approaches being taken by the SESAR and NEXTGEN programmes. SESAR's emphasis is on i4D (using aircraft RTA capabilities – the aircraft themselves calculate the Required Time for Arrival) while the FAA's emphasis is on ADS-B (Automatic Dependent Surveillance - Broadcast) for Interval Management (where aircraft positions are sent by the aircraft and are monitored and controlled centrally). This potentially may lead to a global harmonisation problem for aircraft operators and manufacturers, i.e. multiple solutions for the same operational problem in the same timeframe.

5.12.2 US Unmanned Air Vehicles

Figure 48. Lockheed Martin Unmanned Aerial Vehicles [218]

Lockheed Martin are key proponents of military autonomous vehicles for aerospace, land and underwater marine [218]. Two examples of their autonomous air vehicles are shown in Figure 48. These are the Aerial Reconfigurable Embedded System (ARES) design concept which was developed as part of the Transformer (TX) programme in 2009 [219]. Transformer aimed to develop and demonstrate a prototype system that could provide flexible, terrain-independent transportation for logistics, personnel transport and tactical support missions for small ground units. The other is the K-Max unmanned cargo helicopter which is designed to keep forward operating bases supplied, reducing the number of truck convoys, and the troops that protect them, on the dangerous roads of Afghanistan. Here difficult terrain and threats, such as ambushes and Improvised Explosive Devices (IEDs) can make ground-based transportation to and from the frontline a dangerous challenge. While manned helicopters can easily bypass those problems, they often present logistical challenges of their own and can subject flight crews to different types of threats. Additionally Lockheed Martin also make smaller Unmanned Aerial Systems such as Desert Hawk III that enables soldiers to see what is over the next hill and "persistent surveillance" platforms like PTDS, High Altitude Airships, Hybrid Air Vehicle and ISIS [219] to keep "eyes in the sky" over large areas for weeks, months and even years at a time.

5.12.3 Amazon Prime

Figure 49. Amazon Prime Air [220]

In the civilian domain Amazon are developing their Prime Air concept [220] with drones that deliver packages to customers (See Figure 49). The main goal of the new delivery system is to get packages into customers' hands within 30 minutes or less using unmanned aerial vehicles. Actual deployment of such systems is still many years away as a major barrier is gaining approval from the FAA for operations. This would be even more complicated for operations in Europe due to the more fragmented nature of airspace control. Amazon do not see this as an issue but rather an opportunity to work on the underlying technology and improve payload and endurance which are presently very limited.

5.12.4 US Maritime

In 2009 IHS Global Insight completed a study for the Maritime Administration of the US Department of Transportation, titled "An Evaluation of Maritime Policy in Meeting the commercial and Security Needs of the United States" [221]. This highlighted that US maritime policy supported the nation's domestic maritime trades but did not support international shipping trade and policy reforms were needed. The Maritime Administration has reacted by creating offices at major US gateway ports (See Figure 50), starting with 10 of the largest ports on the West, East and Gulf Coasts, the Great Lakes and the inland river system. These offices interact with stakeholders, including headquarters staff, state and local authorities, port operators, shippers and carriers to identify Federal and state funding and cooperate on planning, environmental and community projects.

Figure 50. Gateway Office Locations in the US

The aim is to identify bottlenecks and ways of improving freight movement. For instance, the Gateway Office in Southern California has worked with public and private sector participants to tackle congestion and better understand the connection between improved cargo flow, economic vitality, community improvement and environmental sustainability. The gateway in Anchorage is leading a public-private partnership with the Port of Anchorage to redevelop its port complex to enhance the transportation of goods within the state. This includes construction of new berths and piers, introduction of new container cranes, on-site rail and railroad trailers, and development of a modern container yard to improve efficiency and reduce truck traffic. This approach to port revitalization is expected to be replicated at other U.S. ports. Public Private Partnerships are seen as the key way of funding and developing ports within America [222].

Here there are major infrastructure funding initiatives such as the Transportation Infrastructure Finance and Innovation Act (TIFIA) programme that provides direct loans, loan guarantees and standby lines of credit as a result of the Fixing America's Surface Transportation Act (FAST Act) with $1.435 billion in capital over five years. This can be used for surface transportation infrastructure including highways, passenger and freight rail, port access, public transit, intermodal freight facilities and international bridges and tunnels. To date, the TIFIA programme has provided $22.7 billion in credit assistance to support more than $82.5 billion in transportation infrastructure investments to help build 56 major transportation projects around the country [223].

At the maritime industry level the American Maritime Partnership (AMP) represents the domestic industry. It has 450-plus members including vessel owners and operators, shipboard and shoreside workers, shipbuilders and repair yards, equipment manufacturers and vendors, dredging and marine construction contractors, numerous maritime associations and national security organizations. A strong domestic maritime industry is seen as being critical for America's economic, national, and homeland security. This is supported by maintaining the Jones Act [224] as the foundation of America's domestic maritime policy. This requires that any vessel transporting goods or passengers between two points in the United States or engaging in activities in US waters must be US owned, US built, and US crewed.

5.13 Rest of the World

MarketsandMarkets [225] forecasts the smart transportation market to grow from $46.72 Billion in 2015 to $138.76 Billion by 2020, growing at a Compound Annual Growth Rate (CAGR) of 24.3% from 2015 to 2020. North America and Europe are expected to be the largest markets in terms of revenue contribution. The Asia Pacific (APAC) region, however, is expected to show the highest potential growth due technological advancements and the presence of leading smart transportation vendors. Additionally, the Middle East and Africa (MEA) and Latin America (LA) markets are also showing a growth in smart transportation. The report also describes the competitive landscape of the smart transportation market. This includes a comparative analysis of the technological and marketing strategies that the key players are adopting. Notably at present the key strategies followed are providing customised solutions or buying smaller domain expert companies. The leading players in this market are Cisco Systems, Inc., General Electric Company, IBM Corporation, Accenture PLC, Indra, Cubic Corporation, Kapsch, and LG CNS.

5.13.1 Worldwide ITS

A Network of National ITS Associations was officially launched on 7 October 2004 in London [226]. This Network is a grouping of national ITS interests formed in order to ensure that ITS knowledge and information is transmitted to all actors at the local and national level. The Network currently consists of 27 member organisations. The Network Secretariat is at ERTICO-ITS Europe and is a multi-sector, public/private partnership pursuing the development and deployment of Intelligent Transport Systems and Services. It connects public authorities, industry players, infrastructure operators, users, national ITS associations and other organisations together and works to bring “Intelligence into Mobility”. The ERTICO work programme [227] focuses on initiatives to improve transport safety, security and network efficiency whilst taking into account measures to reduce environmental impact. The vision is of a future transport system working towards zero accidents, zero delays with fully informed people, where services are affordable and seamless, the environment is protected, privacy is respected and security is provided. At a worldwide level the ITS World Congress [228] is an annual event to promote and showcase ITS technologies organised by ERTICO – ITS Europe, ITS America and ITS Japan. This event attracts over 8,000 people.

5.13.2 Asia-Pacific Economic Cooperation (APEC)

The Smart Transport pillar of the Energy-Smart Communities Initiative [229] will examine clean and efficient ways of moving both goods and people throughout the Asia-Pacific region. Work will focus on options to reduce travel times, costs, energy use, and carbon emissions for urban and freight transport. A number of multinational projects have been proposed across the region:

- Energy-Efficient Urban Transport Network (Australia, Canada, Indonesia, Singapore, Chinese Taipei, US)
- Energy-Efficient Freight Transport Network (Australia, Indonesia, Chinese Taipe, US)
- Electromobility Survey And Road Map (Australia, Canada, Hong Kong, China, Indonesia, Japan, Malaysia, Singapore, Chinese Taipei, US)

- Electric Vehicle Demonstrations (Canada, Indonesia, Japan, Malaysia, The Philippines, Chinese Taipei, US)

5.13.3 Japan

In Japan there is great interest in car-to-car, car-to-infrastructure, and infrastructure-to-car communication. This is being used for warning drivers of upcoming hazards. Already Japan has installed sensors on highways which are used to notify motorists that a car is stalled ahead. Transmission of car data to infrastructure opens up the opportunities to centrally fuse and process data to detect events such as rain (wiper activity), congestion (frequent braking activities) and ice detection (from ABS activations). Transmission from infrastructure-to-car can be used to provide driver recommendations to avoid traffic or warn of hazards increasing road safety.

5.13.4 India

The US Department of Transportation is offering sustainable transport solutions for the Indian cities of Allahabad, Ajmer and Visakhapatnam [230]. This is a bilateral cooperation in the field of smart cities including efficient public transportation systems, intelligent transport systems, traffic information and control, multimodal integration and capacity building and training in the field of urban transportation. Task forces have been set up for Allahabad, Ajmer and Visakhapatnam in association with United States Trade Development Agency. The US Government is focusing on promoting regional transport solutions and the planned initiative will build 100 smart cities in India.

5.14 ICT Regulations

5.14.1 eCall

EU regulation is driving the introduction of car emergency vehicle notification systems (eCall) [231]. Additionally, insurance companies are interested in introducing driver behaviour tracking functionalities. Using the system in an emergency the vehicle occupants can manually eCall or the vehicle can automatically call via activation of in-vehicle sensors after an accident. The eCall device establishes an emergency call carrying both voice and data directly to the nearest emergency point. The voice call enables the vehicle occupant to communicate with the eCall operator. At the same time, data is sent containing information about the incident, including time, precise location, the direction the vehicle was traveling, and vehicle identification. The pan-European eCall system aims to be operative for all new type-approved vehicles as a standard option. Depending on the manufacturer of the eCall system, it could be mobile phone based (Bluetooth connection to an in-vehicle interface), an integrated eCall device, or a functionality of a broader system like navigation, telematics device, or tolling device. Going one stage further the EC funded project SafeTRIP [232] is developing an open ITS system that will improve road safety and provide resilient communication through the use of S-band satellite communication. This would allow greater coverage of the Emergency Call Service within the EU. Work on the eCall standard has been ongoing for a number of years and currently it is targeted for implementation in 2017. This has been slowed by lack of support for it from some member states and currently other technologies are overtaking it combining the same functionality with congestion and traffic management information.

5.14.2 Decarbonisation of Transport

The legal requirements introduced by the European Commission toward decarbonisation of transport have defined an EU global target of 40% reduction of greenhouse gas emissions with a need for 27% of the global energy mix coming from renewable energy sources by 2030. To meet this there is a need to deploy alternative fuel vehicles infrastructures and introduce electrification of cars and public transportation systems. This requires full integration of electric vehicles in urban mobility policies and in the electricity grid, both as energy consumers and potential storage facilities. The European Commission will present a strategic transport R&I agenda by 2016 and under action 11 the EC will propose a comprehensive road package. This will include a number of measures including promoting procurement of clean vehicles, a more efficient pricing of infrastructure, the roll-out of ITS, as well as creating the market conditions to support deployment of alternative fuels.

5.15 Standards

5.15.1 CAR 2 CAR

There is a key need for communication standards. The CAR 2 CAR Communication Consortium (C2C-CC) [127] [233] is a non-profit, industry driven organisation initiated by European vehicle manufacturers and supported by equipment suppliers, research organisations and other partners.

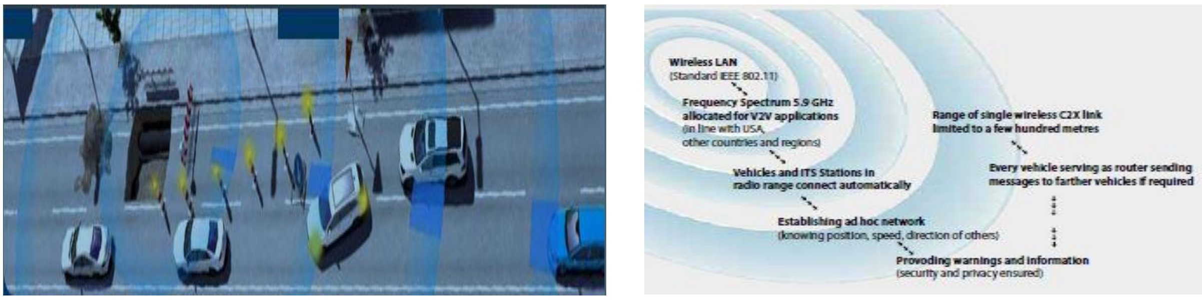


Figure 51. Car2car Communication Consortium [233]

The C2C-CC (See Figure 51) [233] is dedicated to the objective of further increasing road traffic safety and efficiency by means of cooperative Intelligent Transport Systems (C-ITS) with Vehicle-to-Vehicle Communication (V2V) supported by Vehicle-to-Infrastructure Communication (V2I). It supports the creation of European standards for communicating vehicles spanning all brands. As a key contributor the C2C-CC works in close cooperation with European and international standardisation organisations. In cooperation with infrastructure stakeholders the C2C-CC promotes the joint deployment of cooperative ITS. The European Commission forecasts a heavy increase of vehicle kilometres. To improve mobility on the roads it has adopted the ITS Action Plan [234] indicating 24 concrete measures in 6 priority areas.

An iMobility Forum has been created and a number of R&D programmes including large scale field operational tests are being performed. These are expected to contribute to the reduction of road fatalities, improve efficiency and reduce the environmental impact of road traffic in all areas including smart cities.

Figure 52. Partners in CAR 2 CAR

The C-ITS will provide new active safety measures to enhance the existing passive safety systems preventing or mitigating traffic accidents. As energy consumption and emissions need to be reduced and road traffic needs to exploit road capacities, new driving measures are required to support sustainability, e.g. green driving. The aim is to develop an open European standard for C-ITS with an associated validation process focusing on V2V Systems. This is to be supported with realistic deployment strategies and business models to speed up the market penetration and a roadmap for deployment of C-ITS (for V2V and V2I). A key aim is to also provide a validation route for these technologies. Specifications will be provided to the standardisation organisations, in particular ETSI TC ITS, in order to achieve common European standards for ITS. There is also an aim to push for the harmonisation of C2C Communication Standards world-wide such as 802.11.P and promote the allocation of a royalty free European wide frequency band for V2V Applications and joint deployment of C-ITS by all stakeholders.

The mandate M/453 of the European Commission [235] paved the way for the development of the minimum set of standards by the European standardisation organisations ETSI, TC, ITS, and CEN in 2012, ensuring the interoperability of C-ITS**.** Deployment will rely on these standards covering the whole communication chain, including security and privacy issues and starting with day-one applications based on selected common message sets. The project will demonstrate the C2C-System as proof of technical and commercial feasibility.

The standard is close to finalisation and a MOU exists between the major OEMs (See Figure 52). Critically day-one applications will reveal if the standards are sufficient and whether further work is required. The initial applications are concentrated on providing all the information in the car rather than having centralised information being sent to the car so cars will also utilise sensing radar, laser scanners and image detection. Importantly cars must be able to understand each other and not be dependent on the OEM.

5.15.2 POSSE

Project POSSE ("Promotion of Open Specifications and Standards in Europe") is funded under the INTERREG IVC programme. The POSSE project is led by Reading Borough Council in the UK with national co-funding from the Department for Transport towards this project. The project will help share experiences from UK and German open specifications frameworks with roads authorities in a number of Member States (Czech Republic, Italy, Lithuania, Norway and Spain).

5.15.3 ISO ITS Standards

ISO/TC 204, Intelligent transport systems, focuses on standardization of information, communication and control systems in the field of urban and rural surface transportation and covers the areas of traveller information, traffic management, public transport, commercial transport, emergency services and commercial services in the intelligent transport systems (ITS) field.

Other Working Groups (WG) and sub-committees (SC) of ISO are developing technical standards which include:

- WG on Infrastructures of sensor network e.g. ISO/IEC DIS 29182-1 Information technology – Sensor networks: Sensor network reference architecture
- WG on Governance of IT which incorporates the mechanisms, methods, and models which ensure the conformance of IT to underlying and required policies, regulations, laws, and ethical guidelines.
- SC on Telecommunications and information exchange between systems

6 5G

6.1 European Drivers and Policy Initiatives

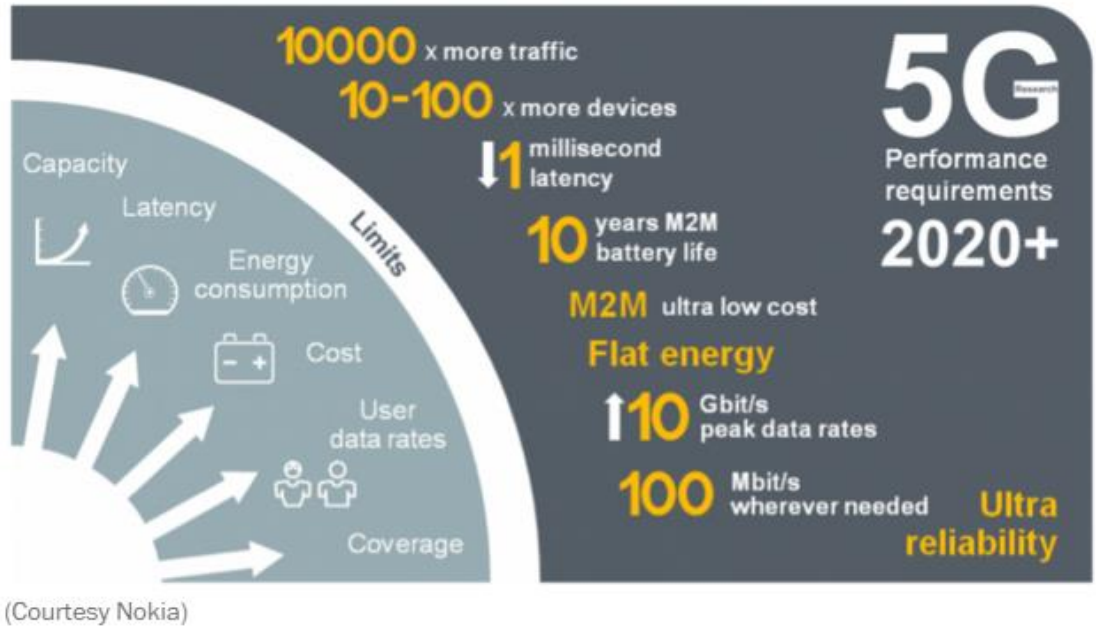


Figure 53. 5G Performance Requirements 2020+

To support the development of smart cities there is a need for substantially improved communication networks. The fifth generation (5G) cellular network (See Figure 53) is a revolutionary change to the traditional cellular network which was utilised for the sole purpose of moving content (voice, video, data, etc.) between two or multiple parties. 5G extends the cellular network from content delivery to a “Control Network” that opens up new doors to new applications such as:

- manoeuver and monitoring of virtual or real time objects (e.g., robots in a factory or hazardous environment),
- controlling smart vehicles on a street (automated traffic control and driving),
- walking using an exoskeletons, remote surgery, (E-health care services), etc.
- new levels of human-IoT interaction including immersive augmented reality and immersive gaming.

However, these new applications also add new stricter requirements on cellular networks such as a need for an end-to-end latency of 1ms for control purposes, extremely high reliability of 99.9999% for controlling cars, very dense connectivity and increased battery life to enable IoT or device-to-device communication. Future networks will also be highly heterogeneous.

Since the demand for the data rate increases by one order of magnitude every 5 years (according to Moore’s law) the 5G network needs to be a massive broad band to cope with increasing throughput requirements. This is estimated to be in excess of 10 Gbps for cellular and above 100 Gbps for short range communications beyond 2020. To meet future data rate requirements more spectrum will be needed. The current cellular network utilises the frequency band below 6GHz but large chunks of contiguous spectrum are only available at higher frequencies from 10 GHz to 100 GHz. There is thus a need to harmonise these spectrum bands globally and provide spectrum access policies, e.g. licensed spectrum access, license assisted access and dynamic spectrum access. A key requirement is a “global standard” based on a consensus between major players around the world most notably in the EU and US. The EU Commissioner specifically highlighted this at the Mobile World Congress 2015 in Barcelona. Multiple white papers have been published on the future of 5G in the EU and US which set out a similar set of requirements for latency, security, reliability and data rates.

The increased ability for interconnectivity and transfer of content will lead to new services and here there are also privacy issues. As new services will also involve car manufacturers, the automation industry, etc. there is a need to engage with key manufacturers to understand requirements, usage scenarios, definitions and business cases.

As part of the Digital Agenda the EC has put forward a number of actions to support the development of 5G [236]. In 2012, the European Commission, under the lead of Neelie Kroes, committed €50 million for research to deliver 5G mobile technology by 2020.

6.2 European 5G Initiatives

6.2.1 The 5G Infrastructure Public Private Partnership

Figure 54. 5G Infrastructure Public Private Partnership

In a report from the GSMA Intelligence [237] it is highlighted that network operators need to move fast with 5G. The EC is supporting this, in particular, by helping to establish PPP structures for 5G development (See Figure 54). To support 5G in Europe the 5G Infrastructure PPP has been set up. The EU is investing €700 million over the next seven years into the 5GPPP through the Horizon 2020 programme. EU industry will match this investment by up to 5 times, to more than €3 billion. The aims of the 5G Infrastructure PPP are to:

- Provide 1000 times higher wireless area capacity and more varied service capabilities compared to 2010
- Save up to 90% of energy per service provided. The main focus will be in mobile communication networks where the dominating energy consumption comes from the radio access network
- Reduce the average service creation time cycle from 90 hours to 90 minutes

- Create a secure, reliable and dependable Internet with a "zero perceived" downtime for services provision
- Facilitate very dense deployments of wireless communication links to connect over 7 trillion wireless devices serving over 7 billion people
- Ensure for everyone and everywhere the access to a wider panel of services and applications at lower cost

6.2.2 METIS 2020 and METIS-II

The METIS project [238] is driven by several telecommunications companies. A key aim is to reach world-wide consensus on the future global mobile and wireless communications system. The overall technical goal is to provide a system concept that will provide 1000 times higher mobile system spectral efficiency compared to current LTE. The METIS-II [239] builds on the METIS project and is developing the overall 5G radio access network design and will provide the technical enablers for efficient integration and use of the various 5G technologies and components that have been developed. METIS-II will also provide a 5G collaboration framework within the 5G-PPP for a common evaluation of 5G radio access network concepts and help prepare actions towards regulatory and standardisation bodies.

6.2.3 5GrEEn

The 5GrEEn project [240] (which is linked to METIS and started in 2013) is focused on the design of Green 5G Mobile networks. Here the goal is to develop guidelines for the definition of new generation network with particular care of energy efficiency, sustainability and affordability aspects.

6.2.4 i-JOIN

In November 2012, the FP7 Interworking and JOINt Design of an Open Access and Backhaul Network Architecture for Small Cells based on Cloud Networks (i-JOIN) project [241] was launched. This project coordinated by the IMDEA Networks Institute (Madrid, Spain) is exploring the RAN-as-a-Service (RANaaS). The RAN functionality is flexibly centralised through an open IT platform based on a cloud infrastructure. The aim is to allow joint design and optimisation of access and backhaul, operation and management algorithms, and architectural elements, integrating small-cells, heterogeneous backhaul, and centralised processing. iJOIN is studying the requirements, constraints, and implications for existing mobile networks, specifically 3GPP and LTE-A.

6.2.5 CROWD

The EU funded CROWD (Connectivity management for eneRgy Optimised Wireless Dense networks) project [242] was launched in 2013. Led by the IMDEA Networks Institute it is investigating the design of sustainable networking and software solutions for the deployment of very dense (1000x higher than current density – users per square metre), heterogeneous wireless networks. Sustainability is defined in terms of cost effectiveness and energy efficiency. Heterogeneity arises from a number of factors including coverage radius, the technologies used (4G/LTE vs. Wi-Fi), and deployment strategies (planned vs. unplanned distribution of radio base stations and hot spots).

6.2.6 NetWorld2020 ETP

NetWorld2020 [243] is a European Technology Platform for communications networks and services. Here the communications networks being considered are between users of both mobile and fixed equipment. The NetWorld2020 European Technology Platform brings together industry leaders, innovative SMEs, and leading academic institutions from the communications sector. The NetWorld2020 Expert Group drafted a White Paper on the topic "5G Experimental Facilities in Europe" and a public consultation was held which finished in January 2016. Based on the received feedback the document will be updated and finalised, followed by an endorsement process within the ETP.

6.3 National Initiatives

6.3.1 UK

6.3.1.1 5G Innovation Centre

In September 2015 the University of Surrey opened a 5G Innovation Centre (5GIC) with the aim of securing the UK's role in leading the development of the next generation communications technology. The centre has over 170 researchers and has attracted over £70 million of investment, including £12 million from the Higher Education Funding Council for England (HEFCE). The 5GIC is the world's largest academic research centre dedicated to next generation mobile and wireless connectivity. In addition to academic expertise, major industry partners, e.g. EE, Huawei, O2, Vodafone, HEFCE, Enterprise M3, TEOCO Corporation, BBC, BT, Cobham, Anite, Ascom, Digital Catapult, Fujitsu, Rohde & Schwarz, Samsung, Roke, McLaren Applied Technologies, Ofcom, Imagination Technologies, ITRI, MYCOM OSI, Three and Ordnance Survey, are also partners in the centre. Technology that enables one terabit per second (Tbps) communications speeds has been developed (more than 1,000 times faster than the highest 4G speed) and 15 patents have been filed. The aim is to work in cooperation rather than competition to create a single standard for 5G. Commercialisation of technologies is expected from 2020. A 4G network testbed is also available to researchers which will be upgraded to 5G and Internet of Things. The testbed will provide 10Gbs/per cell by 2018, ten times faster than the highest speed available over 4G. Already Huawei, BBC R&D and the 5GIC have demonstrated ultra-high-definition (4k) video streaming to a mobile device. The centre has also demonstrated a 5G-Sparse Coding Multiple Access radio waveform that can support at least three times the number of IoT devices than would be possible with 4G [244][245].

6.3.1.2 Kings College London

Work at Kings College [246] being led by Mischa Dohler on 5G is concentrated on the Tactile Internet [247]. The term "Tactile Internet" was first coined by Gerhard Fettweis from the Technical University of Dresden to describe using touch for real-time remote control of robotic systems. Work at Kings College is trying to “close the data cycle” so that it is possible to touch and feel remote systems. What is needed for this is very fast data rates thousands of times faster than today’s average 4G. Work is being supported by Ericsson and Samsung to investigate the potential of the technology [248].

6.3.2 Germany

6.3.2.1 fast zwanzig20

Zwanzig20 [249] is a partnership for innovation initiated by the Technische Universität Dresden and funded by the BMBF. The programme "Zwanzig20 - Partnership for Innovation” aims at a supra-regional, inter-, trans- and multi-disciplinary collaborations of partners and promotes openness and transparency. In particular, a project called “Fast Wireless” is looking at reliable and real-time-capable 5G-Mobile. Here the target is low latency of 1 ms in distributed control applications with a very high number of users, i.e. sensors and actuators, per radio cell.

6.3.2.2 5G Lab Germany

Within the 5G Lab Germany [250], 20 professors from TU Dresden are collaborating in an interdisciplinary team with more than 500 scientists to advance research on the key technologies for the 5th generation of mobile communications (5G) and its applications. Applications being considered include Tactile Internet applications, e.g. automated driving and robotic-aided tele-surgery. To achieve this goal, the whole value chain is being addressed: from the semiconductor chips across wireless data transmission, networking and mobile edge clouds to Tactile Internet applications.

6.3.2.3 Berlin 5G

5G Berlin [251] is a Fraunhofer led research initiative formed in 2014 by Fraunhofer HHI and FOKUS based on existing technology knowhow and testbed activities in wireless broadband. The aim is to integrate core technologies and expertise from academia and industry across disciplinary borders and test latest technologies, system components and applications in a real world setup. New partners can join this initiative to develop and test innovative 5G infrastructures, products, and applications.

6.3.2.4 5G:Haus

5G-Haus [252] is a virtual laboratory set up by Deutsche Telekom to develop the architecture and steer standardisation work in cooperation with Continental, Fraunhofer ESK and Nokia Networks. They have demonstrated communication between vehicles via the LTE cell network. The aim is for vehicles to share hazard information on the motorway which requires very short transmission times.

6.3.3 Finland

The 5G Test Network Finland (5GTNF) [253] coordinates and combines the research and technology development activities from the 5G infrastructures built under the Tekes 5thGear programme [254]. 5GTNF creates a single coherent entity from the numerous smaller test networks around Finland and represents them as an integrated innovation platform to the research community, industry and other interested parties on a national and international level.

6.3.4 Multinational

6.3.3.1 Ericsson 5G

Within Europe Ericsson is very active in 5G and is supporting a number of projects. The company is working with King's College London and the Technische Universität Dresden to collaborate on 5G research, addressing technical implications and the societal challenges of implementing 5G technology. A focus for the work is machine-type communication and Smart Sustainable Cities applications. Ericsson is also funding work at the Royal Institute of Technology, Chalmers University of Technology and Lund University in Sweden. At a world-wide level Ericsson has also teamed with LG Uplus and MTS for 5G development, as well as working to unify 5G infrastructure through the 5GEx project.

6.4 US 5G Drivers and Policy Initiatives

In the US there is a lot of activity in 5G mainly funded by NSF at the research level but there are no major 5G programmes being funded by government at present. This is something which is being called for by the community with a proposal for a major $500M programme on 5G from the White House.

6.4.1 MOBILE NOW Act

On the 3rd of March, 2016, the Senate Committee on Commerce, Science, and Transportation approved the MOBILE NOW Act [255] to boost the development of next-generation 5G wireless broadband by ensuring more spectrum is made available for commercial use and reducing the red tape for building wireless networks.

6.4.2 5G Americas and 5G Forum USA

5G Americas (which changed its name from 4G Americas on February 12, 2016) is an industry trade organisation headquartered in Bellevue, Washington, composed of leading telecommunications service providers and manufacturers [256]. The organization's mission is to advocate for and foster the advancement and full capabilities of LTE wireless technology and its evolution to 5G. 5G Americas' key aim is to develop a connected wireless community while leading 5G development for all of the Americas. The organisation is addressing the following areas:

- Standards recommendations, technical requirements and advocacy for LTE, LTE-Advanced and LTE-Advanced Pro technologies and beyond
- Supporting the 3GPP technology path as it evolves to 5G technology
- Serving as a resource for information on LTE wireless technology and 5G throughout the Americas

5G Americas organises a 5G Forum in the US every year which brings the community together. 5G Americas is also supporting the Global 5G Event in Beijing, China on May 31-June 1, 2016 collaborating with The Fifth Generation Mobile Communications Promotion Forum (5GMF) (Japan), 5G Forum (Republic of Korea), IMT-2020 (5G) Promotion Group (China) and The 5G Infrastructure Association - Public Private Partnership (5G PPP) (Europe).

In October 2015 5G Americas published a white paper on 5G Technology Evolution Recommendations, expanding upon 4G Americas' view of 5G recommendations in 2014.

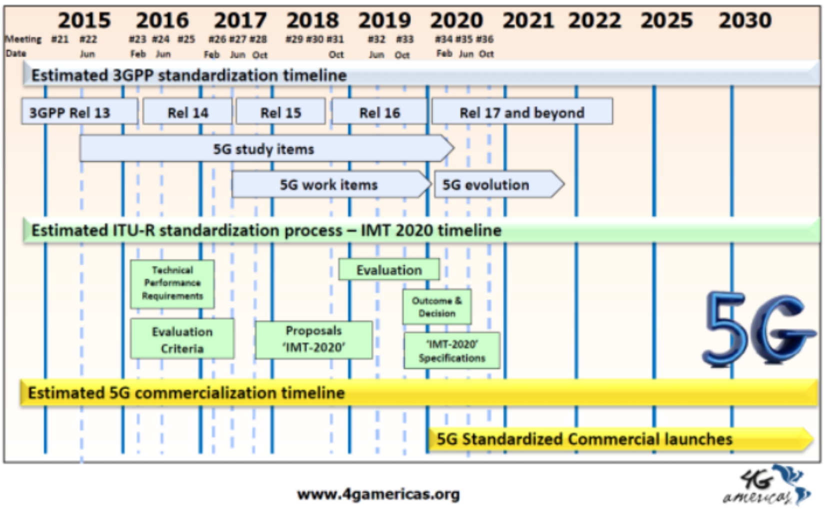


Figure 55. 5G Americas Roadmap

A key recommendation from this was that the US should invest in a national programme in 5G in order to compete with the rest of the world. Figure 55 shows the proposed technology roadmap to 2030.

6.4.3 US Research Initiatives

6.4.3.1 University of Texas at Austin

The Wireless Networking and Communications Group (WNCG) is an interdisciplinary center for research and education at the University of Texas at Austin with an emphasis on industrial relevance. Founded in 2002, the group includes 20 faculty from the departments of Electrical and Computer Engineering, Aerospace Engineering, Mathematics, and Computer Sciences. The group is addressing mmWave research to demonstrate the viability of the technology for 5G systems [257]. The research is investigating data rates, blockages, system coverage, sensitivity to interference and antenna arrays. Approaches to hybrid beamforming transmission strategies are being developed to adaptively configure arrays at the transmitter and receiver. Ways for propagation channel estimation are also being developed, which can aid the beamforming process [258].

Five technologies that could lead to both architectural and component disruptive design changes have been identified: device-centric architectures, millimeter wave, massive MIMO, smarter devices, and native support for machine-to-machine communications. UT Austin and Stanford work together in this area and they have recently been awarded a NSF grant of $978,000.

6.4.3.2 Stanford University & Berkeley

Stanford University in collaboration with Berkeley are working on Software-Defined Networking (SDN) and Network Functions Virtualization (NFV) which are two key pillars for 5G [257]. The concept for SDN arose out of the graduate work of Martin Casado at Stanford in collaboration with Nick McKeown, also at Stanford, and Scott Shenker at Berkeley. The Open Networking Research Center (ONRC), was set up to develop and support open source SDN tools and platforms for OpenFlow and SDN. This is sponsored by CableLabs, Cisco, Ericsson, Google, Hewlett-Packard, Huawei, Intel, Juniper, NEC, NTT Docomo, Texas Instruments and VMware.

The ONRC is made up of the networking research groups at Stanford University and UC Berkeley and an independent, non-profit Open Networking Laboratory (ON.Lab). The ONRC collaborates with the Open Networking Foundation (ONF) on the Open Networking Summit, bringing a cross-section of industry engineers, business leaders and researchers together for tutorials and keynotes.

6.4.3.3 NYU Wireless

New York University Wireless [259] was established in 2012 as a multi-disciplinary research centre, focusing on 5G wireless research in the medical and computer science fields. The centre is funded by the National Science Foundation and has an Industrial Affiliates board of 10 major wireless companies. NYU WIRELESS has conducted and published channel measurements that show that millimeter wave frequencies are viable for multi-Gigabit per second data rates for future 5G networks.

6.4.3.4 Rutgers University

The Cyber-Physical System (CPS) Lab at Rutgers University, funded by NSF, are working on dynamic provisioning and allocation under the Cloud Radio Access Network (C-RAN). They have shown that the dynamic demand-aware provisioning in the cloud will decrease the energy consumption while increasing the resource utilization. They have also implemented a testbed to demonstrate the feasibility of C-RAN and developed new cloud-based interference cancellation techniques.

6.4.3.5 T-Mobile and Ericsson US

Figure 56. Ericsson Prototype 5G Networking Technology at Mobile World Congress. (Source Stephen Shankland/CNET)

T-Mobile US, Inc. and Ericsson are working together and will jointly evaluate the performance and applicability of potential 5G key technologies. An aim is to develop a pre-standards 28GHz 5G test system for lab and field trials in the United States [260] with trials beginning in the second half of 2016. The work builds upon Ericsson's long-standing partnership with T-Mobile for LTE-Advanced and network transformation. The two companies will develop and test selected 5G use-cases and services to enable T-Mobile to evaluate emerging 5G technologies, drive 5G technology development and standardization, and to explore new business opportunities. Notably Ericsson are predicting 150 million 5G subscriptions by the end of 2021. T-Mobile currently delivers Americas fastest 4G LTE network and the market is waiting for 5G consumer smartphones and standards. Ericsson has announced more than 20 agreements to test 5G with operators across the globe and Ericsson 5G Radio prototypes, designed for operator field trials, are already achieving more than 25 Gbps mobile throughput.

6.4.3.6 Verizon

Verizon is planning field trials of 5G networks in 2017 at their Basking Ridge headquarters with a planned entry into service date of 2020 with 1GBps. Already, U.S. providers are promising to deploy 5G networks as early as 2020 [261]. The 5G network will provide speeds 200 times faster than the 5 Mbps generally available today on Verizon's LTE network. Verizon is also working with Alcatel-Lucent, Ericsson, Cisco, Nokia, Qualcomm and Samsung to test 5G in their innovation centers. The company is also talking to NTT Docomo. Verizon has set up a 5G Technology Forum that includes venture capitalists and the company has created "sandbox” testing areas for 5G technology, in its innovation centers in Waltham, Massachusetts, and San Francisco. Verizon considers other countries to be further ahead when it comes to policies on spectrum allocation for 5G [262].

6.5 Rest of the World

6.5.1 Next Generation Mobile Networks

The NGMN Alliance [263] has defined a 5G Roadmap that shows an ambitious time-line with a launch of first commercial 5G systems in 2020. The roadmap also defines how the industry players can achieve the required standardisation, testing and trials to make mature technology solutions available. The white paper highlights that standardization of technology is essential for the global success of future 5G solutions and the related ecosystem. This is to allow multi-vendor interoperability and economies of scale whilst reducing complexity and cost of interfaces. A challenge is that there are a range of interfaces, network elements and legacy systems, so it is necessary for numerous standardization bodies to come together for 5G standardization. Here the main risks are diversity of interests, conflicting standards and redundant options. This could result in development delays. Some coordination is required to avoid parallel work on similar areas (with potentially conflicting standards) so that solutions from different organisations are harmonised into an absolute minimum set.

6.5.2 South Korea

The South Korean mobile operator KT has said that it will launch a live 5G service for the 2018 Winter Olympic Games in the city of Pyeongchang. There have been a number of initiatives in South Korea. In 2008, the South Korean IT R&D programme of "5G mobile communication systems based on beam-division multiple access and relays with group cooperation" was formed. South Korea's Ministry of Science, ICT and Future Planning have also announced that it is committing $1.5 billion to its "5G Creative Mobile Strategy" [264]. The Korea 5G Forum was set up a collaborative development environment for 5G wireless communication and was founded by the Ministry of Science, ICT (information and communications technology) and Future Planning (MSIP). The forum brings together telecommunications companies, semiconductor companies, academia, and research institutes [265] and cooperates internationally on standardization, research and development. The 5G Forum collaborates with the EU (5GPPP and NGMN Alliance), Global Forum Wireless World Research Forum (WWRF), China (IMT-2020 PG, FuTURE Forum), Japan (5GMF) and India (GISFI) [266].

In 2014 an agreement was signed between the European Commission and South Korea to work towards a global definition of 5G, to cooperate in 5G research and also on harmonization of radio spectrum to ensure global interoperability. A coordinated call for research project proposals was held in 2016. Additionally a memorandum of understanding has been signed between the EU's 5G Infrastructure Association 5G-PPP (whose members include Alcatel-Lucent, Atos, Deutsche Telekom, Ericsson, Nokia, Orange, Telecom Italia, Telenor and Telefonica) and South Korea's 5G Forum.

The ETRI (KR) 5G Giga Communication Research Laboratory [267] is researching and developing 5G mobile communications technologies to lead the Korean governments "creative economy". The research areas being addressed include core technologies of mmWave wideband mobile communication and C-P-D-N (Contents-Platform-Device-Network)-interconnected technologies. Specifically, 5G high-capacity/low-latency wireless communications, 5G massive/low-power wireless communications, L1/L2/L3 core technologies for mmWave devices and base stations, and antenna/RF/channel research for mobile communications are being considered. Research is also being performed in digital holography broadcast-communication.

6.5.3 China

In China, three ministries: the Ministry of Industry and Information Technology (MIIT), the National Development and Reform Commission (NDRC) and the Ministry of Science and Technology (MOST) have set up an IMT-2020 (5G) Promotion Group to coordinate all 5G activities in Chinese industry and academia [264]. In November 2013, Chinese telecom equipment vendor Huawei stated that it will invest $600 million in research for 5G technologies in the next five years. This does not include additional investment to productise 5G technologies for global telecom operators. Huawei plans to test 5G technology in Malta and is looking to set up a research and development facility there depending on the 5G test results [268]. Huawei sees Europe as a big potential market and also sees the need for a global 5G standard. Huawei is actively engaged in many European projects. Huawei is a key contributor to the 5G PPP and is working on five of the 19 co-funded projects. Huawei is a Board Member of the 5G Infrastructure Association, and is contributing to several projects in the H2020 Framework Programme, e.g. METIS-II, FANTASTIC-5G, mmMAGIC, 5G-Xhaul and 5Gex projects. It is also providing £5 million of funding for 5G research and a testbed at the 5G Innovation Centre at the University of Surrey, UK. Additionally, it has launched the 5G Vertical Industry Accelerator (5G VIA) in Munich targeting a large-scale 5G testbed to simulate real-world scenarios. In 2015 Huawei won an award for the "Biggest Contribution to 5G Development" [269].

In 2015 Huawei and Ericsson began testing 5G-related technologies in rural areas in the Northern Netherlands at Loppersum in North Groningen. As most tests are currently being performed in urban areas testing in the countryside allows new applications to be considered, e.g. autonomous cars, tractors, home appliances, monitoring elderly people, delivering music, etc. [270].

6.5.4 GSMA

The GSMA represents the interests of mobile operators worldwide, uniting nearly 800 operators with more than 250 companies in the broader mobile ecosystem, including handset and device makers, software companies, equipment providers and Internet companies, as well as organisations in adjacent industry sectors. The GSMA will play a significant role in shaping the strategic, commercial and regulatory development of the 5G ecosystem [271]. This will include areas such as the definition of roaming and interconnect in 5G, and the identification and alignment of suitable spectrum bands. The GSMA released a major new report at the GSMA Mobile 360-Europe event held in Brussels in December 2014, outlining its perspectives on the development of 5G. The report, 'Understanding 5G: Perspectives on Future Technological Advancements in Mobile' [237], provides an overview of network technology innovation today and how this is setting the agenda for the 5G future. It outlines the technical requirements of future 5G networks and explores potential use cases as well as the implications for operators and other mobile ecosystem players.

Many of the 5G technical requirements, e.g. network functions virtualisation (NFV), software-defined networks (SDN), heterogeneous networks (HetNets) and Low Power, Low Throughput networks are already being brought to market by vendors and deployed by operators as part of 4G. There is still an opportunity for growth in 4G, which still only accounts for 5 per cent of the world's mobile connections. At a country level, however, 4G has taken off far more in South Korea (69% of connections), Japan (46% of connections) and US (40% of connections) [237]. In the developing world 4G penetration is 2%. The expectation is that mobile operators will invest US$1.7 trillion globally in network infrastructure over the period 2014-2020, the majority of which will be spent on 4G networks.

An application that requires at least one of the two key 5G technical requirements (greater than 1 Gbps downlink and sub-1ms latency) can be considered a "true" 5G use case. Here there are opportunities for virtual reality/augmented reality/immersive or tactile internet, such as gaming, wearable tech. or health services, autonomous driving/connected cars and wireless cloud-based office/multi-person videoconferencing.

6.5.5 Alvarion Israel

In April 2012, Alvarion set a world record, reaching a tenfold increase in mobile broadband infrastructure capacity. Their $6 million Beyond Next Generation (BuNGee) project achieved a 'pre-5G' throughput of 1Gbit/s per square kilometre at Alvarion's premises in Tel Aviv. (A speed of 1Gbit/s allows you to download a standard high-definition movie in about a minute.) The demonstration confirmed that high-speed mobile Internet solutions were commercially viable.

6.5.6 Japan

Japan's government has been less active than the EU, China and South Korea in setting up national 5G R&D initiatives, however, Japanese companies are active and NTT Docomo plans to showcase the technology at the

2020 Tokyo Summer Olympics [272]. The company is performing "experimental trials" of 5G technologies with six vendors: Alcatel-Lucent, Ericsson, Fujitsu, NEC, Nokia and Samsung. Companies in Japan are also leading the Japan's Association of Radio Industries and Businesses (ARIB) "2020 and Beyond AdHoc" group.

Docomo produced a White Paper [273] in a July 2014 outlining the need for data rates 100 times higher, latency of 1 millisecond and a 1,000-times increase in systems capacity while at the same time reducing energy consumption. Docomo expect a 100-fold increase in the number of simultaneously connected users compared to 4G LTE. To achieve this they are working on millimeter-wave band technology, which allows multi-beam multiplexing and massive multi-input-output (MIMO) technologies [274]. These operate in the 6 to 66 gigahertz frequencies. Rather than broadcasting signals from a base station in all directions, individual signals can be transferred between individual terminals and a base station as required. In a crowded hot spot a cluster of smaller antennas can be used to eliminate interference from nearby terminals which reduce data rates and make better use of signal power. Already Docomo and Ericsson have shown that multi-beam MIMO technology can transmit data with a cumulative 20-Gbps throughput with four mini base-stations, each equipped with 64 antenna elements. Two Ericsson 5G prototype terminals, located 9 meters and 3 meters respectively from the base station were each able to simultaneously download over 10 Gbps over a 15-GHz wireless band. The companies also showed that it was possible to transmit data at 10 Gbps over a distance of 70 meters from the base station and then at 9 Gbps over a distance of 120 meters.

6.6 Standards

The uptake of 5G depends upon standardisation to be in place, however, the roll out of 5G is expected to be gradual allowing equipment upgrades to occur before some of the key 5G standards are formalised in 2018 and 2019 [275]. Pre-standard "5G-ready" equipment using software defined network (SDN) technology will allow network operators and enterprise customers to move to upgrade to full 5G once standardisation is in place for spectrum allocation and licences are issued.

6.6.1 ITU

The International Telecommunications Union wants to bring together people along with things, data, applications, transport systems, and cities in a smart networked communications environment. Mobile data traffic across the globe grew 69 percent between 2013 and 2014, reaching 2.5 exabytes (over a billion billion bytes) per month, according to Cisco. Analysts expect data consumption to climb to 24.3 exabytes per month by 2019 which cannot be met by existing 4G LTE. The International Telecommunication Union (ITU)’s IMT-2020 Focus Group [276] has defined a 5G network blueprint for technology improvements taking into account 60 research proposals to address gaps in the 5G wire-line network infrastructure, such as software and high-level network architecture [277].

6.6.2 Joint Standardisation

In order to get joint agreement on technical fundamentals and 5G spectrum bands globally by 2018 NTT Docomo (Japan), KT and SK Telecom (South Korea), and Verizon(US) are forming the 5G Open Trial Specification Alliance with the aim of driving the technology forward and creating standards for network equipment makers to follow.

6.6.3 3GPP

3GPP standardization is progressing and speeding up towards 5G. At a RAN 5G Workshop in September 2015, 5G standardisation activities were initiated with first study items on new waveforms, channel modelling >6GHz, and Radio Access Network architecture.

6.6.4 IEEE 5G initiative

The IEEE 5G initiative, which targets the creation of a global meta-standard for 5G, is considering the requirements of the BRIC and low-income countries in Africa, Asia and South America to enable 5G applications in large rural, low populated areas.

6.7 Need for Regulation

The U.N.'s International Telecommunications Union is working on spectrum harmonization for 5G so that the same frequencies are used worldwide [278]. Global harmonization is important for networking equipment and device manufacturers who operate in an international market to keep prices low for potentially billions of mobile devices. Harmonization was not possible for 4G LTE and this has resulted in slower deployment in some parts of the world, particularly Europe. The US has a dominant lead in 4G LTE but the rest of the world is now concentrated on 5G. A problem with 5G is that multiple international bodies are involved in different aspects of 5G standardisation. Long-term spectrum planning is essential and an issue in the US is that valuable 5G spectrum is already allocated to departments and agencies of the federal government, however, much of it is unused or underutilised.

In many countries development depends on government funding but in the US innovation is driven by entrepreneurs. Putting in place the right policies is crucial to unlocking private investment for 5G technologies. It is estimated that network upgrades will cost $2 trillion [279]. There is a push for "permissionless innovation in 5G design" in the US but this has been challenged by "net neutrality" regulations adopted by the FCC which are the subject of a legal challenge [280] [281]. This may inhibit 5G experimentation.

7 Big Data

7.1 European Big Data Drivers and Policy Initiatives

The area of data is seen as vital to support one of Europe's 10 political priorities: the vision of a Digital Single Market (DSM)[282]. This strategy aims to open up digital opportunities for people and business and enhance Europe's position as a world leader in the digital economy. The DSM covers the free movement of persons, services and capital to allow individuals and businesses to seamlessly access and exercise online activities under conditions of fair competition. Key to this is to provide a high level of consumer and personal data protection, irrespective of nationality or place of residence.

Big Data has become increasingly important. It is used to describe large amounts of data being produced very quickly by a high number of diverse sources, either by people or sensors (e.g. gathering climate information, GPS signals, etc.) that needs to be processed at the same speed. The applications of Big Data cover many sectors, from healthcare, manufacturing, transport and energy. Key to the future knowledge economy is the ability to extract value at the different stages of the data value chain. The US currently leads in this area with big companies being at the centre of the data revolution. Within Europe the research and innovation funding for Big Data is currently considered insufficient with many smaller uncoordinated activities being performed. It is also more difficult to translate technology advances within Europe into business opportunities due to a complicated European legal environment and a lack of access to large datasets. This is particularly a problem for SMEs. The EC has thus identified a number of issues that need addressing:

- Lack of a "scale" in the EU research/ innovation
- Fragmented legal landscape
- Skills shortage
- Delays in the take-up of data technologies
- Lack of a supporting data "ecosystem"

In July 2014 the European Commission defined a new strategy on Big Data with the aim of supporting and accelerating the transition towards a data-driven economy in Europe [283]. The strategy has a number of goals to accelerate innovation create productivity growth, and increase European competitiveness in data within the global market to make Europe a key player. Over 150 research and innovation projects have been funded with over €50m EU funding in 2014 targeted at Big Data and over €89m in 2014-15 targeted at Big & open data. A key initiative is the setting up of the Big Data Public Private Partnership.

7.1.1 Open Data

Critical to maximising the benefits from Big Data is the ability to access and share data. Here there is a need for Open Data to allow authorised people from the same, or different, organisations to share information (EU Open Data policy framework) [284]. Through the use of shared data it is possible to develop a holistic view of a theme that is being addressed or gain new insights about areas. However, the sharing of data between agencies is difficult unless trust exist. Typically each department sharing data will have a separate set of Information Governance requirements which makes it difficult to combine data. Here there is a need for a common information governance regime with agreed common measures in place for data exchange. This requires three key elements:

- Semantics – the meaning of information
- Syntax – the format of information
- Data Quality – the confidence to re-use information

7.2 European Initiatives

7.2.1 Big Data Value Public-Private Partnership

Figure 57. Big Data Value Public-Private Partnership

The Big Data Value Public-Private Partnership [285] (See Figure 57) was set up in January 2015. This aims to strengthen the data value chain within Europe and allow it to play a role in the global market. In order to achieve this the European Commission has teamed up in a Public-Private Partnership with both large and SME industry, researchers and academia. The PPP cooperates in data-related research and innovation to support a data driven economy in Europe. A key aim is to build a community working on data in Europe. This is supported by the Big Data Value Association which includes data providers, data users, data analysts and research organisations. The association is a non-profit, industry-led organisation whose founding members include ATC, IT Innovation, IBM, SINTEF, University of Bologna (CINI), Polytechnical University of Madrid, NOKIA Solutions and Networks, THALES, University of Duisburg Essen, Siemens, SAP, Engineering, TIE Kinetix, ANSWARE, Software AG, Orange, Atos, INDRA, ITI, VTT, Fraunhofer, DERI, and the Technical University of Berlin.

7.2.2 Open Data for Smart Cities

There are two key projects in Europe considering the exploitation of open data for smart cities [286]. Coordinated by ESADE Business School, the Open Cities and Commons for Europe projects aim to enable open innovation in the public sector in seven European cities: Amsterdam, Barcelona, Berlin, Bologna, Helsinki, Paris and Rome.

7.2.2.1 Open Cities Project

The Open Cities project [287] enables participating cities throughout Europe to publish their data as Open Data. By doing so the project is encouraging the creation of web and mobile civic applications to enable better services, lower costs and improve transparency. Two Open Data Platforms have been created (one for static data and one for dynamic data). Around this data two Worldwide App Challenges have been organised. The Open Cities Open Data Platform [288] developed by Fraunhofer FOKUS can be easily customised to match an organization's specific requirements. The platform supports the entire Open Data lifecycle process, which includes identifying, publishing, discovering, enriching, and consuming data. Additionally, the Pan European Federation of Open Data Platforms has created the Open Cities data catalogue which is a federated repository of existing city open data catalogues. This has been used for the pan-European Open Data App Challenge. The platform provides a consolidated view on all of the open data available from the city portals of Amsterdam, Berlin, Barcelona, Helsinki and Paris.

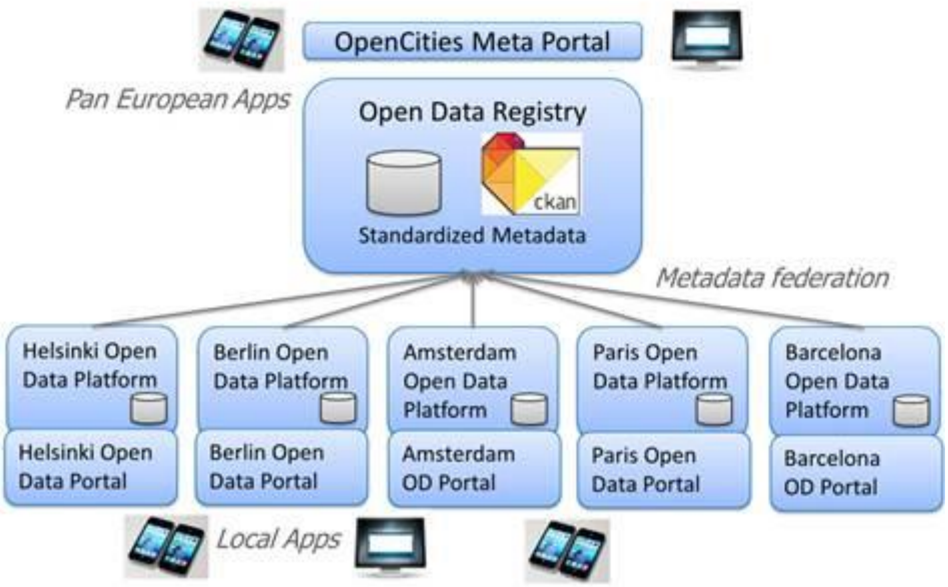


Figure 58. Open Cities Open Data Platform

The key benefit of the Open Cities data catalogue is that it provides easy access to searching, finding and browsing of data. This is useful for both apps developers and users. The Open Cities Open Data Platform, as shown in Figure 58, has been used as the basis for the Open Data Portal in Germany [289].

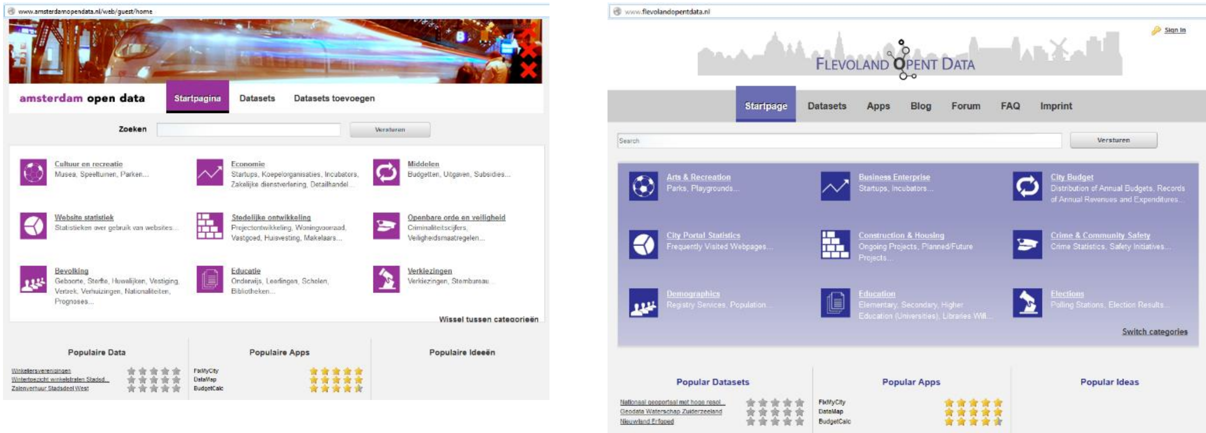


Figure 59. Open Data Amsterdam and Open Data Flevoland

The model has been already successfully "replicated" and implemented on-site in the city of Amsterdam [290] and in the province of Flevoland (See Figure 59).

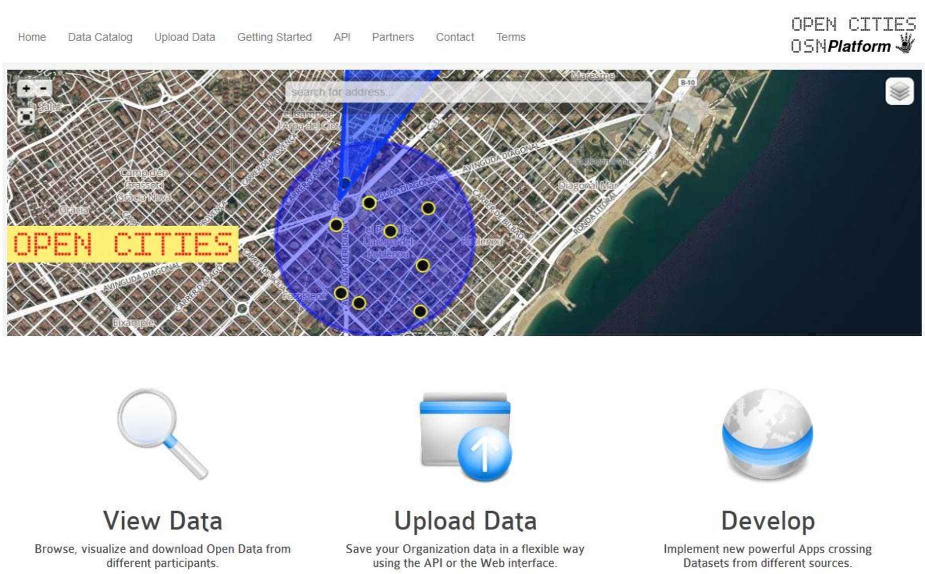


Figure 60. Open Sensor Network Platform (OSNP)

The Open Sensor Network Platform (OSNP) developed by Pompeu Fabra University (see Figure 60) offers a central point to publish and store data generated by sensors and dynamic services. This can be used for services related, for instance, to urban transport, tourism and demographics. The Consortium also runs an Open Cities App Challenge, inviting developers from all over the world to submit innovative ideas. Developers can turn their ideas into working apps through the "Hack at Home platform", which allows participants to present their ideas, get advice from mentors and form teams with designers, developers and coders to build apps for the participating cities. The Open Cities App Challenge has attracted more than 100 applications submitted from all over the world including apps for audio-based augmented-reality application for blind people, for providing real-time information on transportation and parking systems, for providing information on public transportation, bike rentals and traffic status. The aim of the challenge is to help Paris, Amsterdam, Barcelona, Berlin, Helsinki, Rome and Bologna to benefit from the talents of app creators and find solutions for managing tourism in cities.

7.2.2.2 Commons for Europe

The Commons for Europe Project [291] has three key aims to:

- Identify the needs of public administrations and citizens,
- Promote the creation of new applications that can provide innovative services, and
- Share the results openly among multiple European cities.

Solutions based on mobile and web applications that improve services, reduce costs and provide greater transparency are being developed. The team led by ESADE Business School [292] works with seven European cities to identify the types of new services that could benefit citizens and meet their needs through innovation. The Consortium has a team of technical experts in web and mobile applications that can offer services. The project intends to create an organisation called Code for Europe [293] similar to Code for America [294] to engage with promising young developers to provide mentoring and training. The aim is that any applications developed should be designed to work in any of the seven cities involved in the programme but, in addition, they will also be made available to any other European city.

The second key aim of the project is to promote knowledge and deployment of user driven Bottom-UP Broadband (BUB) networks in metropolitan and rural environments. This is being led by Guif.net [295] and the Universitat Pompeu Fabra who are driving creation of a pan-European network. The work is exploring new technologies such as Super-WiFi, bandwidth-sharing in fibre networks and sensor integration.

To avoid duplication of effort the Commons for Europe is developing a Code for Europe [293], a marketplace for civic innovation that features apps and digital services aimed at improving the lives of communities. Developers can add their apps to this resource with information on how they have been deployed and where to measure impact. World Bank sponsorship has been obtained to promote the Europe Commons repository in Latin and Central America.

7.2.2.3 Citadel on the Move

Citadel on the Move is a European Commission funded (CIP PSP) project [296] which aims to make it easier for citizens and application developers from across Europe to use Open Data to create innovative mobile applications. Citadel on the Move is addressing this by:

1. Defining strategies that make it easier for local government to release data in useable, interoperable formats;
2. Creating and providing templates that make it easier for developers and citizens to create mobile applications that can be potentially used and shared across Europe;
3. Pooling tools and resources into an Open Data Commons that facilitates access to data in different formats by shared templates and applications.

7.3 National Initiatives

7.3.1 Open Helsinki – Hack at Home programme

The City of Helsinki is looking for new ways to support developers who want to use open data in order to create digital services for their citizens. The Open Helsinki – Hack at Home programme [297] was launched on the 14 of June 2013 and encourages developers to create useful applications. The underlying themes of the programme are transparency of city decision-making and enabling better feedback to civil servants from citizens. Notably the Helsinki Region Infoshare service received the European Prize for Innovation in Public Administration. Hack at Home is an international concept, linking developers and organisations around the world. The collaboration of mentors, who give feedback and support in the different phases of the development process, and developers is at the very heart of the programme. Hack at Home also offers a forum to put together teams around ideas

7.3.2 UK

Data and digital are considered key to growth in the UK economy. In the UK a Public Data Group (PDG) was formed in 2011 bringing together 4 organisations (Companies House, Land Registry, Met Office and Ordnance Survey) that all concentrated on collection, management and distribution of vital data sets [298][299]. The aim of the group was to identify shared improvements, best practice and efficiencies across areas including surveying and IT. Work focused on data policy and a number of projects were run, e.g. the GeoVation challenge on Housing to use data to solve housing issues. The PDG Board met for the final time in April 2015 and the PDG was replaced by a Business Innovation and Skills Digital Culture, Services Platforms and Data Board bringing together senior officials and a wider family of organisations.

7.3.2.1 Open Data Institute

The Open Data Institute (ODI) [300] was officially launched at Shoreditch in December 2012 with the support of £2 million per year for five years from the Technology Strategy Board and $750,000 from the Omidyar Network. The Institute, founded by Sir Tim Berners-Lee and Prof Nigel Shadbolt, is an independent, non-profit, limited company. Its remit is to catalyse an open data culture that has economic, environmental and social benefits.

7.3.2.2 Data Governance

One of the main barriers to effective information sharing is the fact that different organisations collect information for different purposes and attach a different meaning or interpretation to it. The key to success is to rationalise Information Governance regimes across public services and address the semantics, or context, of information. To support this in the UK Sheffield City Council is developing an 'Information Governance Toolkit' for Local Government. The Local eGovernment Standards Body (LeGSB) is also creating a Public Service Concept Model (PSCM). This recognises that departments each have their own concept model that describes their own activities and outcomes but there are common concepts that are typically linked. A Smart Cities Concept Model, derived from the PSCM, would allow city organisations to share data by providing a simple neutral language to describe each data source, and the links between them. This approach could lead to a common agreed expression of the issues facing a city, such as: Congestion, Families, Skills, Ageing Population, Dementia, etc., and identify the different organisations and interventions necessary. Importantly, the information should not be stored in one place. Each organisation publishes their shared data over the web, and this is brought together (as linked data) to meet a particular need.

7.4 US Big Data Drivers and Policy Initiatives

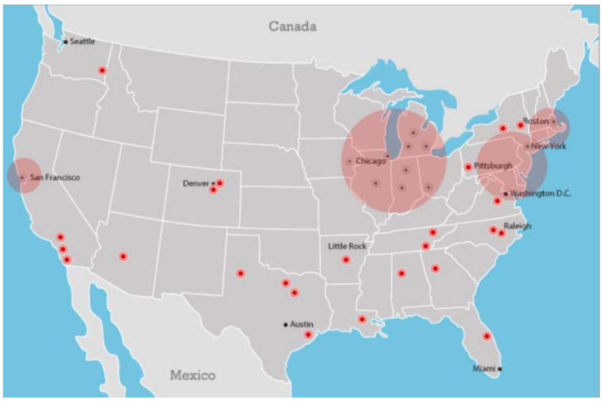


Figure 61. Map of US Big Data Research Activities

In the US Big Data has been a key theme since 2012 through the Big Data Research and Development Initiative. This was set up to support the ability to extract knowledge and insights from large and complex collections of digital data. Following commitment from central government, a number of agencies such as NSF, NIH, DARPA and the Department of Defence (DoD) launched their own Big Data Initiatives. Figure 61 shows a map of Big Data research across US universities.

7.4.1 Policy Issues in the US

As more initiatives were established it was clear that there were a number of policy issues that need to be tackled by coordinated policy measures. More specifically, the report "Report To The President Big Data And Privacy: A Technological Perspective", Executive Office of the President President's Council of Advisors on Science and Technology May 2014 [301], presents a number of policy issues on regulation and promotion of research capacity of RTOs, while the National Science Foundations (NSF), through its NITRD Big Data Senior Steering Group, has highlighted the need for formulating policies on enhancing Education and Workforce Development and establishing new ways of partnerships.

The Policy in the US focuses more on the actual uses of Big Data and less on its collection and analysis. The US wants to lead both in the international arena and at home. The policies and regulation do not promote technological solutions, rather they state intended outcomes. There is also an accent on policies to strengthen and stimulate US research in practical privacy-related technologies. Additionally, there is focus on aspects of social science that promote the successful application of technologies.

7.4.2 NSF Big Data Research Initiative

NSF through its Big Data Research Initiative [302] is developing new methods to derive knowledge from data; constructing new infrastructure to manage, curate and serve data to communities; and supporting new approaches for associated education and training. This includes actions on core techniques and technologies for advancing Big Data in science and engineering and Big Data solicitation, graduate education and training.

Core to NSF's strategy is the Cyberinfrastructure Framework for 21st Century Science and Engineering, or "CIF21" [303]. The aim of CIF21 is to foster the development and implementation of a national cyberinfrastructure for researchers in science and engineering to achieve a democratization of data. NSF announced new awards ($10 million each) under its CIF21 and Expeditions in Computing programmes, as well as awards to expand statistical approaches to address Big Data, support cyberinfrastructure, the geosciences and training. The aim is to support fundamental science and underlying infrastructure to enable the Big Data revolution. As an example a $10 million award under the Expeditions in Computing programme was given to the University of California, Berkeley to integrate algorithms, machines and people to turn data into knowledge and insight. The objective is to develop new scalable machine-learning algorithms and data management tools that can handle large-scale and heterogeneous datasets, novel data center-friendly programming models, and an improved computational infrastructure. Another example is the NSF geosciences programme called EarthCube, supported by the CIF21 framework, which is developing a community-guided cyberinfrastructure to integrate Big Data across geosciences. A key requirement is to integrate data from disparate locations and sources with eclectic structures and formats that has been stored as well as captured in real time.

NSF is also supporting proposals under a Big Data Solicitation in collaboration with the National Institutes of Health (NIH). This programme aims to extract and use knowledge from collections of large data sets in order to accelerate progress in science and engineering research. Specifically, it will fund research to develop and evaluate new algorithms, statistical methods, technologies, and tools for improved data collection and management, data analytics and e-science collaboration environments.

In the near term, NSF is providing opportunities and platforms for science research projects to develop the appropriate mechanisms, policies and governance structures to make data available within different research communities. In the longer term, the aim is to build a larger-scale national framework, for the sharing of data among disciplines and institutions. Considering the longer term NSF is supporting a focused research group that brings together statisticians and biologists to develop network models and automatic, scalable algorithms and tools to determine protein structures and biological pathways. At an educational level NSF is funding a research training group in Big Data that will provide training for undergraduates, graduates and postdoctoral fellows to use statistical, graphical and visualization techniques for complex data. In addition, cross-disciplinary efforts are being encouraged such as data citation to increase opportunities for the use and analysis of data sets; participation in an Ideas Lab to explore ways to use Big Data to enhance teaching and learning effectiveness; and the use of NSF's Integrative Graduate Education and Research Traineeship (IGERT) mechanism to educate and train researchers in data enabled science and engineering.

7.4.3 NIH BD2K Centers

BD2K funds research and training activities that support the use of Big Data to advance biomedical research and discovery [304]. This includes efforts in enhancing training, resource indexing, methods and tools development, and other data science-related areas. The BD2K Centers of Excellence programme has established 11 Centers of Excellence for Big Data Computing and one Center that is a collaborative project with the NIH Common Fund LINCS programme, called the LINCS-BD2K Perturbation Data Coordination and

Integration Center. The Centers are located all across the United States. They are large-scale projects aiming to develop new approaches, methods, software tools, and related resources. The Centers also provide training to advance Big Data science in the context of biomedical research. The 12 BD2K Centers function as a consortium and collaborate with one another, with the purpose of furthering the field of biomedical data science research. To harness the full potential of Big Data scientists must be able to readily find, cite, and access existing data and other digital objects, such as software. There is no existing infrastructure or incentive available for this which presents barriers to data use and sharing. This leads to duplication of effort and makes it difficult to see where there is sparse research coverage. Funding is thus being provided to address resource discovery, citation, and access. Training and Targeted Software Development awards are also being made to fund software and tools development to tackle data management, transformation, and analysis challenges in the biomedical research community.

7.4.4 DARPA

The Defense Advances Research Projects Agency (DARPA) is promoting the creation of open-source software tools that can help with the processing and analysis of Big Data, providing US$3m in funding to the software company Continuum Analytics. The company is using the open source Python programming language which is currently used by the oil and gas, physics and signal processing industries. The plan is to add support for large, multi-dimensional arrays and matrices and create visualization techniques for the interactive exploration of large multi-dimensional data sets. DARPA’s XDATA programme [305] is focused heavily on the warfighting environment, where a “virtual” net of sensors and communications systems offer levels of battlefield awareness. In times of battle, data usage can see extreme spikes and current Department of Defence systems cannot handle or analyse the information that results from this. There is a need to efficiently fuse, analyse and disseminate the massive volumes of data this network produces. The volume and characteristics of the data, and the range of applications for data analysis, require a fundamentally new approach to data science, analysis and incorporation into mission planning, on timelines consistent with operational tempo.

Notably DARPA will allow results produced by XDATA funding to be used by other US government agencies. The tools are seen as solid foundation for continued innovation in the rapid analysis and visual exploration of massive, interconnected data from heterogeneous sources. XDATA plans to release open-source software toolkits for the applied mathematics, data visualization and computer science communities to address challenges being raised by Big Data.

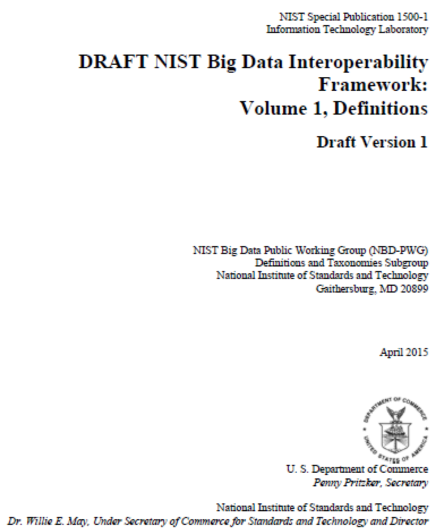
7.4.5 DoD

Big Data is major priority for agencies within the Department of Defense, with many opportunities for contractors working on intelligence gathering, analysis and cyber-security. Deltek forecasts that Defense spending on Big Data will rise steadily for the rest of the decade at a compound annual growth rate (CAGR) of 8.7%. Advanced analytics and technologies like distributed computing are fast becoming integral components of modern, networked weapons systems. This shift reflects not only the growing complexity of weapons but also of the command and control capabilities employed by the military. Faced with dwindling numbers of personnel, all branches of the DoD are turning to networked and unmanned weapons commanded and controlled from a distance. The Department of Defense's 2016 budget request includes $25 million more for Big Data-related research and development than 2015 and all of the military services are funding R&D efforts related to Big Data with a number of projects in the 2016 Defense Research, Development, Test, and Enhancement (RDT&E) budget.

There are also a number of large defence contracts targeting Big Data. The US Cyber Command and the General Services Administration has issued a request for information seeking support for the Cyber National Mission Force [306]. The RFI requests analysis capabilities to fuse "reports from multiple intelligence sources (HUMINT, SIGINT, IMINT, MASINT) to provide intelligence preparation of the battlespace, target development, and early warning of emerging threats." The Defense Information Systems Agency (DISA) [307] is also expected to release a request for proposals for new Joint Management System (JMS) software that will include advanced analytics capabilities. The JMS is critical to the secure functioning of DoD's Joint Regional Security Stacks. The new commercial software should have the ability to "harvest security insights from data that is not intuitively security-related." DISA is also looking for Big Data analytics to add to its Cyber-Security Advanced Analytics Cloud (CSAAC) which defends DoD networks where they connect to the Internet. Contractors must provide software with advanced analytical capabilities that is open source and commercial-off-the-shelf. Northrop Grumman was awarded a $74 million task order in March 2015 for operation of the Acropolis Big Data storage portion of the CSAAC.

Defense officials have also announced the establishment of a Defense Insider Threat Management and Analysis Center (DITMAC) to identify and mitigate the security challenges posed by insider threats. Developed in the aftermath of the 2013 shooting at the Washington Navy Yard it will utilise an array of predictive analytics that facilitate the identification of insider threats before they become a major hazard.

7.4.6 NIST Big Data Public Working Group (NBD-PWG)


NIST Special Publication 1500-1
Information Technology Laboratory

DRAFT NIST Big Data Interoperability Framework:
Volume 1, Definitions

Draft Version 1

NIST Big Data Public Working Group (NBD-PWG)
Definitions and Taxonomies Subgroup
National Institute of Standards and Technology
Gaithersburg, MD 20899

April 2015

U. S. Department of Commerce
Penny Pritzker, Secretary

National Institute of Standards and Technology
Dr. Willie E. May, Under Secretary of Commerce for Standards and Technology and Director

Figure 62. NIST Big Data Interoperability Framework

NIST is leading the development of a Big Data Technology Roadmap [308]. This roadmap will define and prioritise requirements for interoperability, portability, reusability, and extensibility for Big Data analytic techniques and technology infrastructure in order to support secure and effective adoption of Big Data (See Figure 62). To help develop the ideas in the Big Data Technology Roadmap, a community of interest has been formed from industry, academia, and government. The goal is to develop consensus on definitions, taxonomies, secure reference architectures, and the technology roadmap. The aim is to create vendor-neutral, technology and infrastructure agnostic deliverables that enable stakeholders to pick-and-choose the best analytics tools for their processing and visualization requirements on the most suitable computing platforms and clusters. At the same time data needs to flow between the stakeholders in a cohesive and secure manner. A number of deliverables have been defined covering a range of key areas: Big Data Definitions, Big Data Taxonomies, Big Data Requirements, Big Data Security and Privacy Requirements, Big Data Security and Privacy Reference Architectures, Big Data Reference Architectures, and a Big Data Technology Roadmap.

7.5 Rest of the World

7.5.1 Worldwide Open Data Readiness

Country	Rank	Readiness Sub-Index	Implementation Sub-Index	Impact Sub-Index	ODB Overall
United Kingdom	1	100.00	100.00	79.91	100.00
United States	2	95.26	86.67	100.00	93.38
Sweden	3	95.20	83.14	71.95	85.75
New Zealand	4	81.88	65.49	89.81	74.34
Norway	5	91.88	70.98	46.15	71.86
Denmark	5	83.54	70.20	55.73	71.78
Australia	7	87.88	64.71	51.10	67.68
Canada	8	79.11	63.92	51.59	65.87
Germany	9	74.50	63.14	53.81	65.01
France	10	79.39	64.31	39.07	63.92
Netherlands	10	85.82	67.06	21.42	63.86
Korea (Rep. of)	12	77.19	54.90	24.56	54.21
Iceland	13	62.99	52.94	26.45	51.01
Estonia	14	72.38	49.41	24.00	49.45
Finland	14	91.19	41.18	40.87	49.44
Japan	14	76.99	47.06	27.94	49.17
Spain	17	67.48	49.41	21.13	48.19
Austria	18	68.56	39.22	48.62	46.03
Israel	18	61.82	45.88	25.38	45.58
Italy	20	50.39	42.75	45.69	45.30
Russia	20	54.43	40.39	48.86	44.79
Switzerland	22	65.11	41.57	26.80	43.24
Czech Republic	22	61.83	40.00	35.38	43.18
Kenya	22	49.70	45.88	21.55	43.06
Mexico	25	49.10	45.49	8.37	40.30
Chile	25	65.70	30.22	18.27	40.11
Portugal	27	60.38	38.04	19.25	38.63
Brazil	28	66.03	32.16	27.87	36.83
Singapore	29	70.28	35.29	8.97	36.29
Ireland	29	61.61	32.55	23.92	35.76
Thailand	31	38.09	39.22	14.88	35.33
Argentina	31	40.08	30.47	17.29	35.00
Belgium	31	72.01	28.63	25.64	34.80
India	34	57.36	33.73	9.87	33.38

Figure 63. Open Data Barometer 2013 Global Report

The Open Data Barometer [309] published by the Open Data Institute UK and the World Wide Web Foundation is a measure of the prevalence and impact of open data initiatives around the world in 88 countries (See Figure 63). It analyses global trends, and also ranks countries and regions according to an index that considers: readiness to secure the benefits of Open Data; actual levels of implementation; and the impact of such initiatives, combining peer-reviewed expert survey data and secondary indicators. The Barometer ranks the UK as the most advanced country for open data readiness, implementation and impact, scoring above the USA (2nd), Sweden (3rd), New Zealand (4th), Denmark and Norway (joint 5th). The leading developing country is Kenya (21st), ranking higher than rich countries such as Ireland (29th) and Belgium (31st).

The index highlights a number of things. Firstly, Open Data is still in its infancy and many governments are still at the stage of exploring how providing open data can unlock value, stimulate innovation and increase transparency and accountability. The availability of truly open data, however, remains low with only around 10% of the surveyed countries providing published data in bulk machine-readable forms, and under open licenses. Thirty-one countries have at least one open dataset, and just over 50% of the datasets surveyed among the 11 top-ranked countries qualified as being “fully open”. This makes it difficult for users to access, process and work with government data. In particular, entrepreneurs face significant legal uncertainty over their rights to build businesses on top of government datasets. In general, leading countries in the ODB are investing in the creation of "National Data Infrastructures" to provide a foundation for public and private innovation and efficiency. Mid-ranking countries have put in place an open data portal and run competitions and events to catalyse the re-use of data, however, they have often failed to make key datasets available, failed to have strong "Right to Information laws" which prevents citizens from using open data, or have weak or missing Data Protection Laws. Low-ranking countries have not yet started to engage with open data. Many developing countries lack basic foundations such as well-managed and digitised government datasets.

7.6 Need for Regulations

7.6.1 European Data Protection Directive

The European Data Protection Directive (Directive 95/46/EC) [310] protects an individual with respect to processing of personal data and on the free movement of such data. This EU directive which regulates the processing of personal data was adopted in 1995. It is an important part of the European approach to privacy and human rights law. A new draft General Data Protection Regulation was announced by Europe on 25 January 2012 [311] which replaced the Data Protection Directive. In particular the right to privacy is a highly developed area of law in Europe. All the member states of the EU are also signatories of the European Convention on Human Rights (ECHR). Article 8 of the ECHR provides a right to respect "private and family life, his home and his correspondence". The European Court of Human Rights has given this article a very broad interpretation in its jurisprudence. In 1980, in an effort to create a comprehensive data protection system throughout Europe, the Organisation for Economic Cooperation and Development (OECD) issued "Recommendations of the Council Concerning Guidelines Governing the Protection of Privacy and Trans-Border Flows of Personal Data" [312]. This sets out seven key principles governing protection of personal data were:

1. Notice—data subjects should be given notice when their data is being collected;
2. Purpose—data should only be used for the purpose stated and not for any other purposes;
3. Consent—data should not be disclosed without the data subject's consent;
4. Security—collected data should be kept secure from any potential abuses;
5. Disclosure—data subjects should be informed as to who is collecting their data;
6. Access—data subjects should be allowed to access their data and make corrections to any inaccurate data; and
7. Accountability—data subjects should have a method available to them to hold data collectors accountable for not following the above principles.

Although these guidelines set out a number of key principles for Europe they were not binding and data privacy laws still vary widely across Europe. The US endorsed the OECD recommendations but did not implement them. In 1981 the Convention for the Protection of Individuals with regards to Automatic Processing of Personal Data [313] was negotiated within the Council of Europe. This convention obliges the signatories to enact legislation concerning the automatic processing of personal data. This states that personal data should not be processed at all, except when certain conditions are met with respect to transparency, legitimate purpose and proportionality. The EC also realised that diverging data protection legislation within different EU member states impeded the free flow of data within the EU which resulted in the Data Protection Directive being proposed.

7.6.2 Safe Harbour

The international "Safe Harbour Privacy Principles" have been defined with the aim of enabling some US companies to comply with privacy laws that protect European Union and Swiss citizens [314]. According to the Safe Harbour principles US companies who store European customer data may self-certify that they adhere to 7 key principles that comply with the EU Data Protection Directive and with Swiss requirements. This has been jointly developed by the US Department of Commerce, the European Union and the Federal Data Protection and Information Commissioner of Switzerland. The European Commission came to the conclusion in 2000 that the United States' principles complied with the EU Directive but this was ruled as being invalid in October 2015 by the European Court of Justice when a customer complained that his Facebook data was insufficiently protected. A new framework was agreed for transatlantic data flows on 2nd February 2016, known as the "EU-US Privacy Shield" with the aim of meeting the requirements set out by the European Court of Justice. The new arrangement has stronger obligations on US companies to protect the personal data of Europeans and this is backed up by stronger monitoring and enforcement by the U.S. Department of Commerce and Federal Trade Commission. In particular, the new arrangement includes commitments by the US that public authorities can only gain access to personal data transferred subject to clear conditions, limitations and oversight, preventing generalised access. Europeans will also be able to raise an enquiry or complaint with a new Ombudsperson.

The Commission promised to deliver the full text of the Privacy Shield agreement [315] by the end of February 2016. This was done and in March 2016, the authorities met to decide if the "shield" is strong enough. Here it was highlighted that the UK, France and Hungary might not meet the ECJ's Safe Harbour test. Notably several countries in Europe, e.g. France, Germany, Poland, the UK and the Netherlands permit certain types of surveillance that are not targeted at identified suspected individuals. Here it is possible to apply 'keywords' or 'selectors' to large communications data flows crossing their territory and also intercept external communications that are not targeted at specific individuals. This has been the subject of recent court cases in the UK where it is possible for communications received via submarine cables to be intercepted. In France, a new law passed in 2015 allows spies to use International Mobile Subscriber Identity catchers to intercept telephone data, access emails and online communications of anyone suspected of being linked to terrorism with little or no judicial oversight. There have also been other cases with respect to privacy. For instance the European Court of Human Rights found that Hungary violated Article 8 of the Convention on Human Rights [315] – the right to respect for private and family life was contravened by a law that allows police to carry out secret intelligence gathering on the grounds of national security, which can search and record private electronic communications without consent and without any judicial oversight. In other European countries the surveillance framework is more complex as there are a number of different overlapping laws with varying checks and balances. For instance, in Germany a parliamentary control panel oversees strategic telecommunications surveillance carried out by the Federal Intelligence Service (BND).

A key problem is that while it is possible for lawyers and academics to argue the validity of national laws when it comes to meeting the privacy shield there is no power when it comes to national security.

Google, Facebook and Amazon are keen for EU data regulators to define in specific terms what Europe's new privacy rules demand. As the privacy shield is still under debate for business the safe option at present is to keep European data in Europe. 4500 US companies relied on the old Safe Harbour agreement for legal cover which suddenly became invalid [315]. Currently only 27 % of cloud services provide Europe-only data storage. This has actually increased from 14 % in June 2015 according to a survey of 16,000 cloud services by Skyhigh Networks. Companies are looking at moving their data centres to Europe and particularly Germany where there are some of the strictest data privacy laws. A challenge is that the storage, processing and personnel must also all be local. This presents problems as although some companies such as Adobe already has European data centres, its cloud services may still require transfers to the US to provide some features. It may also be necessary for support personnel to access data stored in Europe from the US (or other countries) which requires the rules on data transfer outside the EU to be met.

Encryption is thought to be a way forward. For instance ID data can be encrypted before it enters the cloud with the data owner keeping the encryption keys. This gets around Safe Harbour and Privacy Shield laws but only 1% of cloud companies offer this as it is expensive. Self-encryption is possible but this often prevents the data being processed by needed cloud services.

7.6.3 US 14th Amendment of the Constitution

The US has no single data protection law comparable to the EU's Data Protection Directive. In the US privacy legislation has developed in an *ad hoc* basis when required by certain sectors and circumstances. Fundamental within the US is “The Fourteenth Amendment (Amendment XIV)” which was adopted in the United States Constitution on July 9, 1868 [316]. The amendment addresses citizenship rights and equal protection of the laws, and was proposed in response to issues related to former slaves following the American Civil War. The first section of The Fourteenth Amendment is one of the most litigated parts of the Constitution and has been used as the basis or a number of landmark decisions, e.g. such as Roe vs. Wade (1973) regarding abortion, Bush vs. Gore (2000) regarding the 2000 presidential election, and Obergefell vs. Hodges (2015) regarding same-sex marriage. Critically the amendment limits the actions of all state and local officials, including those acting on behalf of officials.

The right to privacy or the “right to be left alone” is a key area within the US. While not explicitly stated in the U.S. Constitution, some of the amendments provide a degree of protection. Privacy is most often protected by statutory law in the US, e.g. the Health Information Portability and Accountability Act (HIPAA) protects a person's health information, and the Federal Trade Commission (FTC) enforces the right to privacy in various privacy policies and privacy statements.

There is a challenge, however, when there is a need to balance privacy against the needs of public safety and improving the quality of life, e.g. seat-belt laws and motorcycle helmet requirements. Most Americans accept that government surveillance and collecting of personal information is necessary. The right to privacy often relates to the right to personal autonomy where an individual has the right to choose whether or not to engage in certain acts or have certain experiences. Several amendments to the U.S. Constitution have been used in varying degrees of success in determining a right to personal autonomy:

- The First Amendment protects the privacy of beliefs
- The Third Amendment protects the privacy of the home against the use of it for housing soldiers
- The Fourth Amendment protects privacy against unreasonable searches
- The Fifth Amendment protects against self-incrimination, which in turn protects the privacy of personal information
- The Ninth Amendment says that the "enumeration in the Constitution of certain rights shall not be construed to deny or disparage other rights retained by the people." This has been interpreted as justification for broadly reading the Bill of Rights to protect privacy in ways not specifically provided in the first eight amendments.

However, the right to privacy is most often cited in the Due Process Clause of the 14th Amendment, which states:

> *No state shall make or enforce any law which shall abridge the privileges or immunities of citizens of the United States; nor shall any state deprive any person of life, liberty, or property, without due process of law; nor deny to any person within its jurisdiction the equal protection of the laws.*

However, the protections have been narrowly defined and are usually interpreted as only applying to family, marriage, motherhood, procreation and child rearing. The controversial *Roe v. Wade* case in 1972 case established the right to privacy as fundamental, and required that any governmental infringement of that right had to be justified by a compelling state interest.

In the US a person has the right to determine what sort of information about them is collected and also how that information is to be used. In the marketplace this is enforced by laws intended to prevent deceptive practices and unfair competition. The Privacy Act of 1974 [317] prevents unauthorised disclosure of personal information held by the federal government. A person has the right to review their own personal information, ask for corrections and be informed of any disclosures. This has also been imposed upon financial institutions in the Financial Monetization Act (1999) which requires financial institutions to provide their customers with an explanation of what kind of information is being collected and how it is being used. Safeguards are also required to protect customer information, e.g. the Fair Credit Reporting Act, protects personal financial information collected by credit reporting agencies. The act puts limits on who can access the information and requires agencies to have simple processes by which consumers can get their information, review it and make corrections.

Online privacy is also important in the US and Internet users can protect their privacy by taking actions that prevent the collection of information, for instance to not allow tracking cookies. Browsers and social media platforms, e.g. Facebook and Twitter, allow user selected privacy settings, from sharing everything to only sharing with friends. At a minimum level this can be only a name, gender and profile picture and increasingly citizens are aware that it is necessary to protect personally identifiable information to prevent identity theft.

Also within the US the Children's Online Privacy Protection Act (COPPA) [318] enforces a parent's right to control what information websites collect about their children. In particular websites that target children younger than 13 or knowingly collect information from children must post information on their privacy policies and also get parental consent before collecting information from children. Parents can thus decide how such information can be collected.

As well as a right to privacy there is also a right to publicity. Here there is a right to control the use of his or her identity for commercial promotion. Unauthorised use of someone’s name or likeness is recognised as an invasion of privacy. This is classed into 4 areas: intrusion, appropriation of name or likeness, unreasonable publicity and false light. For instance, if a company falsely uses a person's photo in an advert claiming that the person endorses a product, the person can file a lawsuit claiming misappropriation.

A challenge is that the Supreme Court in the US approaches the right to privacy and personal autonomy on a case-by-case basis. Notably public opinion is constantly changing regarding relationships and activities. The boundaries of personal privacy are also changing due to social media and a move towards "sharing." As a consequence the definition of the “right to privacy” is constantly changing.

7.7 Standards

7.7.1 ISO/IEC JTC 1 Study Group on Big Data (BD-SG)

The ISO/IEC Joint Technical Committee (JTC) 1 on Information Technology has set up a Working Group (WG) focused on standardization for Big Data. The American National Standards Institute (ANSI) holds the secretariat to JTC 1. The objective is to identify standardization gaps, develop foundational standards for Big Data, develop and maintain liaisons with all relevant JTC 1 entities and raise awareness of standardisation efforts. A Study

Group has been mapping the existing landscape for key technologies and relevant standards/models/studies /use cases and scenarios for Big Data from JTC 1, ISO, IEC and other standards setting organizations. It has also identified key terms and definitions commonly used in the area of Big Data. The current status of Big Data standardization considering market requirements, standards gaps, and standardization priorities have been identified and recommendations have been made in 2014 [319].

7.7.2 IEEE Standards Association

The IEEE Standards Association introduced a number of standards related to Big Data applications enabled by the Internet of Things and a specific standard is under development [320]. This standard "IEEE Standard for an Architectural Framework for the Internet of Things (IoT)" defines the relationships between devices used in industries, including transportation and health care. It also provides a blueprint for data privacy, protection, safety, and security, as well as a means to document and mitigate architecture divergence.

7.7.3 ITU

The International Telecommunications Union (ITU) created its first standards for Big Data services, entitled 'Recommendation ITU-T Y.3600 "Big Data - cloud computing based requirements and capabilities” in 2015 [321]. Recommendation Y.3600 provides requirements, capabilities and use cases of cloud computing based Big Data as well as its system context.

.

8 IoT/CPS

8.1 European IoT/CPS Drivers and Policy Initiatives

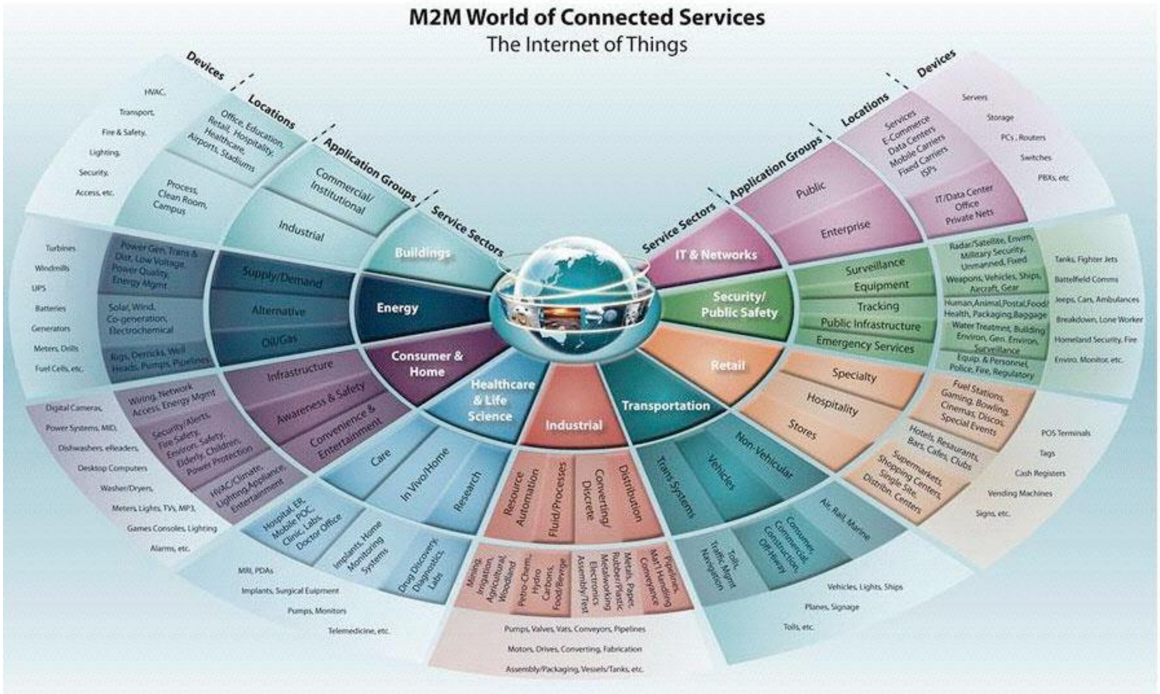


Figure 64. M2M World of Connected Services

Within Europe Support for development and integration of Cyber-Physical Systems and the Internet of Things is seen as essential for the future. As the embedded world meets the Internet world there will be an increasing number of interacting systems with strong connectivity utilised in both society and in industry (See Figure 64). Connectivity between embedded systems and computing devices is predicted to grow massively over the coming years. Gartner [322] for instance, estimates that there will be 26 billion connected devices (excluding PCs, tablets and smartphones) by 2020 world-wide, and even higher predictions of 40-50 billion devices are being made by other analyst companies. This equates to a global market value of $1.9 trillion, of which 80% is expected to come from services.

Europe is a world leader in the area of time-critical and safety-critical systems and to maintain this position there is a need to be able to design, develop and deploy highly distributed and connected digital technologies [323]. Underlying this is a need for the development and introduction of platforms for CPS deployment. This is seen as key to the future but only through building a supporting ecosystem of developers and users can a platform flourish and become successful. Europe has a strong position in ICT market with an ecosystem of world leading suppliers and systems integrators. The embedded systems industry alone creates 50,000 new jobs every year and Europe accounts for 34% of world production of embedded systems with particular strengths in the automotive sector, aerospace and health.

CPS/IoT/digitalisation is expected to change our everyday lives and open up new business opportunities with opportunities to provide efficient, environmentally friendly, autonomous and safe mobility in the automotive, aeronautics, rail, maritime and logistics sectors; greater efficiency in management and operations for process automation, manufacturing, conventional/renewable power plants, energy conversion, smart grids and smart metering; greater benefits to citizens via smart, safe and secure cities, energy efficient buildings and green infrastructure (traffic management, lighting, water and waste management); and smart devices and services for smart home functionality, home monitoring, health services and assisted living.

To support this European Commissioner Gunther Oettinger in his speech on “A Digital Single Market Strategy”, highlights the need for Industrial Leadership in the Digital Economy. The second key pillar of this strategy is to create leadership in platforms for digital industry with the objective to “ensure the availability of state-of-the-art open and interoperable platforms that any business can use to make its products, processes or services ready for the digital age”. The development of such platforms requires collaboration between actors across value chains, including users and the supply industry so it is necessary to bring these together. To achieve this the ECSEL Joint Technology Initiative and PPPs in Factories of the Future, 5G and Big Data have been set up and it is planned to launch at least 5 large-scale platform projects per year until 2018. Investment in platform-building in Horizon 2020 is expected to reach more than €800 million in the next five years with matching investment from industry and government of €3 billion until 2020. To build the Digital Single Market it is also necessary to address the skills gap and legal issues. Collaboration and consensus building on standards and platforms for strategic positioning of European industry is required as it is essential to have common standards and interoperable solutions throughout the products and services life cycles.

Within the European Union the concept of “Smart Everything Everywhere” is very much a key concept for the future. The majority of IoT research and development to date has focused on sensors and on providing connectivity, whereas the real value to users and society is from using the information provided by the sensors and networks in a smart fashion (and in connecting sensing to actuation to create a CPS). Connectivity from the Internet of Things is thus seen as an enabling technology for Cyber-Physical Systems that close the loop from sensors to actually influence users and physical systems. The enormous potential of these technologies has been recognised by the European Union, as CPS and IoT are key pillars of the Europe 2020 initiative Digital Agenda for Europe [324] and of other research and innovation programmes, e.g. the ECSEL Joint Undertaking, EUREKA/ITEA, and the ARTEMIS Industry Association.

Cyber-Physical Systems are an important area for Europe with a 410B€ market, 4 million associated jobs worldwide of which one quarter are in Europe, contributing both to the employment and to the quality of life and the industrial competitiveness across all sectors.

A major initiative launched in April 2016 is the Digitising European Industry initiative [325]. This aims to link national initiatives for the digitisation of industry and related services and to boost investment through strategic partnerships and networks. Although many areas within Europe have embraced the take up digital technologies and processes some sectors are lagging behind such as construction, agro-food, textiles and steel. SMEs are particularly lagging behind in their digital transformation. It is estimated that digitisation of products and services will add more than €110 billion of revenue for industry per year in Europe in the next five years. To support this several EU Member States have launched strategies to support the digitisation of industry, however, the aim of the Commission is to coordinate activities across Europe to avoid fragmentation. Key areas being addressed are standards for 5G, cloud computing, Internet of Things, data technologies and cyber-security. The Commission will also set up a European cloud to give Europe's 1.7 million researchers and 70 million science and technology professionals a virtual environment to store, manage, analyse and re-use a big amount of research data. The Commission intends to:

- help coordinate national and regional initiatives on digitising industry
- focus investments in EU's public-private partnerships
- invest €500 million in a pan-EU network of digital innovation hubs (centres of excellence in technology) where businesses can obtain advice and test digital innovations.
- set up large-scale pilot projects to strengthen Internet of Things, advanced manufacturing and technologies in smart cities and homes, connected cars or mobile health services.
- adopt future-proof legislation that will support the free flow of data and clarify ownership of data generated by sensors and smart devices. The Commission will also review rules on safety and liability of autonomous systems.
- present an EU skills agenda that will help give people the skills needed for jobs in the digital age.

It is expected that €50 billion of public and private investments will be mobilised in support of the digitisation of industry. In order to create critical mass the Commission has an approach of “clustering” projects in key areas. In the following sections key clusters and projects are highlighted in the areas of IoT and CPS.

8.2 IOT Initiatives in Europe

8.2.1 IERC European Research Cluster on the Internet of Things

The IERC (IoT European Research Cluster) [326] is bringing together EU-funded projects with the aim of defining a common vision for IoT technology, identifying research challenges, and coordinating and encouraging the convergence of ongoing work. The cluster includes over 40 European projects including CLOUT, VITAL, SOCIOTAL, RERUM, COSMOS, CITY PULSE, ALMANAC, SMARTIE, SMART-ACTION, FITMAN, ASPIRE, CASCADAS, CONFIDENCE, CuteLoop, DACAR, EPoSS, EU-IFM, EURIDICE, GRIFS, HYDRA, IMS2020, Indisputable Key, iSURF, LEAPFROG, PEARS Feasibility, PrimeLife, RACE networkRFID, SMART, StoLPaN, SToP, TraSer, WALTER, IOT-A, INTREPID, IOT@Work, ELLIOT, SPRINT, NEFFICS, IOT-I and CASAGRAS2. Communication between these projects is seen as essential to create a competitive industry and to provide secure, safe and privacy preserving deployment of IoT. Additionally, the IERC also links to Member States’ initiatives and engages with policy activities such as BRIDGE, AITPL, AMI-4-SME, CE-RFID, CoBIS, Dynamite, PRIME, PROMISE and SMMART, and cooperates with other large initiatives such as FIA, 5G, ARTEMIS-IA, AENEAS, EPoSS and the ECSEL JU.

Although the IERC has a European aim to enhance Europe's competitiveness and to drive the development of an information based economy and society it also has a global dimension facilitating knowledge sharing at the global, industrial and organisational level to encourage and exchange best practices and new business models that are emerging in different parts of the world. The main objectives of the IERC are to:

- Establish a cooperation platform and develop a research vision for IoT activities in Europe and become a major entry and contact point for IoT research in the world.
- Define an international strategy for cooperation in the area of IoT research and innovation and have an overview of the research and innovation priorities at the global level.
- Coordinate the cooperation activities with other EC Clusters and ICT projects.
- Coordinate and align the SRIA agenda at the European level with the developments at the global level.
- Organise debates/workshops leading to a better understanding of IoT and Future Internet, 5G, cloud technology, and adoption.

8.2.2 AIOTI

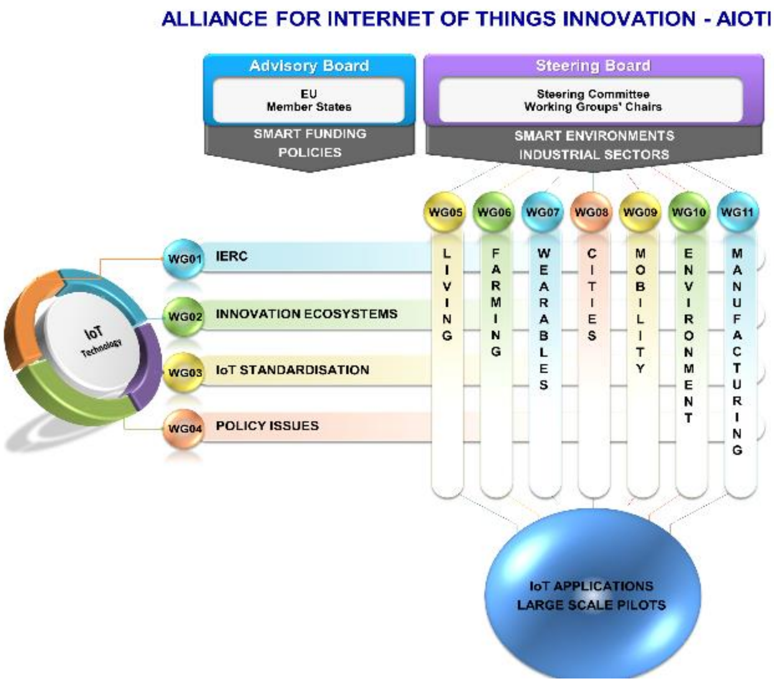


Figure 65. AIOTI

The Alliance for the Internet of Things (AIOTI) [327] was launched by the European Commission with key IoT players with the aim of creating a European IoT ecosystem that can promote dialogue and interaction to give the EU a lead in the technology. The AIOTI is helping the European Commission prepare strategy for future IoT research (See Figure 65) as well as providing input to innovation and standardisation policies. In particular, it has been providing input to the design of IoT Large Scale Pilots to be funded under H2020.

8.2.3 H2020 Pilot Projects

The European Commission call with €100 million on Internet of Things Large Scale Pilots [328] is aimed at promoting IoT take up in Europe and development of open technologies and platforms to support IoT ecosystems. The Large Scale Pilots are goal driven with the aim of using IoT approaches for real-life industrial/societal challenges. The areas include smart living environments for ageing well, smart farming and food security, wearables for smart ecosystems, reference zones in EU cities and autonomous vehicles in a connected environment. The Large Scale Pilots will involve stakeholders from both the supply and demand side and contain all the technology development, testing, integration and innovation activities for use, application and deployment of IoT. Coordination and support actions are also being funded to encourage cooperation and support cross-fertilisation between pilots and use cases. The pilot areas are:

- Pilot 1: Smart living environments for ageing well (EU contr. up to €20 million)
- Pilot 2: Smart Farming and Food Security (EU contr. up to €30 million)

- Pilot 3: Wearables for smart ecosystems (EU contr. up to €15 million)
- Pilot 4: Reference zones in EU cities (EU contr. up to €15 million)
- Pilot 5: Autonomous vehicles in a connected environment (EU contr. up to €20 million)

A further call will be made in 2017 on sophisticated platform architectures for smart objects, embedded intelligence, and smart networks. International joint IoT calls are also being supported with Japan, South Korea, China and Brazil.

8.2.4 BUTLER

Under the EU FP7 call the BUTLER project (uBiquitous, secUre inTernet-of-things with Location and contEx-awaReness) [329] was funded [€14.9 million] to develop secure and smart life assistant IoT applications using a context and location aware, pervasive information system. BUTLER is now finished and BUTLER components are available on the Open Platform Portal [330]**.** BUTLER emphasised pervasiveness**,** context-awareness and security for IoT and developed new technologies to form a “bundle” of applications, platform features and services. This included improving and creating technologies to implement secure, pervasive and context-aware IoT for different scenarios, e.g. Home, Office, Transportation, Health, etc. A new flexible smartDevice-centric network architecture was created where platforms (devices) function according to three well-defined categories**:** smartObject (sensors, actuators, gateways), smartMobile (user’s personal device) and smartServers (providers of contents and services), interconnected over IPv6. Several field trials were also performed.

8.2.5 FIWARE

FIWARE [331] is an EU initiative to create a truly open, public and royalty-free architecture and set of open specifications that will allow developers, service providers, enterprises and other organizations develop products. A key aim is to provide an infrastructure to support cost-effective creation and delivery of digital services. These need to provide a high quality of service with guaranteed security. A set of open APIs are being provided to developers to foster innovation and entrepreneurship. FIWARE is seen as a foundation for the Future Internet, cultivating a sustainable ecosystem for both service providers delivering new applications and solutions meeting the requirements of established and emerging use areas, and end users/consumers participating in content and service consumption/creation. The project is developing 16 Future Internet Accelerators including applications on Smart Cities, E-Health, Transport, Energy and Environment, Agrifood, Media and Content, Manufacturing and Logistics, Social and Learning.

8.3 European Initiatives in CPS

8.3.1 ECSEL Joint Undertaking

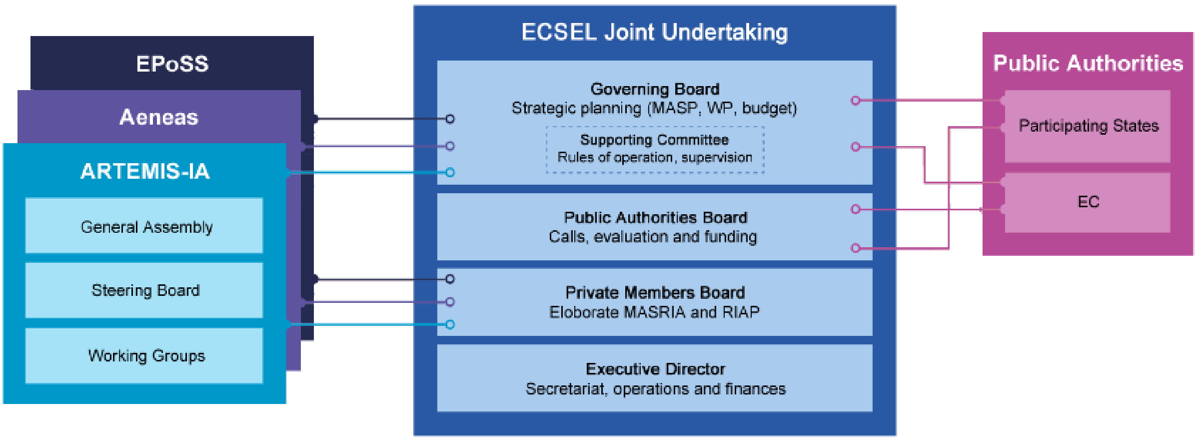


Figure 66. Overview of ECSEL Undertaking

The ECSEL-JU (Electronic Components and Systems for European Leadership) programme [332] was created from a merger of ARTEMIS-JU and the ENIAC-JU in June 2014 and will finish in 2024. ECSEL has coverage from industry in a number of areas including micro-/nanoelectronics, embedded and Cyber-Physical Systems and smart systems as shown in Figure 66. Within the programme projects are funded in several application areas and in key enabling technologies as shown in Figure 67.

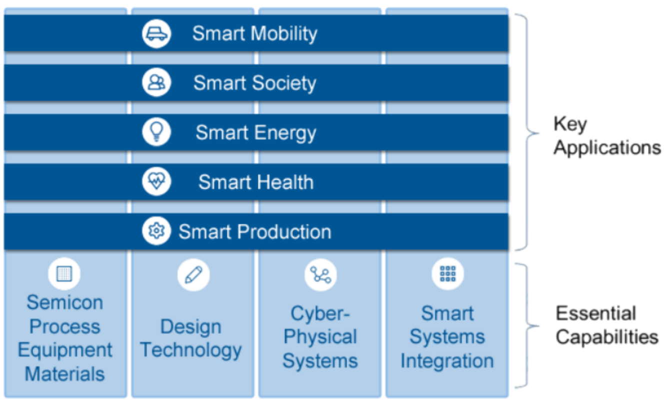


Figure 67. ECSEL Applications and Essential Capabilities

The strategy of ECSEL is decided by a Governing Board which comprises the ARTEMIS Industry Association, AENEAS and EPoSS, participating states and the European Commission. ECSEL makes its own calls to fund R&I projects via the Public Authorities Board. Call topics are agreed by participating states, associated countries and the European Commission.

8.3.2 ARTEMIS-IA

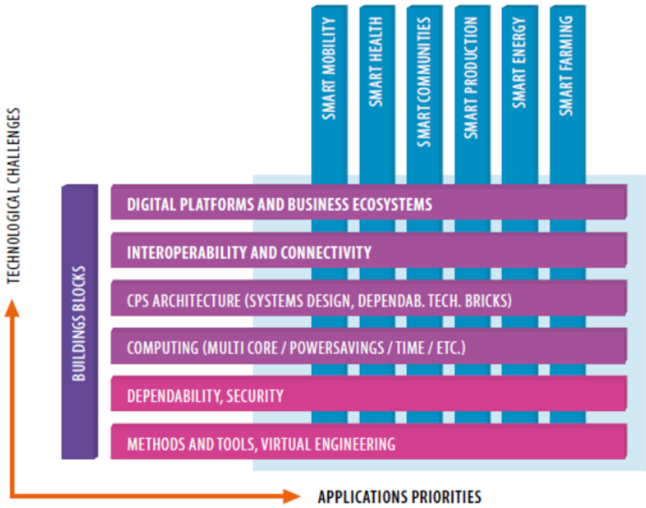


Figure 68. ARTEMIS Strategic Roadmap

The ARTEMIS Industry Association (Advanced Research and Technology for Embedded Intelligence and Systems) [333] is an association of European actors in Embedded & Cyber-Physical Systems. ARTEMIS represents its members (industry, SMEs, universities and research institutes) coordinating strategy and promoting R&I interests to the European Commission and the Public Authorities of the participating states. The Industry Association follows on from the ARTEMIS European Technology Platform and maintains responsibility for the ARTEMIS Strategic Research Agenda (SRA) on Embedded & Cyber-Physical Systems (See Figure 68). There are more than 180 members and associates from all over Europe with a wide range of backgrounds and disciplines being represented.

8.3.3 CRYSTAL - CRitical sYSTem engineering AcceLeration

Funded by the former ARTEMIS Joint Undertaking there are still ongoing projects. The CRYSTAL project [334] is developing an Interoperability Specification (IOS) and a Reference Technology Platform (RTP) as a European standard for safety-critical systems. The project has a budget of €82 million with 71 partners from 10 different European countries including OEMs, suppliers, tool vendors and academia. Driven by industry, CRYSTAL aims to provide mature, ready-to-use integrated tool chains with TRL of 7. A loose coupling between tools is being used to enable sharing and interlinking of data via standardised and open Web technologies. A key aim is to provide common interoperability across various life cycle domains. Real-world industrial use cases from the automotive, aerospace, rail and health sectors are being used as a focus for the work. This builds upon previous successful projects like CEASAR, SAFE, iFEST and MBAT.

8.3.4 EMC2 Embedded Multi-Core Systems for Mixed Criticality Applications in Dynamic and Changeable Real-time Environments

EMC² [335] is another ARTEMIS Joint Undertaking project of note that is an Innovation Pilot Programme on computing platforms for embedded systems. The objective of EMC² is to enable the use of multi-core technology across several embedded systems domains. There are 6 Technology Work Packages and a number of Living Labs in the Automotive, Aerospace, Space, Shipping, Railway and Logistics domains. The aim is to allow cost efficient integration of different applications with different levels of safety and security on a single computing platform in an open context. EMC² is addressing dynamic adaptability in open systems, handling of mixed-criticality applications under real-time conditions, scalability and flexibility, full-scale deployment and management of integrated tool chains, through the entire lifecycle. The project has 99 industry and research partners from 19 European countries with an effort of around 800 person years and a total budget of about €100 million.

8.3.5 I4MS and Competence Centres

Figure 69. I4MS

The EC I4MS initiative (ICT Innovation for Manufacturing SMEs) was launched in 2013 (See Figure 69) with a budget of €77 million [336]. The aim of the initiative is to help SMEs and mid-caps in the manufacturing sector by providing access to competences that can help in assessing, planning and mastering digital transformation and in providing access to innovation networks and best practice examples. Financial support is also directly provided for digital transformation. Underlying this is the idea to foster collaboration across manufacturing value chains through the help of the competence centres and innovation hubs (HPC centres, universities, application oriented research organisations) across Europe. Short duration experiments are funded to transfer know-how and technology from the innovation hubs to SMEs and mid-caps bridging the competence gap and providing financial means to adopt leading edge technology that can be used to bring innovative new products and services to market. Here cross-border experiments are particularly supported with an intention to broaden the field of the application and open up new markets. Participating competence centres benefit as they extend their research oriented activities with industrial projects.

8.3.6 SmartAnythingEverywhere

Figure 70. Smart Everything Everywhere

The Smart Everything Everywhere (SAE) initiative [337] is combining efforts from a number of initiatives (See Figure 70). €25 million of funding is being used to support around 100 experiments with the aim of involving more than 200 SMEs and midcaps in the field of Cyber-Physical Systems (CPS), Internet of Things (IoT) and Smart Systems Integration (SSI). Open calls are made from 4 different initiatives within SAE.

- EuroCPS - A network of design centres boosting and initiating synergies between SMEs, major CPS-platforms and competency providers to capture the emerging markets of IoT products. 30 SME led experiments have been initiated.
- CPSeLabs – A CPS engineering infrastructure, knowledge and tools for realising novel CPS-based products and services. The CPSELabs marketplace provides an open forum for sharing platforms, architectures and SW tools for the engineering of dependable and trustworthy CPS. This innovation initiative funds focused 12-18 month experiments with 3-6 partners.
- Gateone – Is an innovation service for European "smartisation" by SMEs with a focus on bioelectronics technologies. 50 small scale experiments have been funded to deliver innovation concept demonstrators with SMEs engaged in the testing phase.
- Smarter–SI – This initiative provides smart access to manufacturing for systems integration. It utilises a Community Foundry Model (CFM) to accelerate Smart Systems Integration for SMEs to exploit in niche markets (low volume high value) by providing access to design facilities and manufacturing capabilities for prototyping, early validation and first production. A test bed to realise 10 application experiments has been set up.

8.3.7 European H2020 CPS Projects

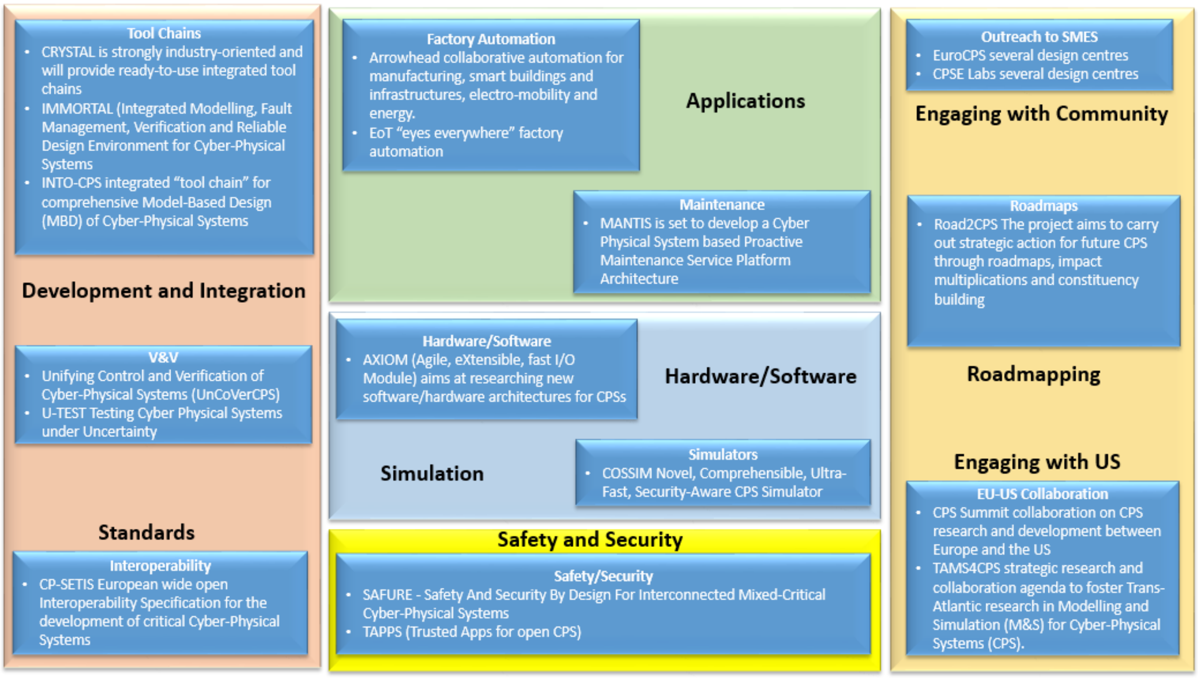


Figure 71. Overview of EU H2020 CPS Projects

In the CPS Cluster of projects the EC has funded 8 Research and Innovation Actions, 4 Innovation Actions and 3 Coordination and Support Actions under H2020 (See Figure 71) to provide coverage across a number of areas. The 8 Research and Innovation Actions are addressing areas such as co-simulation/modelling of all of system levels, including circuits, communication networks, firmware, operating system, system architecture and software layers with a view to providing model-based design. The aim is to reduce development cost and time by managing and reducing complexity. There are a broad range of use cases and the projects support more fundamental and longer term research issues than projects supported by ARTEMIS or ECSEL. The different projects and their coverage are briefly outlined below.

Research and Innovation Actions

- TAPPS: Trusted Apps for open CPS developing a platform for open CPS Apps with high security standards
- SAFURE: SAFety and secURity by design for interconnected mixed-critical Cyber-Physical Systems providing safety and security by construction for mixed–critical systems at design and run-time
- UnCoVerCPS: Unifying Control and Verification of Cyber-Physical Systems within the tool chain through modelling, verification, conformance testing and code generation
- U-TEST: Testing Cyber-Physical Systems under Uncertainty by developing systematic, extensible, and configurable model-based and search-based testing methodologies for building dependable CPS, and testing for uncertainty
- AXIOM: Agile, eXtensible, fast I/O Module to allow easy programmability of multi-core multiboard systems

- IMMORTAL: Integrated Modelling, Fault Management, Verification and Reliable Design Environment for Cyber-Physical Systems addressing reliable design and real time fault management in multi-core CPS
- INTO-CPS: INtegrated TOol chain for model-based design of CPSs providing an integrated tool chain for comprehensive model-based design of CPS
- COSSIM: A Novel, Comprehensible, Ultra-Fast, Security-Aware CPS Simulator providing an open-source framework to simulate the networking and processing parts of a CPS more accurately, more quickly and while considering security

Innovation Actions

In addition to EUROCPS and CPSELabs already described in the previous section two further projects are being funded:

- EOT: Eyes of Things building an ultra-low power and low cost vision platform for surveillance, augmented reality/wearable, cloud computing and perceptual computing
- CP-SETIS: Towards Cyber-Physical Systems Engineering Tools Interoperability Standardisation to produce an International Open Standard for development tools

Coordination and Support Actions

Three Coordination and Support Actions (CSAs) are being funded. One is developing strategic roadmaps for CPS and the other two are addressing EU-US collaboration.

- Road2CPS: Strategic action for future CPS through roadmaps, impact multiplication and constituency building
- TAMS4CPS: Trans-Atlantic Modelling and Simulation For Cyber-Physical Systems
- CPS-SUMMIT: Bringing experts together to identify research areas where the EU and US may work together, e.g. trustworthy systems

8.3.8 European Cluster of CPSoS Projects

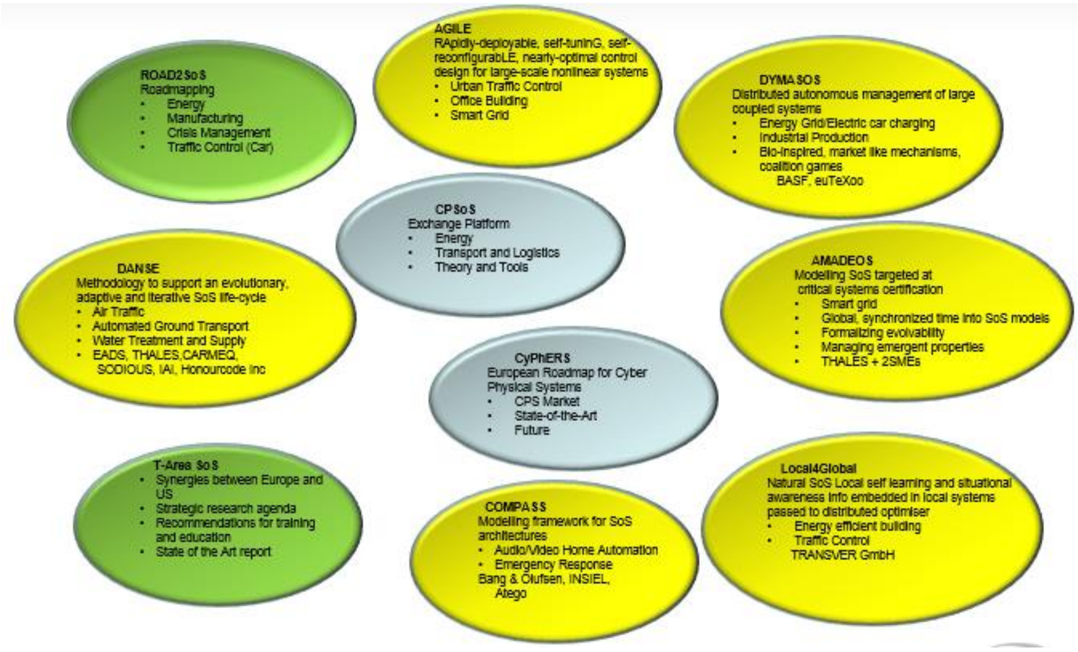


Figure 72. European Cluster of CPSoS Projects

At the Systems of Systems level the European Commission has also funded a number of Integrated Projects and Research and Innovation Projects to create a cluster of Cyber-Physical Systems of Systems projects (CPSoS). These are shown in Figure 72.

Figure 73. DANSE and COMPASS Integrated Projects

Two large Integrated projects (See Figure 73) were funded DANSE (Designing for Adaptation and evolutionN in System of systems Engineering) which addressed approaches for SoS engineering considering the need to deal with an evolving, adaptive and iterative life cycle, and COMPASS (Comprehensive Modelling for Advanced

System of Systems) which addressed model-based techniques for developing and maintaining Systems of Systems based on augmenting SysML with CML supported by proof and model checking tools. These projects addressed a diverse number of applications, including aerospace, autonomous vehicles, water management, emergency management and audio/video/home automation.

Other smaller projects within the cluster are:

- AMADEOS: Architecture for Multi-criticality Agile Dependable Evolutionary Open System-of-Systems
- AGILE: RApidly-deployable, self-tuninG, self-reconfIgurabLE, nearly-optimal control design for large-scale nonlinear systems for Urban Traffic Control (UTC) targeting a road network of Chania, Greece, and control of an Office Building
- LOCAL4GLOBAL: System-of-Systems that act LOCALly For optimising GLOBALly to create a plug-and-play control mechanism for the constituent systems of a SoS
- DYMASOS: Dynamic Management of Physically Coupled Systems of Systems addressing the management of large physically coupled systems of systems.

There have also been a number of roadmapping activities.

- CyPhERS: Cyber-Physical European Roadmap. The CyPhERS project developed a European strategic research and innovation agenda for Cyber-Physical Systems (CPS) identifying and prioritising research areas, support measures for both horizontal and vertical cooperation, research funding policies, training and standardization.
- ROAD2SOS: A Roadmap for Innovation in SoS. The project defined roadmaps for the domains of distributed energy generation and smart grids, integrated multi-site industrial production, emergency and crisis management, and multi-modal traffic control.
- T-AreaSoS: Trans-Atlantic Research and Education Agenda on Systems of Systems with the aim to create a commonly agreed EU-US Systems of Systems (SoS) research agenda.
- CPSoS: Cyber-Physical Systems of Systems. CPSoS provides a forum and an exchange platform for systems of systems related communities/projects and has also produced a strategic research and innovation agenda.

The CPSoS project is particularly relevant to the areas of smart cities, smart transportation and smart energy and led to the formation of the PICASSO project. The project analysed a number of key domains to formulate a view on the key challenges of CPSoS and to put forward recommendations for future research. The project highlighted that CPSoS are large, often spatially distributed physical systems with complex dynamics as shown in Figure 74. They are socio-technical systems with user/operator interaction but rely on distributed control, supervision and management. Partial autonomy of the subsystems is common to manage complexity of operation, and as the systems are in place for many decades, they dynamically evolve and reconfigure on different time-scales. Due to the complexity of interactions there is also a possibility of emerging behaviors.

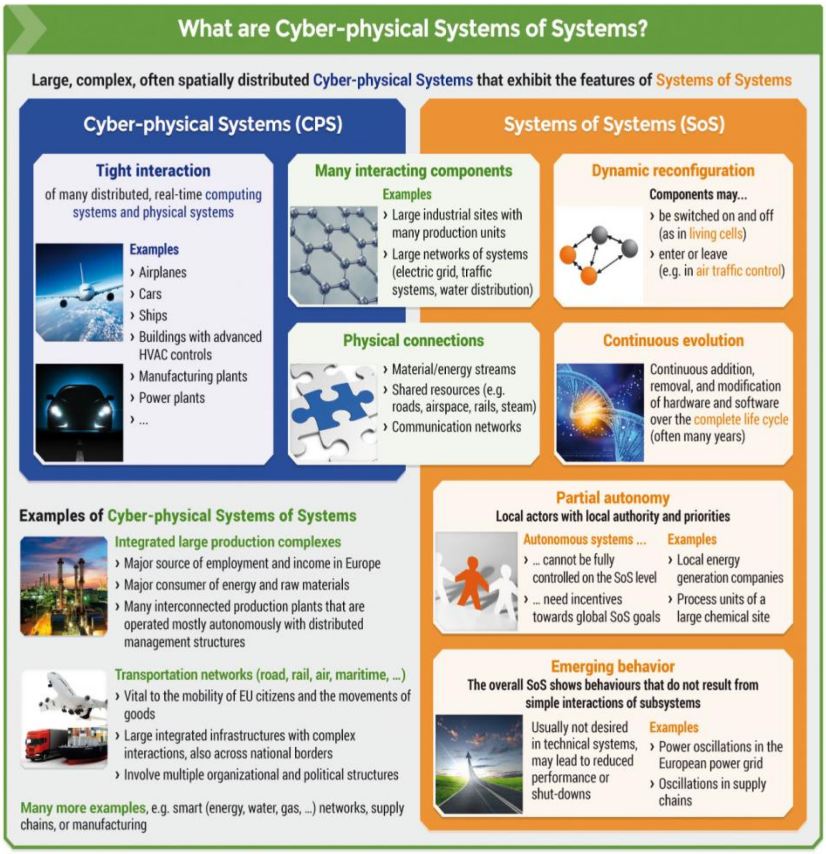


Figure 74. Cyber-Physical Systems of Systems

Three key research areas identified in CPSoS are the need for:

- Distributed, reliable and efficient management of Cyber-Physical Systems of Systems
- Cognitive Cyber-Physical Systems of Systems
- Engineering support for the design-operation continuum of Cyber-Physical Systems of Systems.

The project also identified needs for collaboration at a world-wide level, the needs for standards for interoperability, regulatory support and legal support to cover areas such as liability.

8.4 National CPS Initiatives

There are many national projects across Europe that address aspects of the development and use of CPS and IoT and it is not possible to cover them all in this report. However, a key notable initiative within the manufacturing sector that has gained considerable traction across Europe and is influencing developments at a European level, is Industry 4.0.

8.4.1 Germany

8.4.1.1 Industrie 4.0

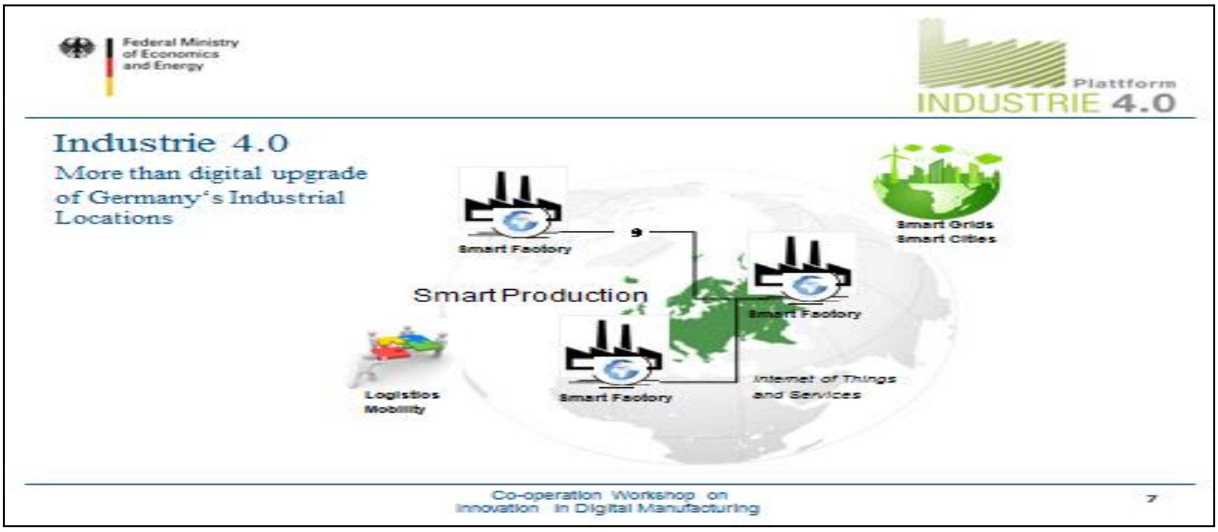


Figure 75. Industrie 4.0

A major initiative in Germany that is addressing the CPS area within manufacturing and automation is Industrie 4.0 [338] (See Figure 75). This is being supported under the German Government's HighTech Strategy 2020 which covers health, nutrition, communication, safety, climate, energy and mobility. There are 10 forward looking projects, two of which are in communications, with €200 million of funding from government. The working group identified 8 action areas: standardisation, reference architecture, mastery of complex systems, national broadband infrastructure, security, organisation and structure, vocational and further education, legal framework and resource efficiency. The aim is to achieve a quantum leap in organisational management through the entire value chain and product life-cycles. Key technologies identified are dynamic self-organising systems, real-time availability of information, Big Data management and optimisation. An aim is to realise research in the real world and BITKOM, VDMA and ZVEI are working together in the Platform Industrie 4.0. A scientific advisory board has been formed and 4 working groups on strategy, standardisation, research and security have been created. This initiative although German is also driving activities across Europe.

8.5 US activities

8.5.1 US IoT Drivers and Policy Initiatives

Developments in IoT in the US are being largely driven by companies with major players Google, Cisco, etc. dominating the marketplace. Various consortia and alliances have been formed to promote the uptake of IoT in the US. The vital importance of IoT has also been acknowledged by the Department of Commerce and it has been made a top priority as part of the Department's Digital Economy Agenda. An inquiry is being initiated by the National Telecommunications and Information Administration (NTIA) to review the current technological and policy landscape taking input from industry, researchers, academia, and society. The aim is to issue a green paper on key potential benefits and challenges of IoT, and identify possible roles for the federal government in fostering the advancement of IoT technologies in partnership with the private sector.

8.5.2 US IoT Initiatives

8.5.2.1 Industrial Internet Consortium

The US Industrial Internet Consortium (IIC) [339] although originally American is now attracting members from all over the world. It is a non-profit organisation with 14 staff (See Figure 76). Launched by AT&T, CISCO, GE, IBM and Intel, it is strongly tied to Object Management Group (OMG). There are currently 130 members (20 from the EU) and it is growing quickly. There are 20 working groups. The consortium has developed use cases in healthcare, transportation, manufacturing and smart grid and 3 approved testbeds have been developed.

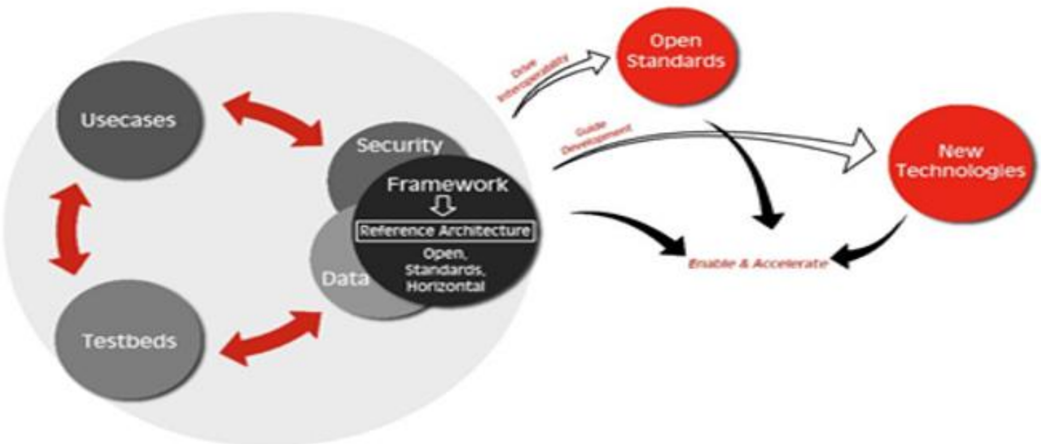


Figure 76. Industrial Internet Consortium

The initiative is addressing revenue generation, new operational efficiencies to drive down costs and improvements in customer satisfaction. This will create new markets and new working styles. Workforce productivity gains will be gained from digitalisation of tasks and reduced maintenance costs will result from use of predictive maintenance. Material and energy saving is also a key aim from reduced waste by precision monitoring to predict and control machines. There are working groups on security, technology, legal issues (e.g. who does data belong to), marketing and testbeds. Existing technology is used to identify research topics which are then investigated with the industrial members. It is not a standards organisation but it does evaluate and influence standards, e.g., ISO/IEC OMG and World Wide Web Consortium (W3C).

8.5.2.2 Allseen Alliance

Figure 77. AllSeen Alliance Structure

The Allseen Alliance [340] is a non-profit consortium which is dedicated to providing an open environment for the Internet of Things to allow the widespread adoption of billions of products, systems and services (See Figure 77). The aim is to create a vibrant ecosystem and thriving technical community of hardware manufacturers and software developers who can create interoperable products that can discover, connect, communicate and interact directly with other devices, systems and services regardless of brand. This has been developed as part of the collaborative AllJoyn open source project, which provides an industry-supported software and service framework for smart connected products. The AllSeen Alliance organization is open and inclusive.

8.5.2.3 Open Interconnect Foundation

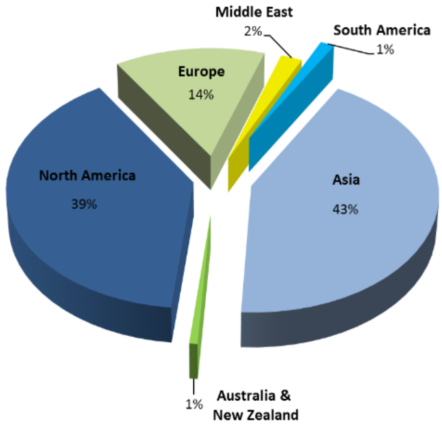


Figure 78. Open Interconnect Consortium Membership by Country

The Open Interconnect Foundation [341] (See Figure 78) was founded by major companies working on IoT chips, software, platforms and products for the Internet of Things to work together towards a single standard for IoT. It includes Intel, Microsoft, Samsung, Qualcomm, GE Digital and Cisco Systems. The aim is to come up with a single specification, or at least an open source common set of protocols and projects, for wearables, home appliances, industrial equipment, etc. and will provide OCF-certified products. This should allow billions of connected devices (devices, phones, computers and sensors) to communicate with one another regardless of manufacturer, operating system, chipset or physical transport. The aim is to accelerate industry innovation and help developers and companies create solutions that map to a single open specification providing interoperability for consumers, business, and industry. The OCF brings together members of the two major rival organizations: the Open Interconnect Consortium (OIC) and the AllSeen Alliance. Both groups have been promoting their own ways for connected devices to discover each other and determine what they can do together. All OIC members, including Intel and Samsung, are now part of OCF and two key members of AllSeen, Qualcomm and Microsoft, are now in the OCF. Microsoft has already stated that all Windows devices will in future interoperate with the OCF standard. Cisco and GE Digital have also joined OCF along with CableLabs, home appliance maker Electrolux and video and broadband company Arris Group. The OCF is promoting the IoTivity open source project [342].

8.6 US CPS Drivers and Policy Initiatives

8.6.1 NSF Cyber-Physical Systems Programme

The NSF Cyber-Physical Systems programme [343] has so far funded over 300 projects. The goal of the CPS programme is to develop the core system science needed to engineer complex Cyber-Physical Systems. The programme aims to create a research community committed to advancing research and education in CPS and to transitioning CPS science and technology into engineering practice. The programme addresses in particular cross-cutting fundamental scientific and engineering principles that underpin the integration of cyber and physical elements across all application sectors. Additionally, the programme supports the development of methods, tools, hardware and software components, prototypes and testbeds.

In the US there is interest in addressing basic CPS research that is required across multiple application domains. NSF is thus working closely with multiple agencies of the federal government within the US, including the U.S. Department of Homeland Security (DHS) Science and Technology Directorate (S&T); the U.S. Department of Transportation (DOT) Federal Highway Administration (FHWA), and through FHWA, the U.S. DOT Intelligent Transportation Systems (ITS) Joint Program Office (JPO); the National Aeronautics and Space Administration (NASA) Aeronautics Research Mission Directorate (ARMD); several National Institutes of Health (NIH) institutes and centres [including the National Institute of Biomedical Imaging and Bioengineering (NIBIB), Office of Behavioral and Social Sciences Research (OBSSR), National Cancer Institute (NCI), and National Center for Advancing Translational Sciences (NCATS)]; and the U.S. Department of Agriculture-National Institute of Food and Agriculture (USDA-NIFA). This highlights the wide breadth of areas where CPS has a role. There are three classes of research and education projects that are funded by NSF:

- **Breakthrough** projects giving a significant advance in fundamental CPS science, engineering and/or technology that has the potential to change the field. This category focuses on new approaches to bridge computing, communication, and control. Funding for Breakthrough projects may be requested for a total of up to $500,000 for a period of up to 3 years.
- **Synergy** projects to demonstrate innovation at the intersection of multiple disciplines, to accomplish a clear goal that requires an integrated perspective spanning the disciplines. Funding for Synergy projects may be requested for a total of $500,001 to $1 million for a period of 3 to 4 years.
- **Frontier** projects that address clearly identified critical CPS challenges that cannot be achieved by a set of smaller projects. Funding may be requested for a total of $1 million to $7 million for a period of 4 to 5 years.

8.6.2 NITRD - The Networking and Information Technology Research and Development Programme

The NITRD CPS SSG [344] is coordinating programmes, budgets, and policy recommendations for Cyber-Physical Systems (CPS) research and development (R&D). This includes identifying and integrating requirements, conducting joint programme planning, and developing joint strategies for the CPS R&D programmes conducted by agency members of the NITRD Subcommittee (Federal IoT/Cyber-Physical Systems) The Cyber-Physical Systems Vision Statement document produced by NITRD provides a summary of the drivers, e.g. building controls, energy, transportation, healthcare and crosscutting strategic challenges such as cyber-security, privacy and social-technical aspects of CPS. The report also lists the technologies being explored and the multi-agency plans for CPS. Critically the report identified that although a number of federal agencies have independent research efforts to address CPS science and engineering challenges, there are still many gaps in the federal R&D portfolio.

R&D Gaps	DARPA	DHS	DOD/services	DOE	DOE/ARPA-E	DOT	FDA	NIH	NASA	NIFA	NSA	NIST	NSF	OASD (R&E)	Others
Mission R&D: Crosscutting Research and Development															
Core CPS Science and Technology – control, real-time computing, communication concepts, modeling, hardware, and software platforms. Advanced engineered systems: manufacturing, energy, medical devices, transportation		X							X			X	X		
Science of Security for CPS				X							X	X	X		
CPS Virtual Organization (CPS-VO)		X				X					X		X		X
Complex systems, cascading failure, engineered resilient systems, fault identification, diagnosis and recovery		X	X						X			X		X	
Mission R&D: Sector-Specific Challenges															
Aviation safety, certification, enabling bold, visionary aviation systems and technology for a safe, efficient Next Generation airspace									X						
Intelligent transportation infrastructure systems, enabling technology for high confidence next-generation transportation (NextGen, automotive autonomy, intelligent vehicles)		X	X			X			X			X	X		
New control architectures/algorithms and power electronics for distributed generation, storage, and managed consumption			X		X				X			X			
Smart food systems that support safety, logistic efficiencies, cold-chain integrity, and traceability										X					
Time-critical systems, mixed criticality architectures, verification, aviation autonomy		X	X						X						
Rapid design and manufacturing of advanced CPS technologies. Rapid verification and real-time health monitoring and reconfiguration/re-verification. Application to autonomous systems	X		X						X						
Real-time physiological sensing, modeling, control, and feedback; advanced medical devices and system interoperability, integration, and certification							X	X	X			X			
Mission R&D: Crosscutting Standards-Based Platform Technologies															
Cyber-Physical Systems Engineering Testbed		X										X			
Measurement Science and Standards for Model-Based Diagnostics & Prognostics, Time Synchronization, Industrial Cybersecurity												X			
Measurement Science and Standards for Quality Measurement Systems for CPS, Wireless Networking for CPS, Advanced Battery Technology for CPS, Multi-Physics Modeling and Optimization, Adaptive and Predictive Control in CPS												X			
Standards-Based Integrated Architectures and Prototype Platform for CPS		X							X			X			
Education and Crosscutting Research Centers															
Future of skills development and instructor resources for CPS including online CPS training and educational infrastructure resources (e.g., CPS virtual laboratory)		X							X				X		
Research and Infrastructure for innovation in Medical CPS Pilot							X	X				X	X		
CPS Outreach Centers (CPS Government, Industry, Academia cooperative research model)													X		X
Industrial Internet Consortium		X										X			
Transportation CPS Pilot (NSF Engineering Research Centers model)						X			X				X		X

Figure 79. Technical Gaps Identified by NITRD

There are many technical barriers to rapid, predictable development and deployment of CPS as shown in Figure 79. It is not possible to address the gaps agency by agency, sector by sector, or company by company so a multi-agency, multi-sector comprehensive focus on crosscutting R&D challenges in CPS is advocated. This should allow developments for unmanned aerial vehicles or self-driving cars to be applied in other domains. Likewise technology developed for secure reprogrammable networked medical devices could be used in the smart grid. Thus collaboration between industry, university and government contributors in private-public partnerships is being promoted and a number of funding schemes have been proposed.

8.6.3 NIST CPS Initiative

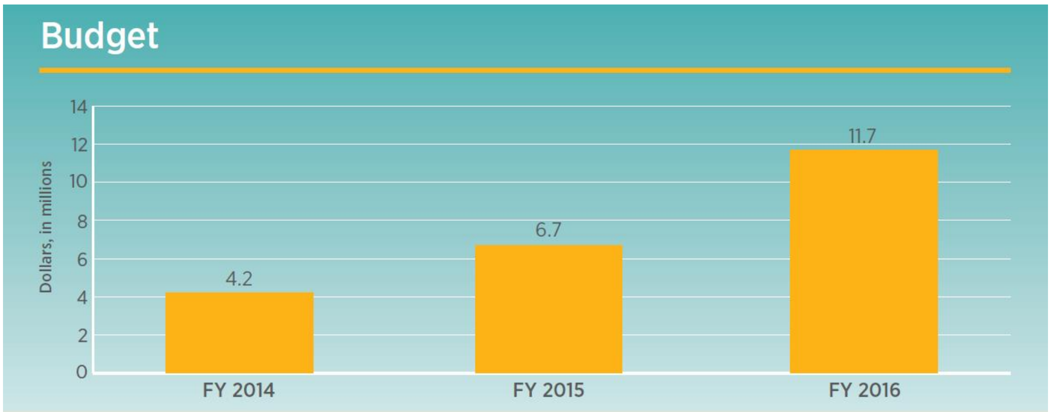


Figure 80. NIST Budget for CPS

The NIST Engineering Laboratory, through the Cyber-Physical Systems and Smart Grid Program Office, is leading NISTs activities on Cyber-Physical Systems. Notably the budget in this area for NIST is increasing as shown in Figure 80 highlighting the importance of the area.

In 2014 NIST formed the Cyber-Physical Systems Public Working Group (CPS PWG). This brings together experts to help define and shape key aspects of CPS to accelerate its development and implementation within multiple sectors. The CPS PWG has prepared a draft CPS Framework as shown in Figure 81.

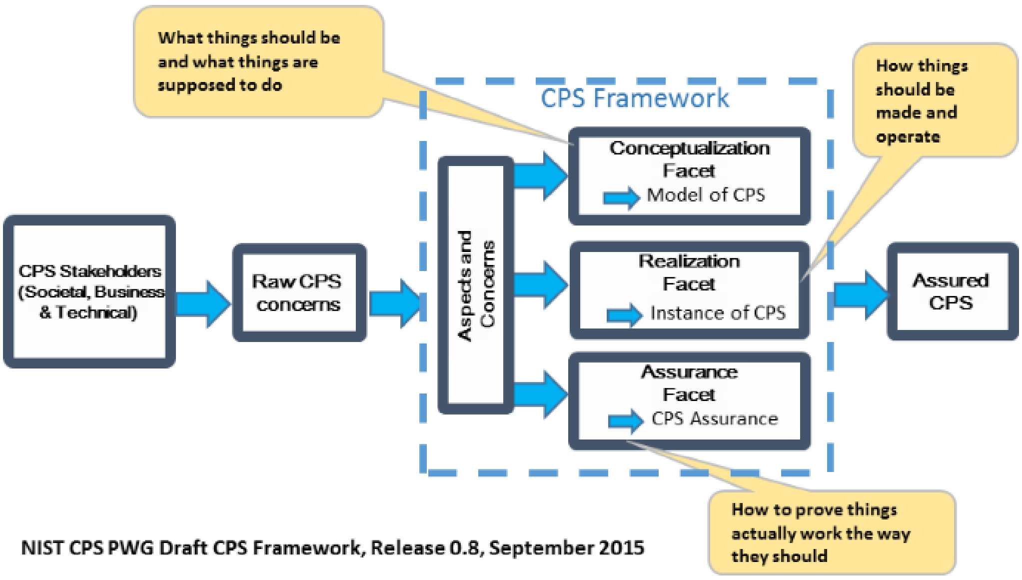


Figure 81. Draft NIST Framework for CPS

The CPS Framework [345] was developed in partnership with industry, academic and government experts and provides a methodology for understanding, designing and building CPS including those with multiple applications. As CPS are multidisciplinary CPS research and standards development is carried out in multiple NIST Laboratories. This includes advanced manufacturing, cyber-security, buildings and structures, disaster resilience, and smart grid. A key goal is to design and develop a CPS testbed to characterise CPS equipment, systems, performance, and standards.

NIST has also investigated the strategic importance of CPS and produced a report [346] "Strategic R&D opportunities for 21st Century Cyber-Physical Systems" which highlights the importance of the technology across a number of sectors including autonomous cars, robotic surgery, intelligent buildings, smart electric grid, smart manufacturing, and implanted medical devices. Key needs identified were:

- Robust, effective design and construction of systems and infrastructure - key to designing dependable systems from the ground up and reducing cost and time to market;
- Improved performance and quality assurance - essential for spurring future investment, acceptance, and use of innovative systems that promise to provide revolutionary improvements to conventional practice;
- Effective and reliable system integration and interoperability - required for highly connected and networked components to work together effectively as a total system; and
- Dynamic, multi-disciplinary education and training - will make possible sustained growth and innovation and spawn a new generation of entrepreneurs, as well as the next generation of cyber-physical systems.

8.6.4 US IoT Global City Teams Challenge

GLOBAL CITY TEAMS CHALLENGE

Figure 82. US IoT Global City Teams Challenge

NIST [347] lead the Global City Teams Challenge (See Figure 82) to help communities around the world work together to address issues ranging from air quality to traffic management to emergency services coordination. Under the challenge communities and innovators are brought together to create teams addressing smart city issues utilising networked technologies to better manage resources and improve quality of life in nine-month projects.

This challenge follows on from the SmartAmerica Challenge, which ran from December 2013 to June 2014. This challenge successfully brought together more than 100 companies, universities and other organizations to form teams that developed and applied networked technologies. In the first round of the Global Cities Challenge more than 40 teams or "action clusters" performed projects related to energy, transportation, public safety, and other key sectors. Partners in the Global Cities Challenge include IBM, AT&T, Intel, NSF, ITA, DoT, State Department, GSA, FIWARE, World e-Governments (WeGO), IIC, The Kingdom of Netherlands and the Republic of South Korea. Participating Organizations include Qualcomm, Bosch, Siemens, CH2M Hill, Mathworks, Pecan Street, Inc., Yeti Analytics, MIT, Vanderbilt, UT Dallas, University of North Texas, Ohio State University and Columbia University.

8.7 Rest of the World

8.7.1 Worldwide Alliances in IoT

Figure 83. Worldwide Alliances in IoT

In the IoT domain there are many world-wide alliances as shown in Figure 83. Many companies are promoting their ideas for the Internet of Things. One example is Intel who have developed an Intel IoT platform [348]. This is an end-to-end architecture based on secure horizontal and interoperable building blocks that functions as an IoT platform that can be deployed across industry sectors, e.g. manufacturing, utilities, healthcare, and public safety, and smart cities.

8.7.2 South Korea and EU

The South Korean Government is investing $350 million over the next 4 years in 300 companies it thinks can compete globally in the IoT ecosystem. There is also a Joint Research initiative with Europe under H2020 to create IoT ecosystems with open and interoperable platforms. This is addressing harmonised IoT architectures and reference implementations, security and privacy mechanisms for devices, architectures, service and network platforms, including characteristics such as openness, dynamic expandability, interoperability, dependability, cognitive capabilities and distributed decision making, cost and energy efficiency, ergonomic and user friendliness. A key aim is to develop joint IoT infrastructure reference implementation models and IoT standardisation with pilot projects in smart cities, health care, smart factories and smart logistics with cross regional demonstrations.

8.8 ICT Regulations

With the explosion of interest in IoT it is increasingly apparent that policy and regulation have a crucial role. IoT deployments at scale have implications for privacy and security, business models and market access, standards and interoperability, and national and supranational priorities. Here a harmonization between the US and Europe is not only advantageous but strongly needed. Engineering trustable, reliable, evolvable and affordable cyber-physical systems connected by the Internet of Things is a scientific and technological challenge that requires huge efforts. Joining forces will help to advance more quickly, meet societal challenges and help both US and European companies compete in world markets.

8.8.1 CPS and IoT Security

Security is a key issue in both CPS and IoT systems. In the US this is being addressed by NIST's Cyber-security and Privacy Subgroup [349]. Here cyber-security and privacy considerations are being considered in all phases of the system development lifecycle, from design through implementation, maintenance, and disposition. The primary aim is to develop a cyber-security and privacy strategy for the common elements of CPS that includes the identification, protection, detection, response and recovery of CPS elements. The subgroup is identifying areas for further CPS cyber-security research and development.

Supporting this the NITRD's Cyber Security and Information Assurance (CSIA) Interagency Working Group is performing research and development to prevent, resist, detect, respond to, and/or recover from actions that compromise or threaten to compromise the availability, integrity, or confidentiality of computer- and network-based systems. This includes applications in power grids, emergency communications systems, financial systems, air-traffic-control networks, national defence, national and homeland security. Research areas include Internet and network security; confidentiality, availability, and integrity of information and computer-based systems; new approaches to achieving hardware and software security; testing and assessment of computer-based systems security; and reconstitution and recovery of computer-based systems and data [350].

Cyber-security has become an increasingly important topic and the President announced a Cyber-security National Action Plan (CNAP) and the Administration released the 2016 Federal Cyber-security Research and Development Strategic Plan [351] which is an update of the Trustworthy Cyberspace: Strategic Plan for the Federal Cyber-security Research and Development Program which was launched in 2011. The plan is aimed at providing methods and tools for deterring, protecting, detecting, and adapting to malicious cyber activities [352].

In 2014, NIST published the Framework for Improving Critical Infrastructure Cyber-security. The NIST Cyber-security Framework Core defines five functions (Identify, Protect, Detect, Respond, Recover). The new plan defines four elements (Deter, Protect, Detect, and Adapt).

Figure 84. IoT Security

Within Europe the area of cyber-security is more fragmented. The Internet of Things Security Foundation (IoTSF) is a group set up by the UK's National Measurement Institute. This is trying to put together guidelines for developers to improve overall security [353]. Elsewhere in Europe there are a number of other national initiatives. Urgent action is needed, however, as the applications being developed and put into service (See Figure 84) are increasingly vulnerable to attack.

9 Key Points Identified, Analysis and Opportunities

9.1 Smart Cities

Within the smart cities domain the report highlights the wide range of areas where "smartness" can be exploited including government, economic and financial systems, building management, manufacturing, education, community and social services, healthcare, transportation, utilities and infrastructure and communications. In Europe a number of initiatives, e.g. the European Initiative on Smart Cities and the European Innovation Partnership for Smart Cities and Communities is investing in sustainable development in as many cities as possible. Key to this is partnership and the aim is to create equal partnerships between cities and companies. The EC is supporting this by creating "Lighthouse Projects" with the intention of these signalling numerous follow-up projects across Europe. Smaller cities are also being aided by the Small Giants Initiative. To support development there is a need for "at scale" experimental research facilities such as SmartSantander and partnerships between companies, governments and knowledge institutions such as Amsterdam Smart City (ASC) (100 partners). Notably there are different levels of "smartness" and there are a large number of cities in Europe (468) which display some attributes of smart cities.

In the US the White House Smart Cities Initiative is investing over $160 million in federal research. NITRD has set up a framework to coordinate Federal Smart Cities activities, agency investments and outside collaborations. A number of initiatives are being supported by NIST including the Global City Teams Challenge. Underlying this is foundational research supported by NSF that supports design and management of Smart and Connected Communities. There are a number of notable smart cities in the US including Boston, New York, Seattle, San Francisco, Washington, San Jose and Chicago.

The smart cities industry is valued at more than $400 billion globally by 2020. Providing technology and services for Smart Cities around the world is thus a major business opportunity and this is a major driver for some national programmes, e.g. in the UK, Japan, South Korea and China. There are many deployments around the rest of the world where best practice could be gleaned.

There are a number of barriers to deployment. There is a critical need for regulation in the area of privacy and in allowing sharing of data to provide services. Smart cities will constantly register and process private data from individuals leading to questions about gathering data with consent and reconciling the value of services with privacy. Anonymising data, encryption and processing in encrypted domains may all be needed. The very wide scope of smart cities, which covers not only interactions with citizens and use of their data, but also control of the energy, waste, transportation systems and social interactions with government, education and e-health, leads to many areas were regulation may be required. Safety is of underlying importance to citizens.

There are several developing standards for smart cities notably in the UK covering a variety of smart city topics, ETSI smart city standards targeted at mobility, transportation, M2M, energy efficiency, security, and ITU-T on Smart Sustainable Cities. China is also very active in standardisation with a number of Chinese bodies.

A growing problem is susceptibility to cyber-attack and here lessons can be learned from countries such as Estonia. In the US NIST is working with the National Cyber-security Center of Excellence (NCCOE) to provide cyber-security solutions based on commercially available technologies for smart city applications.

9.2 Smart Energy and Smart Grid

Energy and Smart Grids are key topics in both Europe and the US driven by national and European green initiatives, e.g. in Europe to reduce greenhouse gas emissions by 40%. Urban areas consume 70% of energy, and account for 75% of the EU's greenhouse gas emissions. Thus buildings, transportation systems, water supply and treatment, and sewage management are an area where most energy savings could be made. Notably nearly 50% of European Smart City initiatives address environmental problems. The European Strategic Energy Technology Plan (SET Plan) has identified the need for development of energy technologies to combat climate change and the need for securing energy supply at the European and global level. To support this the European Energy Research Alliance (EERA) has been set up by leading European research institutes and the SETIS Initiative has been created to support cities and regions in sustainable use and production of energy. An ICT Roadmap for Energy Efficient Neighbourhoods has been created and KIC InnoEnergy has been set up as a commercial company dedicated to promoting innovation, entrepreneurship and education in the sustainable energy field.

At a national level policies are also driving change, e.g. in Germany to phase out nuclear power and in the UK cutting greenhouse gas emissions by 80% by 2050. The low carbon economy strategy in the UK is driving the setup of public private research partnerships and a range of initiatives for electivity and heating. Every home will be supplied with a smart meter helping consumers to understand their energy consumption and make savings.

In the US as part of the Reinvestment and Recovery Act there are a number of government initiatives and policies including totalling $3.4 billion of investment grants for Smart Grid projects. This includes funding to promote energy-saving choices for consumers, increasing efficiency, and fostering the growth of renewable energy sources such as wind and solar. The Energy Independence and Security Act of 2007 (EISA) also made it policy to modernise the nation's electricity transmission and distribution system to create a smart electric grid. This is supported by the Administration's commitment in the "Blueprint for a Secure Energy Future" and "A Policy Framework for the 21st Century Grid: Enabling Our Secure Energy Future."

Around the world different approaches are being adopted and a wide variety of technologies and services are being demonstrated driven by national and regional business drivers. In the US peak load reduction technology and dynamic pricing tariffs are being pursued. In Europe emphasis is on improving energy efficiency and reducing emissions through the decentralised production. In the Asia-Pacific region China is modernising and improving grid reliability and Australia and New Zealand are exploring new techniques for load management. There are major investments in China ($128 billion) to reduce carbon intensity by investment in renewable power and to create grid interconnectivity with neighbouring countries such as Russia, Mongolia, Kazakhstan, Pakistan, Myanmar, Laos, Nepal and Thailand. Since 1992 China has relied heavily on electricity it purchases from Russia. Other countries also actively pursuing smart grids are Brazil, Mexico South Korea and Japan.

The smart grid market is led by regulation and reductions in emissions, consumer choice and energy security are driving adoption of smart grid technologies. Regulation in the UK and Germany is introducing smart metering and tariffs. A number of pricing structures are being explored: tiered pricing rates that reflect system capacity and time-of-use pricing (off-peak/on-peak) schemes. Introducing "Critical Peak" prices has been found in a US pilot to be the most effective technique to trigger load reduction.

Across Europe grid regulation varies considerably making smart grid investments difficult. In Europe the Electricity Directive and the Energy Services Directive provide a mix of obligations and incentives to Member States to establish a common regulatory framework. Other bodies also need to be involved such as the Agency for the Cooperation of Energy Regulators (ACER) that fosters cooperation among European energy regulators to ensure market integration and the harmonisation of regulatory frameworks within the framework of the EU's energy policy objectives and the Council of European Energy Regulators (CEER) that represent national regulators.

In the smart grid area there is a need for standards for interoperability and safety. Standards are voluntary in Europe and are developed by industry and market actors. The European Commission and EFTA have issued the Smart Grid Mandate M/490 which was accepted by CEN, CENELEC and ETSI. In the US EISA asked NIST and FERC to facilitate the development and adoption of interoperability standards. NIST is leading this coordinating the development of a framework that includes protocols and model standards for information management to achieve interoperability of Smart Grid devices and systems.

Security is another key concern and smarter grids lead to increased vulnerabilities from intrusions, error-caused disruptions, malicious attacks, destruction, and other threats. As the electric grid network is key to the operation of a country, cyber-security is a key topic on both sides of the Atlantic. The European Commission has put together a multi-stakeholder and multidisciplinary group of experts to discuss and work on relevant matters regarding the security and resilience of communication networks and information systems for Smart Grids across Europe. Although standards for smart grid cyber-security are already available these need to be maintained and enhanced as it and technology evolves. In Europe Alstom Grid, Intel, and McAfee produced a white paper on smart grid cyber-security. In the US the Administration has proposed specific cyber-security legislation to ensure that grid operators and all stakeholders have access to actionable threat information and provide support for research, development, and demonstration of cyber-security systems. The aim is to identify and prioritise relevant cyber risks - including malware, compromised devices, insider threats, and hijacked systems - and develop standards and guidelines that enable the design of effective plans for mitigating those risks. A number of threat warning bodies have been set up in the US, Electricity Sector - Information Sharing and Analysis Center, the United States Computer Emergency Readiness Team, and the National Electric Sector Cyber-security Organization. The NIST Information Technology Laboratory (ITL), Computer Security Division leads the Smart Grid Interoperability Panel (SGIP) Cyber-security Committee (SGCC) which has produced the NISTIR 7628 Guidelines for Cyber-Security (Volumes 1, 2, and 3) which is widely used by utilities, vendors, and regulators in the US.

9.3 Smart Transportation

North America and Europe are expected to be the largest markets for Intelligent Traffic Systems. Within Europe sustainability is a key issue with a dramatic increase in both freight and passenger transport and associated emissions. There is also an aim to halve casualties with respect to 2001 levels in road transport. The European Commission supports a number of transport Technology Platforms that includes ERRAC (Rail), ERTRAC (Road), ACARE (Aerospace) and WATERBORNE (Marine) that sets the research agenda for each domain. At a national level there are several programmes implementing Intelligent Transport Systems for road users. To coordinate the planning of infrastructure projects across Europe the Trans-European transport networks (TEN-T) policy has an investment programme of EUR 400 billion. The European Commission's aim is to accelerate and coordinate the deployment of ITS applications on the Trans European Road Network (TERN) across Member States in a consistent and harmonised way.

The drivers in the US for intelligent transportation are similar to those in Europe, however, another key driver is homeland security. There is a desire to provide surveillance of roadways and also a means for mass evacuation of people in urban areas as a result of natural disaster or threat. In the US the ITS Joint Program Office (ITS JPO), coordinates across the Federal Highway Administration, Federal Motor Carrier Safety Administration, Federal Railroad Administration, Federal Transit Administration, Maritime Administration, and the National Highway Traffic Safety Administration to plan, programme, and execute the ITS Research Program. This is being supported by a guidance handbook from the SSTI and Smart Growth America and stimulation challenges, e.g. the Smart City Challenge. Looking longer term Beyond Traffic is looking at trends and needs over the next three decades.

9.3.1 Road

The ERTRAC Strategic Research Agenda covers mobility, transport and infrastructure, safety and security, environment, energy and resources, design and production. It highlights a number of key research topics including traffic management, integration of vehicle and infrastructure systems, traffic management using ITS, data collection and processing, business models, optimisation of road space to ensure that vehicles (particularly HGVs) adopt routing systems that minimise adverse impacts, systems for segregating traffic with dedicated infrastructure and prioritised traffic management and methods to assist the booking of optimised slots for freight vehicles. Multi-modal door-to-door mobility is also being considered in the New Mobility Services project. Autonomous driving features to improve safety are being pursued in both Europe and the US with projects like HAVEit and the Swedish Drive Me project and the Google car in the US.

The adoption of electric vehicles and the decarbonisation of transport is a priority in both Europe and the US. In Europe there are a number of “green initiatives” at European level to promote the take up the use of electric vehicles and to reduce pollution across a range of transport modes such as the European Green Cars Initiative and the Smart, Green and Integrated Transport programme and EV4SCC with €6339m funding. In the US the Recovery Act is providing large investments in advanced vehicle and fuel technologies, public transit, and high speed rail and tax credits are being used to encourage uptake of electric cars. Urbanisation is a key challenge and air quality directives such as Euro 6 are driving new truck and powerplant design in Europe. Likewise stricter standards are being introduced in the USA to raise average fuel economy to 35.5 miles per gallon for cars and trucks by 2016. Within trucking there are particular problems for Europe such as a myriad of automatic tolling systems which would benefit from harmonisation but on both sides of the Atlantic telematics is being exploited to reduce carbon footprint and optimise deliveries by major logistics companies such as DHL and UPS.

Increased connections to cars is being driven by regulation in the EU for the introduction of car emergency vehicle notification systems (eCall). Standards for car-to-car and car-to-infrastructure communication need to be global to allow automotive companies to sell their products around the world. The ITS market is global and there are many opportunities in the Asia Pacific region and India. In the EU the CAR 2 CAR Communication Consortium has been developing and testing standards driven by the EC M/453 mandate for European standardisation organisations ETSI, TC, ITS, and CEN to produce a minimum set of standards that ensure interoperability. Likewise in the US there is a focus on vehicle-to-vehicle and vehicle-to-infrastructure connectivity through the application of advanced wireless technologies. The ITS Research Program is developing and testing the underlying technology and applications. The ISO/TC 204 standard particularly addresses intelligent transport systems, with a focus on standardization of information, communication and control systems for urban and rural surface transportation.

9.3.2 Rail

The interoperability regulations and the 2011 Transport White Paper require that the European railway system behaves as a single network. The commercial drivers in the industry are for 24/7 operation, high availability, low cost, safety, increased capacity, recovery from disturbance, low carbon emissions and customer satisfaction. In Europe the Strategy for European Rail Research – Vision 2020, the Strategic Rail Research Agenda, and “Railroute 2050” vision highlights the need for the European Railway Traffic Management System (ERTMS)to replace the existing 20 train control systems utilised across the European Union. Key initiatives are the H2020 supported FOSTER-RAIL and SHIFT²RAIL joint technology initiatives to focus research and innovation (R&I). In the US there is a major need to modernise the rail system and although there has been investment of $11 billion on High Speed Rail initiatives this has been largely spent on upgrading the existing Amtrak service which is limited to 110 miles per hour. Although a further $10 billion has been requested by Congress to support high-speed initiatives there is considerable opposition from republican governors and community opposition for projects that are seen as too expensive and unnecessary. Some high speed rail projects are going ahead, e.g. the controversial Los Angeles - San Francisco route, and privately funded initiatives from All Aboard Florida with a $1.5 billion loan from the Federal Railroad Administration and the Texas Central Railway company, which plans to introduce Japanese bullet trains between Houston and Dallas.

9.3.3 Air Transportation

Air passenger volume is predicted to double air traffic density over the next two decades in an already congested airspace. The Single European Sky ATM research programme SESAR is reforming the architecture of European Air Traffic Control to meet future capacity and safety needs. SESAR aims at developing the new generation air traffic management system capable of ensuring the safety and fluidity of air transport worldwide over the next 30 years. The equivalent of SESAR in the US is NEXTGEN. A concern here from a global perspective is that both systems adopt fundamentally different approaches to air traffic management. Autonomous Unmanned Vehicles are very active area on both sides of the Atlantic with many military programmes. Considering civilian programmes there is only one major national programme in the UK ASTRAEA. In the US there is some activity from Amazon on developing drones for delivering parcels which raises some certification issues with the FAA.

9.3.4 Marine

A key driver in the maritime industry is improving safety of waterborne operations as accidents come with high costs in terms of loss of life, environmental damage and with high economic impact. Traffic management is key for safer and more secure operations. The technology can also be used for optimised shipping operations and voyage optimisation, condition based maintenance, reducing costs and reducing emissions which is driven by strict legislation in Europe at a national level and also at local level in ports. In Europe the WATERBORNE European Technology Platform has defined the Marine Vision 2020 and Strategic Research Agenda which drives funding for projects. There is a major e-Maritime initiative to exploit advanced information technologies within the maritime sector. Unmanned navigation and autonomous ships are also being researched but there are considerable hurdles to adoption coming from regulators concerned about safety and unions who are concerned about job losses. Current regulations dictate minimum crew levels by international conventions.

In the US the Maritime Administration of the US Department of Transportation has highlighted that policy reforms are needed to address international shipping trade. Offices have been created at major US gateway ports to interact with key stakeholders to identify Federal and state funding and cooperate on projects. Public private partnerships are being used to identify bottlenecks and ways of improving freight movement, and to fund redevelopment of port infrastructure, e.g. berths, piers, container cranes, on-site rail and railroad trailers. This is being strongly supported by the Transportation Infrastructure Finance and Innovation Act (TIFIA) programme that provides direct loans, loan guarantees and credit with $1.435 billion in capital over five years. A strong domestic maritime industry is seen as being critical for America's economic, national, and homeland security. The maritime industry is strongly represented by the American Maritime Partnership (AMP) with 450 members and the Jones Act requires that any vessel transporting goods or passengers between two points in the United States or engaging in activities in US waters must be US owned, US built, and US crewed.

9.4 5G

5G extends the cellular network from content delivery to a 'Control Network' that allows new control applications. The EC has committed €50 million for research to deliver 5G mobile technology by 2020. This includes initiatives like the METIS project and the 5G Infrastructure Public Private Partnership to bring together several telecommunications companies. Notably the work on 5G within Europe and the US is largely based at a few key Universities, e.g. 5G Innovation Centre (University of Surrey), Kings College, TU Dresden, Chalmers and Lund, largely in partnership with companies such as Ericsson and Vodafone. A similar situation exists in the US where 5G research is mainly being funded by NSF at institutions such as University of Texas at Austin, Stamford, Berkeley, New York University, and Rutgers. Although 5G America connects the 5G community in the US there are no major national 5G programmes. There are, however, calls for a major $500 million programme from the White House.

There is a key need for spectrum harmonisation for 5G so that the same frequencies are used worldwide and companies who operate on a world-wide basis can produce appropriate equipment. Within the US the MOBILE NOW Act has been introduced to boost the development of next-generation 5G wireless by ensuring more spectrum is made available. Lessons have been learned from 4G LTE where harmonisation was not possible. The US has a dominant lead in 4G LTE but it is not widely deployed in Europe and the rest of the world where the concentration is very much on 5G.

The uptake of 5G depends upon standardisation to be in place, however, the roll out of 5G is expected to be gradual allowing equipment upgrades to occur before some of the key 5G standards are formalised in 2018 and 2019. There are many pre-standards activities going on around the world in 5G with demonstrators from T-Mobile US, Ericsson, Verizon, and large investment from South Korean companies and China with pilots in European countries. Docomo is publicly committed to having a 5G service up and running for the Tokyo Olympics in 2020. To get joint agreement on technical fundamentals and 5G spectrum bands globally by 2018 NTT Docomo (Japan), KT and SK Telecom (South Korea), and Verizon(US) are forming the 5G Open Trial Specification Alliance to drive technology and standards forward. Pre-standard "5G-ready" equipment using software defined network (SDN) technology will allow network operators and enterprise customers to move to upgrade to full 5G once standardisation is in place for spectrum allocation and licences are issued. Other bodies that are likely to influence 5G standards are the Next Generation Mobile Networks NGMN 5G roadmap targeting 2020 for 5G launch, the GSMA to bring together operator, and the ITU for harmonisation.

9.4 Big Data

In Europe the Digital Single Market (DSM) and data driven economy is driving many activities on data. The European Big Data strategy has funded over 150 research and innovation projects and the Big Data Public Private Partnership has been set up with many key players. Similarly the NSF Big Data Research Initiative is driving activities in the US with the Cyberinfrastructure Framework for 21st Century Science and Engineering (CIF21) fostering development and implementation of a national cyberinfrastructure for researchers in science and engineering by making data available within different research communities. Several agencies such as NSF, NIH, DARPA and the Department of Defence (DoD) have their own Big Data Initiatives. Policy in the US focuses more on the actual uses of Big Data and less on its collection and analysis. The US wants to lead both in the international arena and at home. The BD2K Centres of Excellence programme has established 11 Centres of Excellence for Big Data Computing. DARPA and the DoD are also actively engaged. DARPA is creating and providing open source the XDATA software toolkits for applied mathematics, data visualization and computer science. The DoD is increasing Big Data-related research and development with all military services funding R&D in the area. The Big Data Technology roadmap is being led by NIST and this is defining requirements for interoperability, portability, reusability, and extensibility for Big Data analytic techniques, and technology infrastructure in order to support secure and effective adoption of Big Data.

Critical to maximising the benefits from Big Data is the ability to access and share data. In Europe the Open Cities project and Commons for Europe Project are demonstrating the power of open data as well as the Citadel on the Move project that makes it easier for citizens and application developers from across Europe to use Open Data. At a national level a number of projects such as Open Data Helsinki are showing the promise of open data usage. A key barrier is ability to share information effectively. There is a need to rationalise Information Governance regimes across public services and to address the semantics of information to allow sharing. There is also a general lack of openness with respect to data around the world as indicated by the Open Data Barometer published by the Open Data Institute (ODI) which covers 88 countries.

The area of privacy is a key topic on both sides of the Atlantic. In the US there is also an accent on policies to strengthen and stimulate US research in practical privacy-related technologies. This is covered by the 14th Amendment of the US Constitution which gives a person the right to determine what sort of information about them is collected and also how that information is to be used. In the marketplace this is enforced by laws intended to prevent deceptive practices and unfair competition. The Privacy Act of 1974 prevents unauthorised disclosure of personal information held by the federal government. In Europe there are different attitudes and regulation with respect to privacy in different member states. In Germany, for instance privacy is a key concern and privacy is strictly controlled. To try and harmonise the area of privacy the European Data Protection Directive (Directive 95/46/EC) was introduced to protect an individual with respect to processing of personal data and on the free movement of such data. At an international level the "Safe Harbour Privacy Principles" were introduced so that US companies can comply with privacy laws that protect European Union and Swiss citizens. US companies who store European customer data may self-certify that they adhere to 7 key principles. This was challenged and ruled inadequate so a Privacy Shield agreement has been put forward. This is still the subject of intense discussion. In particular, even if US companies have European data centres, cloud services may still require transfers of EU data to the US (or other countries) to provide some features or provide technical support. Encryption is thought to be a way forward. For instance ID data can be encrypted before it enters the cloud with the data owner keeping the encryption keys. This gets around Safe Harbour and Privacy Shield laws, however, it is expensive and only 1% of cloud companies offer encryption.

Standardisation is a key enabler in the field of Big Data. There are already a number of standardisation initiatives at a world-wide level such as the ISO/IEC Joint Technical Committee (JTC) 1 Working Group (WG) on Big Data, the IEEE Standards Association standards related to Big-Data applications and specifically IEEE P2413, and the ITU "Recommendation ITU-T Y.3600" for Big Data services.

9.5 CPS/IoT

The Digital Single Market Strategy and the Digitising European Industry initiative are key drivers in Europe for IoT and CPS with the concept of "Smart Everything Everywhere". There are major initiatives to cluster activities together and support development of platforms. The IERC (IoT European Research Cluster) brings together 40 EU-funded projects with the aim of defining a common vision, identifying common research challenges and coordinating and encouraging the convergence of ongoing work. Likewise the Alliance for the Internet of Things (AIOTI) has the aim of creating a European IoT ecosystem with further IoT Large Scale Pilots being funded to promote IoT take up. There are also major initiatives such as BUTLER and FIWARE which are providing open, public and royalty-free architectures and specifications to allow developers, service providers, enterprises and other organizations to develop products. This is cross sectoral with 16 Future Internet Accelerators addressing Smart Cities, E-Health, Transport, Energy and Environment, Agrifood, Media and Content, Manufacturing and Logistics, Social and Learning.

In the US Developments in IoT are largely being driven by companies with major players Google, Cisco, etc. dominating the marketplace. The Department of Commerce is promoting growth of the digital economy and as part of the Digital Economy Agenda, the National Telecommunications and Information Administration is initiating an inquiry to review the current technological and policy landscape for IoT and issue a "green paper". This will highlight potential benefits and challenges, and possible roles for the federal government in fostering the advancement of IoT technologies in partnership with the private sector. Various consortia and alliances have been formed to promote the uptake of IoT. These include the US Industrial Internet Consortium (IIC), the Allseen Alliance (dedicated to providing and open environment for the Internet of Things) and the Open Interconnect Foundation founded by major companies (Intel, Microsoft, Samsung, Qualcomm, GE Digital and Cisco Systems) working on IoT chips, software, platforms and products with the aim of working together towards a single standard for IoT.

The importance of IoT is recognised world-wide and large investments are being made in a number of countries, e.g. the Korean Government is investing $350 million in 300 companies it thinks can compete globally in the next four years, to develop an IoT ecosystem.

Within Europe there are many projects on CPS and the EC strategy has been to cluster these with clusters being formed on CPS and Systems of Systems. To bring industry together in the areas of micro-/nanoelectronics, embedded and Cyber-Physical Systems and smart systems the ECSEL-JU has been set up. Supporting this the ARTEMIS Industry Association (170 members) is also funding large projects such as CRYSTAL on interoperability and EMC on mixed-criticality systems. Competence centres have also been set up to engage with SMEs. At a national level the Industrie 4.0 programme is driving work on CPS in manufacturing.

In the US work on CPS is being driven by the NSF Cyber-Physical Systems programme which has funded over 300 projects. Here basic CPS research is being addressed that can be used across multiple application domains and NSF is working closely with multiple federal government agencies. The NITRD CPS SSG is responsible for coordinating programmes, budgets, and policy recommendations for Cyber-Physical Systems (CPS) research and development (R&D). Although a number of federal agencies have independent research efforts it has been identified that there are still many gaps in the federal R&D portfolio. The NIST Cyber-Physical Systems and Smart Grid Program Office is leading NISTs activities on Cyber-Physical Systems. A Public Working Group (CPS PWG) has been formed and a CPS Framework has been developed in partnership with industry, academic and government experts. This provides a methodology for understanding, designing and building CPS. NIST also lead the Global City Teams Challenge to help communities around the world work together to address issues including air quality, traffic management and emergency services coordination.

Key challenges are interoperability of systems to allow easier integration of highly complex systems. There is a need to provide standards and regulations that support the creation of an ecosystem of developers and users of CPS and IoT systems. Here a harmonisation between the US and Europe is not only advantageous but strongly needed. Regulation also has a crucial role in the development of CPS and IoT. IoT deployments at scale have many implications including implications for privacy (applications rely on collecting and utilising data from a myraid of sensors) and security where the increasing interconnectedness of systems leads to vulnerabilities to unintentional errors and cyber-attacks. There is also a need for business models and regulation to support market access.

10 Concluding Remarks

This report provides a panorama of ICT policies, regulations, programmes and networks in smart cities, smart transportation and smart energy and also an overview of industry-driven programmes, priorities, networks, major projects in EU and US in the areas of 5G Networks, Big Data, Internet of Things and Cyber-Physical Systems. Additionally, these areas are also actively being pursued at the world level and relevant major programmes around the world have also been identified. Key work with respect to regulations and standards is highlighted for each of the domains.

It is clear that there are many opportunities for joint collaborations between the EU and US. Based on the work in this report a number of suggested collaboration opportunities have been put forward for further discussion in the PICASSO Expert Groups. This includes 15 areas where it may be possible to collaborate on research and policy, 16 areas where there is an opportunity to work together on regulations and 9 areas where it would be beneficial to work together on standards. These will be discussed and refined in future work to identify the key recommendations for future collaboration.

There are many areas where it would be possible to work together. There are key opportunities in the areas of smart cities and IoT/CPS which are rapidly developing areas and where there are common research, regulatory and standardisation needs. There are also great opportunities in the areas of smart energy and smart transportation, however, here there is existing regulation and legislation which needs to be harmonised.

For the underlying technologies which are the basic building blocks of future applications, e.g. 5G, Big Data and IoT/CPS, there are many opportuntiies to work together which would allow bilateral access to EU and US markets and would allow technology and products to be sold on the world stage increasing the competitiveness of EU and US companies in existing and developing markets.

11 References

[1] IBM - Survey on smart cities. A vision of smarter cities. How cities can lead the way into a prosperous and sustainable future. By Susanne Dirks and Mary Keelin, IBM Global Business Services Executive Report, IBM Institute for Business Value.

[2] http://www.ierc.ie/wp-content/uploads/2014/07/IERC-Resident-Engagement-Whitepaper.pdf

[3] *Smarter cities for smarter growth. How cities can optimize their systems for the talent-based economy.* By Susanne Dirks, Constantin Gurdgiev and Mary Keeling. IBM Global Business Services Executive Report, IBM Institute for Business Value.

[4] Mapping Smart Cities in the EU, Directorate General for Internal Policies Economic and Scientific Policy, Jan 2014.

[5] http://www.smart-cities.eu/

[6] European Commission (2011a) 'eGovernment Benchmark Pilot on Open Government and Transparency', prepared by Capgemini, IDC, Rand Europe, Sogeti and DTi. http://ec.europa.eu/information_society/newsroom/cf/dae/itemdetail.cfm?item_id=10145, http://ec.europa.eu/information_society/activities/sustainable_growth/docs/smartcities/smart-cities-adv-group_report.pdf

[7] Communication from the Commission to the European Parliament, The Council and the European Economic and Social Committee 2013, Commission Communication on Smart Cities, October 2012

[8] Smart Cities and Communities Initiative, launched in 2011, http://ec.europa.eu/dgs/connect/en/content/smart-cities

[9] http://setis.ec.europa.eu/implementation/technology-roadmap/european-initiative-on-smart-cities

[10] European Innovation Partnership (EIP) on Smart Cities and Communities (EIP-SCC).

[11] European Commission, 2012, Communication from the Commission – Smart Cities and Communities – European Innovation Partnership.

[12] European Innovation Partnership on Smart Cities and Communities Operational Implementation Plan: First Public Draft Sherpa Group Feb 2014.

[13] European Innovation Partnership on Smart Cities and Communities Strategic Implementation Plan October 2013.

[14] Smart Cities Stakeholder Platform Integrated Action Plan – Report Process & Guidelines Dec 2013.

[15] Smart Cities Stakeholders Platform Finance Working Group Guidance Document using EU Funding Mechanisms for Smart Cities Nov 2013.

[16] https://eu-smartcities.eu/content/small-giants-0

[17] Smart Cities: Background paper, Department for Business, Innovation and Skills, UK, October 2013.

[18] "Preparing the way for smart cities" BSI: https://www.bsigroup.com/Documents/standards/case-studies/BSI-supporting-innovation-smart-cities-case-studies-UK-EN.pdf

[19] BIS Research Paper No. 135, "International Case Studies on Smart Cities", Department for Business, Innovation and Skills, UK, October 2013.

[20] BIS Research Paper No.136, "The Smart City Market: Opportunities for the UK", Department for Business, Innovation and Skills, UK, October 2013.

[21] https://www.gov.uk/government/news/new-initiative-to-support-40-billion-smart-cities-in-the-uk

[22] http://www.bis.gov.uk/foresight/our-work/projects/current-projects/future-of-cities

[23] http://liveablecities.org.uk/

[24] Smart Cities Transforming the 21st century city via the creative use of technology, ARUP 2010.

[25] HyperCat consortium: http://www.hypercat.io/

[26] https://www.gov.uk/government/news/launch-of-smart-cities-initiative

[27] http://www.smartsantander.eu/

[28] http://www.spiegel.de/international/world/santander-a-digital-smart-city-prototype-in-spain-a-888480.html

[29] http://spain-lab.net/project/smart-citizen-fab-lab-barcelonaiaachangar/

[30] http://cityclimateleadershipawards.com/barcelona-barcelona-smart-city/

[31] http://amsterdamsmartcity.com/

[32] http://www.spiegel.de/international/business/amsterdam-as-smart-city-going-green-fast-in-holland-a613503.html

[33] http://www.npr.org/sections/parallels/2013/06/12/190693661/tallinn-the-former-soviet-city-that-gave-birth-to-skype

[34] http://www.river-cities.net/pages/show/Stockholm_2013

[35] https://www.whitehouse.gov/the-press-office/2015/09/14/fact-sheet-administration-announces-new-smart-cities-initiative-help

[36] https://www.nitrd.gov/sccc/

[37] Citizen-Centred Governance: The Mayor's Office of New Urban Mechanics and the Evolutions of CRM in Boston, Case Study, By Susan Crawford and Dana Walters, July 30, 2013.

[38] Portney, K. 2005. Civic Engagement and Sustainable Cities in the United States. Public Administration Review, 65(5): 579-591.

[39] http://www.cisco.com/c/dam/en_us/about/ac79/docs/ps/motm/City-24x7_PoV.pdf

[40] http://venturebeat.com/2014/05/01/nyc-wants-to-turn-all-of-its-payphones-into-a-massive-citywide-wifi-network/

[41] http://www.hudsonyardsnewyork.com/

[42] http://bottomline.seattle.gov/2013/07/09/high-performance-building-pilot/

[43] [http://www.forbes.com/sites/ptc/2014/08/15/5-u-s-cities-using-technology-to-become-smart-and-connected/#39f350b33539

[44] DC Geographic Information System Program: http://octo.dc.gov/node/718302

[45] http://www.smartcommunitieschicago.org/index.html

[46] http://www.fastcoexist.com/1680967/the-top-10-smartest-cities-in-north-america#1

[47] http://smartcities.ieee.org/home/ieee-smart-cities-initiative.html

[48] http://www.scmp.com/comment/insight-opinion/article/1898359/how-hong-kong-can-become-smart-city-connected-future

[49] Research Report on Smart city, Central Policy Unit, The Government of the Hong Kong Special Administrative Region. September 2015. http://www.cpu.gov.hk/doc/en/research_reports/CPU%20research%20report%20-%20Smart%20City(en).pdf

[50] "Comparative Study of Smart Cities in Europe and China" prepared for Ministry of Industry and Information Technology (MIIT), DG CNECT EU Commission with the China Academy of Telecommunications Research (CATR), White paper, June 2014.

[51] http://symposium.net.au/australia-its-time-to-be-the-smart-country/

[52] http://www.computerweekly.com/news/4500256861/Australian-cities-are-getting-smarter

[53] http://www.adelaidecitycouncil.com/assets/documents/NATGEO-adelaide-smart-city.pdf?utm_source=media%20release&utm_medium=PDF-download&utm_content=smart-city&utm_campaign=NatGeo

[54] http://www.citysmart.com.au/

[55] http://www.cityofsound.com/files/c40_melbourne_report_final_email.pdf

[56] http://www.zdnet.com/article/city-of-melbourne-pushes-for-smart-cities-built-on-it/

[57] http://newsroom.cisco.com/feature-content?type=webcontent&articleId=1738492

[58] http://www.nesta.org.uk/news/10-people-centred-smart-city-initiatives/better-reykjavik

[59] http://searchsoftwarequality.techtarget.com/news/4500245158/Data-privacy-lawyer-explains-data-by-design

[60] Privacy and snooping in Smart cities: utopia or reality? vol 11, issue 01, Engineering and Technology Magazine, 18 January 2016, By Katia Moskvitch (http://eandt.theiet.org/magazine/2016/01/privacy-and-smart-cities.cfm?utm_source=Adestra&utm_campaign=E%26T%20News%20Trial%20Programme%20Daily%20Members%20A1%20-%20Day7&utm_medium=Newsletters%20-%20E%26T%20News&utm_content=E%26T%20News%20-%20Frequency%20Trial%20Programme%20%28Daily%29&utm_term=http%3A%2F%2Feandt.theiet.org%2Fmagazine%2F2016%2F01%2Fprivacy-and-smart-cities.cfm&utm_contact=32547089)

[61] http://www.bsigroup.com/Documents/standards/case-studies/BSI-supportinginnovation-smart-cities-case-studies-UK-EN.pdf

[62] Smart city framework – Guide customer service to establishing strategies for smart cities and communities, BSI Standards Publication, PAS 181:2014, Department for Business Innovation and Skills, February 2014.

[63] www.etsi.org

[64] European Commission (2012a) 'Energy Efficient Buildings'. http://ec.europa.eu/research/industrial_technologies/energy-efficient-buildings_en.html

[65] European Commission (2011b) 'Report of the Meeting of Advisory Group ICT Infrastructure for Energy-Efficient Buildings and Neighbourhoods for Carbon-Neutral Cities: Strategic Priorities for the New Framework Programme for Research and Innovation Covering the Period 2014–2020', 16 September.

[66] http://www.europarl.europa.eu/RegData/etudes/etudes/join/2014/507480/IPOLITRE_ET(2014)507480_EN.pdf

[67] http://climate-adapt.eea.europa.eu/cities

[68] https://setis.ec.europa.eu/set-plan-implementation/technology-roadmaps/european-initiative-smart-cities

[69] The ICT Roadmap for Energy Efficient Neighbourhoods (http://www.ireenproject.eu/)

[70] http://www.smartgrids.eu/KIC-InnoEnergy

[71] https://eu-smartcities.eu/content/positive-energy-blocks

[72] http://www.world-nuclear.org/information-library/country-profiles/countries-a-f/france.aspx (Updated 31 March 2016)

[73] http://www.metering.com/frances-smart-grid-project-sogrid-rolls-out-to-1000-homes/

[74] The future of Heating: Meeting the challenge, published in March 2013, UK https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/190149/16_04-DECC-The_Future_of_Heating_Accessible-10.pdf

[75] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/276656/smart_meter_roll_out_for_the_domestic_and_small_and_medium_and_non_domestic_sectors.pdf

[76] Low Carbon Pioneer Cities Heat Networks Project: a process evaluation. Department of Energy & Climate Change, January 2015 (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/457057/Pioneer_Cities_Evaluation_27_08.pdf)

[77] http://www.lowcarboninnovation.co.uk/working_together/strategic_framework/overview/

[78] https://www.gov.uk/government/news/20m-up-for-grabs-for-energy-storage-innovation

[79] https://www.ofgem.gov.uk/sites/default/files/docs/2010/11/lcnbro_0.pdf

[80] http://www.ifhp.org/sites/default/files/staff/PreConferenceReport_FINAL080915.pdf

[81] https://www.epa.gov/laws-regulations/summary-energy-independence-and-security-act

[82] https://www.treasury.gov/initiatives/recovery/Pages/recovery-act.aspx

[83] Blueprint for a Secure Energy Future, March 30, 2011 (http://www.whitehouse.gov/sites/default/files/blueprint_secure_energy_future.pdf)

[84] "A Policy Framework for the 21st Century Grid: Enabling Our Secure Energy Future", National Science and Technology Council, June 2011.

[85] www.SmartGrid.gov

[86] http://www.whitehouse.gov/sites/default/files/microsites/ostp/nstc-smart-grid-june2011.pdf

[87] Global Inventory and Analysis of Smart Grid Demonstration Projects, DNV KEMA Energy & Sustainability, October 2012.

[88] http://smartgrid.ieee.org/about-ieee-smart-grid

[89] Evolution of the smart grid in China, Xu et al., McKinsey on Smart Grid, Summer 2010.

[90] http://www.metering.com/china-to-invest-us31bn-in-provincial-smart-grid-by-2020/

[91] http://www.metering.com/canadas-ontario-seeks-new-projects-for-smart-grid-fund/

[92] http://www.metering.com/smart-grid-trends-in-japan-7-things-to-know/

[93] http://www.metering.com/smart-grid-equipment-market-to-grow-in-south-korea/

[94] http://www.metering.com/brazils-power-outages-push-case-for-smart-grid-technology/

[95] http://www.metering.com/smart-grid-india-government-approves-us210m-investment/

[96] Smart Grid, Smart City: Shaping Australia's Energy Future, Executive Report, July 2014. By Arup, Energeia, Frontier Economics, Institute for Sustainable Futures (University of Technology Sydney), http://industry.gov.au/Energy/Programmes/SmartGridSmartCity/Documents/SGSC-Executive-Report-National-Cost-Benefit.pdf

[97] [http://www.metering.com/smart-grid-mexico-smart-meters/

[98] http://magrid.raabassociates.org/Articles/DNVKEMAReportGlobalInventorySmartGrid%20Projects.pdf

[99] http://www.smartgrids.eu/node/70

[100] https://ec.europa.eu/energy/en/topics/markets-and-consumers/smart-grids-and-meters/smart-grids-task-force

[101] http://www.smartgrids.eu/ACER

[102] http://www.smartgrids.eu/CEER

[103] Smarter Grids: the opportunity, Department Energy and Climate Change, December 2009 (file:///C:/Users/uos/Downloads/smartergridsopportunity.pdf)

[104] A Smart Grid Routemap, Electricity Networks Strategy Group, , February 2010 (http://webarchive.nationalarchives.gov.uk/20100919181607/http:/www.ensg.gov.uk/index.php?article=126)

[105] https://www.ofgem.gov.uk/electricity/distribution-networks/network-innovation/low-carbon-networks-fund

[106] https://www.gov.uk/government/publications/2010-to-2015-government-policy-uk-energy-security/2010-to-2015-government-policy-uk-energy-security

[107] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/285417/Smart_Grid_Vision_and_RoutemapFINAL.pdf

[108] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/486362/Towards_a_smart_energy_system.pdf

[109] http://www.smartgrids.eu/sites/default/files/private/2011_03_01_mandate_m490_en%5B1%5D.pdf

[110] http://www.smartgrids.eu/standards

[111] http://www.cencenelec.eu/standards/Sectors/SustainableEnergy/SmartGrids/Pages/default.aspx

[112] NIST Special Publication 1108R2, NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 2.0

[113] http://www.nist.gov/smartgrid/upload/NIST_Framework_Release_2-0_corr.pdf

[114] Cyber Security of the Smart Grids, Summary Report. The paper was produced by the European Commission using input and comments from the Expert Group on the Security and Resilience of Communication Networks and Information Systems for Smart Grids (file:///C:/Users/uos/Downloads/SummaryReport.pdf).

[115] http://www.mcafee.com/uk/resources/white-papers/wp-smart-grid-cyber-security.pdf

[116] https://www.whitehouse.gov/sites/default/files/microsites/ostp/nstc-smart-grid-june2011.pdf

[117] http://www.nist.gov/el/smartgrid/cybersg.cfm

[118] "Roadmap for Cross-Modal Transport Infrastructure Innovation - Towards a Performing Infrastructure", ERTRAC, ERRAC, Waterborne, ACARE, ECTP, 2013.

[119] "A Sustainable Future for Transport", Directorate-General for Energy and Transport European Commission, 2009.

[120] "European Transport Policy for 2010 - Time to Decide", CEC, 2001.

[121] http://www.errac.org/

[122] http://www.ertrac.org/

[123] http://www.acare4europe.com/

[124] http://www.waterborne-tp.org/

[125] "Keep Europe Moving - Sustainable Transport for our Continent", CEC, 2006.

[126] "Traffic Management for Land Transport", Transport research Knowledge Centre, Directorate-General for Energy and Transport, European Commission, 2009.

[127] www.car-2-car.org

[128] Thematic Research Summary, Intelligent transport systems, 2014 (http://www.transport-research.info/sites/default/files/thematic-analysis/20150430_174628_50849_TRS22_fin.pdf)

[129] http://www.transport-research.info/sites/default/files/thematic-analysis/20150430_174628_50849_TRS22_fin.pdf

[130] Policy Paper: Sustainable Urban Mobility and the Smart City. Scope – Finance – Community Building. POLIS | Cities and regions networking for innovative transport solutions, January 2016, http://www.polisnetwork.eu/uploads/Modules/PublicDocuments/2016-polis-smart-city-policy-paper.pdf

[131] http://ec.europa.eu/transport/themes/its/index_en.htm

[132] "Directive 2010/40/EU of the European Parliament and of the Council of 7 July 2010 on the framework and deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport", 6th August 2010.

[133] "Towards a 50% More Efficient Road Transport System by 2030", ERRAC, 2010.

[134] "Vision 2020 and Challenges", White Paper, ERTRAC, 2004

[135] http://www.transportncps.net/index.php?option=com_k2&view=item&layout=item&id=249&Itemid=344]

[136] https://eu-smartcities.eu/content/new-mobility-services

[137] http://www.drive-c2x.eu/project

[138] http://www.ertico.com/prevent

[139] http://www.cvisproject.org/cvisproject/en/about_cooperative_systems/introduction/index.html

[140] http://www.safespot-eu.org/
[141] http://ercim-news.ercim.eu/en67/special-theme-embedded-intelligence/coopers-automotive-visions-beyond-in-car-driver-assistance
[142] http://www.cvisproject.org/en/links/pre-drive_c2x.htm
[143] http://www.ecomove-project.eu/links/comesafety/
[144] http://www.haveit-eu.org/
[145] https://www.media.volvocars.com/global/en-gb/media/pressreleases/136182/volvo-car-group-initiates-world-unique-swedish-pilot-project-with-self-driving-cars-on-public-roads
[146] http://ec.europa.eu/research/transport/road/green_cars/index_en.htm
[147] https://ec.europa.eu/programmes/horizon2020/en/h2020-section/smart-green-and-integrated-transport
[148] http://urbanforesight.org/projects/projectsites/ev4scc/about-ev4scc/
[149] https://eu-smartcities.eu/content/electromobility
[150] U. Clausen, "A European Perspective of Current and Future Research on Sustainability in Transportation", TRB Conference, Washington 2013.
[151] http://europa.eu/legislation_summaries/environment/air_pollution/l28186_en.htm
[152] http://www.dhl.com/en/about_us/green_solutions/gogreen_products_services.html
[153] http://www.cofret-project.eu/
[154] http://www.greenfreighteurope.eu/
[155] https://www.government.nl/latest/news/2015/12/02/government-authorities-investing-70-million-in-intelligent-transport-systems
[156] http://www-03.ibm.com/press/us/en/pressrelease/40212.wss
[157] [http://www.verkeersnet.nl/3728/enschede-krijgt-vip-reistijdinformatiesysteem/
[158] [http://meet.barcelona.cat/en/visit-barcelona/get-around-the-city/electric-vehicles
[159] http://w41.bcn.cat/mou-te/
[160] http://www.catalonia.com/en/trade-with-catalonia/sustainablemobility.jsp
[161] http://www.zaragoza.es/ciudad/viapublica/movilidad/trafico/trafico.htm
[162] http://www.zaragoza.es/contenidos/sectores/tecnologia/Estrategia-Ciencia-Tecnologia-en.pdf
[163] https://www.ibm.com/midmarket/ie/en/att/pdf/IBM_DCC_130715.pdf
[164] http://www.mobithess.gr/
[165] https://ts.catapult.org.uk/
[166] http://www.mira.co.uk/our-services/intelligent-transport-systems/
[167] http://www.ieee802.org/11/Reports/tgp_update.htm
[168] "Roadmap to a Single European Transport Area - Towards a competitive and resource efficient transport system", European Commission, 2011
[169] "Joint Strategy for European Rail Research -Vision 2020", 2001.
[170] "Strategic Rail Research Agenda 2020 European Rail Advisory Council", May 2007.
[171] http://errac.uic.org/IMG/pdf/Suburban_and_Regional_Railways_Landscape_in_Europe.pdf
[172] http://www.uitp.org/sites/default/files/cck-focus-papers/files/errac_metrolr_tramsystemsineurope.pdf
[173] http://www.railway-research.org/Rail-Research-in-Europe
[174] "RailRoute 2050 - The Sustainable Backbone of the Single European Transport Area", ERRAC.
[175] http://www.errac.org/foster-rail/
[176] http://errac.uic.org/spip.php?article13
[177] http://www.ertms.net/

[178] http://www.shift2rail.org/shift%C2%B2rail-officially-launched-alongside-other-horizon2020-jtis-at-the-european-commissions-launch-event-in-brussels/
[179] "Modernising the European Sky", SESAR. 2011.
[180] "Today's Partners for Tomorrow's Aviation", SESAR,
[181] http://www.gsa.europa.eu/galileo-0
[182] https://www.atmmasterplan.eu/
[183] "European ATM Master Plan - The Roadmap for Sustainable Air Traffic Management", Edition 2, SESAR, October 2012.
[184] "European ATM Master Plan Edition 2", Factsheet, SESAR 2012.
[185] http://www.cleansky.eu/
[186] https://www.thalesgroup.com/en/united-kingdom/defence/watchkeeper
[187] http://www.baesystems.com/enhancedarticle/BAES_157659/taranis-unmanned
[188] http://astraea.aero/
[189] http://www.imo.org/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Nitrogen-oxides-(NOx)-%E2%80%93-Regulation-13.aspx
[190] http://www.vsat-systems.com/
[191] http://www.waterborne-tp.org/
[192] "Waterborne Transport Thematic Research Summary", Transport Research Knowledge Centre, Directorate-General for Mobility and Transport, European Commission, 2010.
[193] "Waterborne Vision 2025 - Waterborne Transport and Operations Meeting the Challenges through Ambitious Innovation", December 2012.
[194] "Waterborne Strategic Research Agenda Implementation", May 2011.
[195] "Waterborne Strategic Research Agenda Overview Issue II", May 2011.
[196] http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/2634-mg-4.2-2014.html
[197] http://www.e-maritime.com/
[198] http://ec.europa.eu/maritimeaffairs/documentation/multimedia/videos/items/video3_en.htm
[199] http://www.economist.com/news/technology-quarterly/21598318-autonomous-cargo-vessels-could-set-sail-without-crew-under-watchful-eye
[200] http://www.its.dot.gov/its_program/about_its.htm#sthash.JFHy2v82.dpuf
[201] [http://www.ssti.us/
[202] The Innovative DOT: A Handbook of Policy and Practice. State Smart Transportation Initiative (SSTI) & Smart Growth America (SGA), January 2015. (http://www.ssti.us/2015/01/the-innovative-dot-a-handbook-of-policy-and-practice-ssti-sga/)
[203] http://www.smartgrowthamerica.org/issues/transportation
[204] https://www.transportation.gov/smartcity
[205] http://arc.applause.com/2015/12/08/smart-cities-challenge/
[206] (https://www.transportation.gov/sites/dot.gov/files/docs/Draft_Beyond_Traffic_Framework.pdf
[207] http://traffic.berkeley.edu/project
[208] http://www.umtri.umich.edu/
[209] J. Parker, "Applying a Systems of Systems Approach for Improved Transportation", SAPIENS, Vol. 3, Issue 2, 2010.
[210] http://www.apple.com/uk/ios/carplay/?cid=wwa-uk-kwg-features-com
[211] http://www.openautoalliance.net/
[212] http://www.inrix.com/companyoverview.asp

[213] https://www.whitehouse.gov/sites/default/files/blueprint_secure_energy_future.pdf

[214] http://en.wikipedia.org/wiki/Google_driverless_car

[215] http://www.forbes.com/sites/alexkonrad/2013/11/01/meet-orion-software-that-will-save-ups-millions-by-improving-drivers-routes/

[216] http://www.nytimes.com/2014/08/07/us/delays-persist-for-us-high-speed-rail.html?_r=0 (August 06, 2014)

[217] http://www.faa.gov/nextgen/

[218] Press Release "Lockheed Martin Plans "System of Systems" Approach For UAVS", Farnborough, England, July 23rd, 2002

[219] http://www.lockheedmartin.co.uk/us/what-we-do/aerospace-defense/unmanned-systems.html

[220] http://www.amazon.com/b?node=8037720011

[221] http://www.ihsglobalinsight.com/Highlight/HighlightDetail15614.htm

[222] *The Maritime Administration and the U.S. Marine Transportation System: A Vision for the 21st Century.* United States Department of Transportation Maritime Administration, November 2007.

[223] http://www.maritime-executive.com/article/us-announces-2016-funding-for-infrastructure-projects]

[224] http://www.americanmaritimepartnership.com/about-amp/

[225] http://www.marketsandmarkets.com/PressReleases/smart-transportation.asp

[226] http://www.itsnetwork.org/

[227] http://www.ertico.com/ertico-its-europe/

[228] http://itsworldcongress.org/

[229] http://www.ewg.apec.org/keypillars.html

[230] http://www.itsinternational.com/categories/utc/news/us-to-offer-smart-transportation-solutions-for-three-indian-cities/

[231] http://ec.europa.eu/digital-agenda/en/ecall-time-saved-lives-saved

[232] http://www.safetrip.eu/

[233] http://www.cvisproject.org/en/links/c2c-cc.htm

[234] http://ec.europa.eu/transport/themes/its/road/action_plan/

[235] M/453 http://ec.europa.eu/enterprise/sectors/ict/files/standardisation_mandate_en.pdf

[236] ec.europa.eu/digital-agenda/en/towards-5g

[237] ANALYSIS, Understanding 5G: Perspectives on future technological advancements in mobile, GSMA Intelligence, December 2014.

[238] https://www.metis2020.com/

[239] https://metis-ii.5g-ppp.eu/

[240] http://www.eitdigital.eu/news-events/news/article/toward-green-5g-mobile-networks-5green-new-project-launched/#gridView

[241] http://www.ict-ijoin.eu/

[242] http://www.ict-crowd.eu/

[243] http://networld2020.eu/overview/

[244] http://www.surrey.ac.uk/mediacentre/press/2015/5g-innovation-centre-officially-opens-university-surrey

[245] http://www.surrey.ac.uk/5gic

[246] http://www.ctr.kcl.ac.uk/5G2015/

[247] http://eandt.theiet.org/magazine/2015/03/tactile-internet-5g.cfm

[248] https://5g.co.uk/news/ericsson-king%E2%80%99s-college-london-5g-research/4066/
[249] http://www.fast-zwanzig20.de/EN/
[250] http://5glab.de/
[251] http://www.5g-berlin.org/
[252] https://www.telkom.com/5ghaus
[253] http://5gtnf.fi/overview/
[254] www.tekes.fi/5thGear
[255] http://www.5gamericas.org/en/newsroom/industry-news/commerce-approves-mobile-now-act-and-nominations/
[256] http://www.4gamericas.org/en/newsroom/press-releases/4g-americas-evolves-name-5g-americas/
[257] http://www.fiercewireless.com/tech/special-reports/top-5-academic-institutions-leading-5g-research
[258] https://wncg.org/tags/5g-wireless-networks
[259] http://wireless.engineering.nyu.edu/
[260] http://www.5gamericas.org/en/newsroom/member-news/t-mobile-and-ericsson-partner-5g-pre-standard-trials/
[261] https://www.washingtonpost.com/news/innovations/wp/2015/10/26/what-is-5g-and-why-should-lawmakers-care/
[262] http://www.cnet.com/uk/news/verizon-to-hold-worlds-first-crazy-fast-5g-wireless-field-tests-next-year/
[263] https://www.ngmn.org/uploads/media/NGMN_5G_White_Paper_V1_0.pdf
[264] http://www.fiercewireless.com/tech/story/china-south-korea-commit-5g-leadership-while-japan-and-us-rely-private-effo/2014-06-08
[265] http://about.keysight.com/en/newsroom/pr/2014/11aug-em14115.shtml
[266] http://www.5gforum.org/#!eng/cvb1
[267] https://www.etri.re.kr/eng/sub6/sub6_0101.etri?departCode=6
[268] http://www.timesofmalta.com/articles/view/20150712/local/pm-thanks-sai-mizzi-as-chinese-telecoms-giant-prepares-to-test-5g-in.576179
[269] http://www.huawei.com/minisite/5g/en/huawei-5gppp.html
[270] http://www.rtvnoord.nl/nieuws/152709/Noord-Groningen-krijgt-onvoorstelbaar-snel-mobiel-internet
[271] http://www.gsma.com/newsroom/press-release/gsma-publishes-new-report-outlining-5g-future/
[272] http://www.fiercewireless.com/story/verizons-mcadam-5g-speeds-will-be-1-gbps-and-will-be-live-verizon-hq-januar/2015-12-08
[273] https://www.nttdocomo.co.jp/english/corporate/technology/whitepaper_5g/index.html
[274] http://spectrum.ieee.org/tech-talk/telecom/wireless/5g-coming-sooner-not-later
[275] https://uk.news.yahoo.com/nokia-5g-pickup-could-begin-early-2017-chief-193049841--finance.html
[276] http://www.itu.int/en/ITU-T/focusgroups/imt-2020/Pages/default.aspx
[277] http://spectrum.ieee.org/telecom/wireless/telecom-experts-plot-a-path-to-5g
[278] https://www.washingtonpost.com/news/innovations/wp/2015/10/26/what-is-5g-and-why-should-lawmakers-care/
[279] http://www.cnet.com/news/how-5g-will-push-a-supercharged-network-to-your-phone-home-and-car/
[280] http://www.forbes.com/sites/larrydownes/2015/09/09/judgment-day-for-the-fccs-latest-net-neutrality-folly/#14b16b046f92

[281] http://www.forbes.com/sites/mergermarket/2015/12/04/fcc-facing-identity-crisis-over-net-neutrality-challenge/#5a8f3b9b2908
[282] https://ec.europa.eu/digital-single-market/en/digital-single-market
[283] Towards a thriving data-driven economy. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Brussels, July 2014.
[284] http://ec.europa.eu/digital-agenda/en/open-data
[285] https://ec.europa.eu/digital-single-market/en/big-data-value-public-private-partnership
[286] http://ec.europa.eu/digital-agenda/en/blog/open-and-smart-cities-common-future
[287] http://opencities.net/
[288] https://ec.europa.eu/digital-single-market/en/blog/open-and-smart-cities-common-future
[289] https://www.govdata.de/
[290] http://data.amsterdam.nl/
[291] http://commonsforeurope.net/
[292] http://www.esade.edu/web/eng
[293] http://codeforeurope.net/]
[294] https://www.codeforamerica.org/
[295] http://guifi.net/
[296] http://www.citadelonthemove.eu/en-us/about/aims.aspx
[297] http://www.forumvirium.fi/en/project-areas/smart-city/open-helsinki-hack-at-home
[298] https://www.gov.uk/government/publications/e-infrastructure-strategy-roadmap-for-development-of-advanced-computing-data-and-networks
[299] https://www.gov.uk/public-data-group
[300] http://theodi.org/
[301] Report To The President Big Data And Privacy: A Technological Perspective", Executive Office of the President President's Council of Advisors on Science and Technology May 2014 (https://www.whitehouse.gov/sites/default/files/microsites/ostp/PCAST/pcast_big_data_and_privacy_-_may_2014.pdf)
[302] http://www.nsf.gov/cise/news/bigdata.jsp
[303] http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504730, http://www.nsf.gov/cise/aci/cif21/CIF21Vision2012current.pdf
[304] https://datascience.nih.gov/bd2k/funded-programs
[305] http://www.darpa.mil/program/xdata
[306] https://defensesystems.com/articles/2015/07/06/us-cyber-forces-private-sector-help.aspx
[307] http://www.disa.mil/
[308] http://www.nist.gov/itl/bigdata/20150406_big_data_framework.cfm
[309] http://theodi.org/news/open-data-barometer-the-odi-publishes-key-research-as-challenger-initiatives-gather-speed
[310] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=URISERV%3Al14012
[311] http://ec.europa.eu/justice/data-protection/
[312] http://www.oecd.org/sti/ieconomy/oecdguidelinesontheprotectionofprivacyandtransborderflowsofpersonaldata.htm
[313] http://www.coe.int/en/web/conventions/full-list/-/conventions/treaty/108
[314] http://www.export.gov/safeharbor/index.asp
[315] Politico, Vol. 2 No.6, February 11-16 2016. Special Report Privacy Shield pp.13-16

[316] https://www.law.cornell.edu/constitution/amendmentxiv
[317] https://www.justice.gov/opcl/privacy-act-1974
[318] http://www.inc.com/encyclopedia/childrens-online-privacy-protection-act-COPPA.html
[319] ISO/IEC JTC 1, Information Technology, Big Data, Preliminary report 2014, ISO, IEC. http://www.iso.org/iso/big_data_report-jtc1.pdf
[320] http://standards.ieee.org/develop/project/2413.html
[321] http://www.itu.int/rec/T-REC-Y.3600-201511-I
[322] Gartner, "Top Strategic Predictions for 2016 and Beyond: The Future Is a Digital Thing"
[323] H.A. Thompson, "Cyber-Physical Systems: Uplifting Europe's Innovation Capacity", Report from the EC Workshop in Brussels, Belgium, October 2013
[324] https://ec.europa.eu/digital-single-market/en/europe-2020-strategy
[325] http://europa.eu/rapid/press-release_IP-16-1407_en.htm
[326] http://www.internet-of-things-research.eu/
[327] https://ec.europa.eu/digital-single-market/en/alliance-internet-things-innovation-aioti
[328] https://ec.europa.eu/digital-single-market/en/news/horizon-2020-work-programme-2016-2017-internet-things-large-scale-pilots
[329] http://www.iot-butler.eu/
[330] http://open-platforms.eu/?s=butler
[331] https://www.fiware.org/
[332] https://artemis-ia.eu/ecsel-joint-undertaking.html
[333] https://artemis-ia.eu/
[334] https://artemis-ia.eu/project/46-crystal.html
[335] http://www.artemis-emc2.eu/
[336] https://ec.europa.eu/digital-single-market/en/news/innovation-manufacturing-smes-i4ms-initiative-enhancing-digital-transformation-european
[337] https://smartanythingeverywhere.eu/
[338] http://www.plattform-i40.de/I40/Navigation/DE/Industrie40/industrie40.html
[339] http://www.iiconsortium.org/
[340] https://allseenalliance.org/
[341] http://openconnectivity.org/
[342] http://www.computerworld.com/article/3035084/internet-of-things/another-iot-group-ocf-may-really-make-it-all-work.html
[343] http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503286
[344] https://www.nitrd.gov/nitrdgroups/index.php?title=Cyber_Physical_Systems_(CPS_SSG)#title
[345] DRAFT, Framework for Cyber-Physical Systems, Release 0.8, September 2015, Cyber Physical Systems Public Working Group (http://www.cpspwg.org/)
[346] Strategic R&D Opportunities for 21st Century Cyber-Physical Systems. Connecting computer and information systems with the physical world. January 2013. (http://www.nist.gov/el/upload/12-Cyber-Physical-Systems020113_final.pdf)
[347] https://www.us-ignite.org/globalcityteams/about/#sthash.e4XmCrwo.dpuf
[348] http://www.intel.co.uk/content/dam/www/public/us/en/documents/corporate-information/policy-iot-framework.pdf
[349] http://www.nist.gov/cps/cpswpg_security.cfm
[350] https://www.nitrd.gov/nitrdgroups/index.php?title=Cyber_Security_and_Information_Assurance_Interagency_Working_Group_(CSIA_IWG)#title

[351] Federal Cybersecurity Research and Development Strategic Plan, *Ensuring Prosperity and National Security*, National Science and Technology Council, Networking and Information Technology Research and Development Program. February 2016

[352] https://www.nitrd.gov/Publications/PublicationDetail.aspx?pubid=61

[353] E&T Engineering and Technology Magazine vol 11, issue 02, IoT security threat, as embedded systems struggle, 15 February 2016, By Chris Edwards.