EcoQUIP

Delivering Efficiency, Quality and Sustainability in Healthcare

Provocation Paper

Challenges, priorities and emerging innovative solutions for the healthcare sector

Prepared for the
Innovation Procurement Workshop
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Lead Market Initiative for Europe

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1 Introduction

EcoQUIP builds on a previous European project (LCB-Healthcare), which identified the relatively high importance of procurement practice as a barrier to innovation. It then went on to demonstrate the transformational potential of innovation procurement[1] methodologies in individual hospitals and different countries. Some of the national case examples will be presented in the workshop and the more detailed lessons can be found in the final publication of the LCB-Healthcare project[2].

The healthcare sector in Europe is a huge and influential market. Every year the sector spends close to 10% of GDP[3] to deliver healthcare services through its 15,000 hospitals and other facilities. The drivers for new solutions are obvious but there are a variety of barriers that inhibit the development and procurement of innovative products & services. Most of these are institutional including traditional approaches to procurement practice and fragmented, organisational structures that are resistant to change. Procurement aggregators are fairly common for commodity products/services but there is a lack of coordinated frameworks that are designed to achieve rapid exploitation of novel solutions.

This provocation paper has been prepared to orientate and stimulate workshop participants in advance of the 1st EcoQUIP workshop on Innovation Procurement. Its purpose is to highlight common areas of need for innovative new solutions and provide some insights into both current and emerging technologies that could address those needs. It is based solely on secondary research and should therefore not be regarded as a detailed review of the subject but rather an interim document that is intended to be thought provoking and encourage constructive debate at the workshop.

The paper highlights developments in a number of thematic areas. It also includes a summary of some recent and current European R&D projects that have been co-funded under the 7th EU Framework Programme for R&D (2007-1013). These examples alone represent a collective investment of some €140 million from the EU and the participants. A key issue for EcoQUIP is to what extent is such projects really addressing the most important unmet needs and, if so, how can the barriers to exploitation be overcome. More importantly, how can EcoQUIP ensure that more of this EU investment is demand-driven?

The next chapter in EU funding begins on 1st January 2014. This is when the new, seven year framework programmes will commence, including the Horizon 2020 Programme for research and innovation. One of the priorities for this new programme is to be more strategic about using public procurement to drive innovation in Europe and, therefore, there will be funding opportunities for consortia of public procurers to prepare and co-finance innovation procurement activities.

An overview of these funding opportunities, and how they might relate to the priority themes for healthcare innovation, will be presented at the workshop.

[1] 'Innovation Procurement' is about buying goods and services in a way that stimulates the supply chain to invest in developing better and more innovative solutions to meet the unmet needs of an organisation

[2] Innovation Procurement: Delivering Efficiency, Quality and Sustainability in Healthcare – 10 Messages from the LCB-HEALTHCARE Pilot Projects - http://lowcarbon-healthcare.eu/newsitem/69

[3] Eurostat, September 2012

2 Healthcare Sector Challenges

Healthcare systems across Europe have to deal with a number of major challenges, such as an ageing population, rising cost of healthcare provision, retention of staff, the growing skills gap and increasing pressure on the sector to reduce its carbon footprint. In this section of the report a number of these challenges are introduced and in Section 3 we discuss specific areas of need that result from them. Possible innovative technology solutions are then introduced in Section 4.

2.1 Elderly Patients and the Prevalence of Chronic Diseases

Probably the biggest challenge for European healthcare is the need to adapt systems to an ageing population. The proportion of elderly (65+) in the EU is projected to grow from 17.4% of the population in 2010 to 30.0% in 2060 and the proportion of very old (80+) from 4.7% in 2010 to 12.1% in 2060[4].

Life expectancy in Europe is continuing to increase; but, although people may be living longer, it does not necessarily mean they are enjoying good health into old age – healthy life expectancy is between seven and ten years lower than average life expectancy.

Cultural changes around family structure, working couples and general attitudes to the elderly have resulted in increasing admission of elderly and the very old into healthcare facilities. Family patterns are such that older people increasingly do not live with their children under one roof anymore and with an increase in the number of women working (for example, in the UK in 1983 this was 51% but in 2012 it was 65%[5]), there has been a decline in the informal care that was provided within a traditional family structure. All of this has led to increased demand for formal care within a professional setting.

The elderly and very old require medical attention more often, frequently suffer from multiple chronic illnesses, have a higher average length of stay in hospitals than other age groups and in many instances need continuous care. It is generally accepted that after the age of 55, the amount of healthcare resources a patient consumes doubles every ten years[6].

Age-related diseases that are becoming more prevalent include neurodegenerative diseases, cancer, cardiovascular and metabolic diseases like diabetes, as well as pulmonary diseases and related infections of immune-deficient patients. In Europe, it is estimated that over 70% of healthcare costs are associated with chronic disease management[7].

Ageing populations and the rise of age-related chronic diseases, however, are not the only causes of increasing healthcare demand in Europe. Lifestyle choices, such as poor diet, lack of exercise and tobacco and alcohol misuse also contribute to a rise in lifestyle-related chronic diseases such as obesity and diabetes. Indeed, in a recent study, Candace Imison, acting director of policy at The King's Fund (a British healthcare think tank) cited obesity, alcohol abuse, smoking and lack of exercise as major challenges for the healthcare system that are driving healthcare needs[8].

[4] Demographic Report 2010 - Older, more numerous and diverse Europeans, European Commission, March 2011

[5] www.eurostat.ec.europa.eu

[6] Contract for a Healthy Future – The Role of Europe's Medical Technology Industry in Steering Healthcare Systems onto a Sustainable Path, MedTech Europe, October 2012

[7] Accelerating the Development of the eHealth Market in Europe, eHealth Taskforce Report, 2007

[8] Future-proofing Western Europe's Healthcare – A Study of Five Countries, The Economist Intelligence Unit, 2011

It has been estimated that over half the UK population could be obese by 2050 and NHS costs attributable to the treatment of overweight and obese citizens are projected to double to £10 billion per year by 2050[9]. The World Health Organisation (WHO) puts France, Denmark and the UK among the 20 biggest consumers of alcohol in the world, with over one in five people in each country smoking[8] as can be seen in the table below. This type of behaviour clearly brings with it risks of chronic disease and higher health costs and has additional implications for an ageing population; it would certainly be cheaper to treat a healthy ageing population than an unhealthy one.

	Adult Smokers (%)	Alcohol Consumption per Head (ltrs)
Denmark	20	13.4
France	26	13.7
Germany	22	12.8
Netherlands	28	10.1
United kingdon	22	13.4

Figure 1: Poor Lifestyle Choices Potentially Leading to Chronic Disease[8,10]

2.2 Patient Empowerment and Demand for New Technologies

It would seem that, in today's society, patients are demanding higher quality care, access to the latest treatments and therapies, and in general a much greater say in the delivery of healthcare services. Public access to health information still varies considerably across European countries and the quality of data in available sources is also highly variable. In spite of this, the established trend is for increasingly well informed and knowledgeable consumers to demand the very best in expertise and quality of services. Furthermore, they want their opinions and preferences to be acknowledged by healthcare professionals. A recent report suggests that even where there is little uptake of published information among patients, the existence of the information systems themselves can encourage changes in provider behaviour and lead to quality improvements[11].

This is all part of a much broader trend towards consumer-focused healthcare.

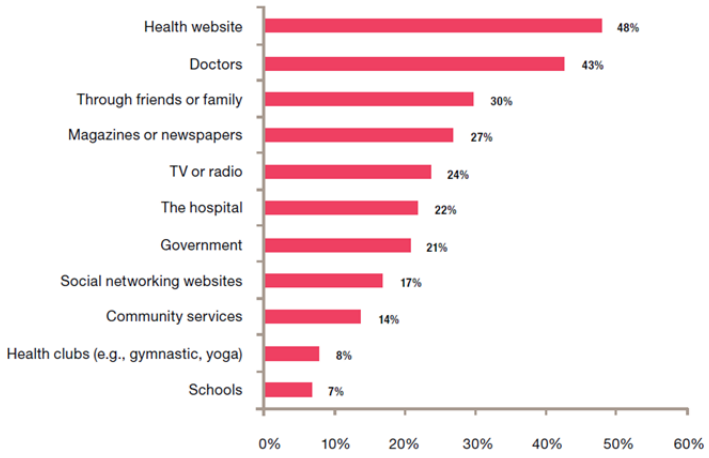

Figure 2: Sources of Health Information for Consumers[1]

[9] The British foresight report 'Tackling Obesities: Future Choices' (2nd Edition).
[10] Based on OECD and WHO data
[11] How Health Systems make Available Information on Service Providers, Rand Europe, 2011

Engaging patients in decisions concerning their health is a positive step but the increasing level of demand, particularly for the latest treatments and drugs, is contributing to the increasing burden on an already over-stretched European healthcare system.

2.3 Pressure on Budgets and Unsustainable Rise in Spending

The issues discussed above all lead to increased spending on healthcare. Public healthcare expenditure in the EU's 27 Member States continues to increase and at a rate that is faster than GDP. As a percentage of EU GDP, it was on average 5.9% in 1990, rose to 7.1% in 2010 and is projected to rise to 8.3% of EU GDP by 2060[12]. Some analysts believe the share of GDP spent on healthcare could double in the coming decade if the status quo continues.

This is an unsustainable trend for Europe, particularly as the proportion of tax paying citizens is reducing. There is a view that in future patients will be asked to contribute more to the cost of their healthcare

European healthcare systems need to invest in new technologies, if they are to improve operational efficiencies and reduce costs, and develop new models of healthcare delivery that make use of emerging technologies that enable dramatic increases in both efficiency and effectiveness of services.

2.4 The Rise of Healthcare Associated Infections

Healthcare associated infections (HAIs), which are also referred to as nosocomial, are infections that were not present or incubating at the time of patient admission and that can cause a range of symptoms from minor discomfort to serious disability and in some cases death.

HAIs are a growing problem for the European Union as Member States spend an increasing share of their budgets on dealing with the resultant problems. The situation is further compounded by the decreasing clinical effectiveness of antibiotics. Further, the elderly, which is a growing proportion of the population treated within healthcare systems, is amongst the group of patients at most risk of acquiring HAIs – patients with weakened immune systems are at the highest risk.

Highly resistant infections are more common in hospitals because of the high levels of antibiotic usage that allows organisms to evolve. This, along with the high concentration of at-high-risk patients means that microorganisms have the ideal opportunity to spread more readily than would otherwise be possible. The importance of addressing these issues are highlighted in Professor Dame Sally Davies 2011 report[13] that sets out 17 recommendations to named organisations to address the threat posed by antimicrobial resistance. Indeed the report calls for global action to mount an effective response.

The actual costs of HAIs to healthcare systems is difficult to calculate as there are many variables that need to be taken into account, such as the number and frequency of infections, their contribution to increased length of stay in acute healthcare facilities, the many systems for prophylaxis and control, the operational consequences for healthcare organisations and the effect on public trust in the healthcare system. According to the European Centre for Disease Prevention and Control (ECDC), the

[12] The 2012 Ageing Report: Economic and budgetary projections for the 27 EU Member States (2010-2060), European Commission, May 2012

[13] Annual Report of the Chief Medical Officer, Volume Two, 2011 Infections and the Rise of Antimicrobial Resistance, Prof. Dame Sally C. Davies

yearly number of patients in the EU with at least one healthcare associated infection can be estimated at 4.1 million (although this is an underestimation as it only represents hospital acquired infections and not infection associated with other healthcare facilities) which is equivalent to one in twenty hospitalised patients. Approximately 37,000 deaths are thought to be caused directly by hospital acquired infections and an additional 110,000 deaths occur yearly in which such infections have been contributing factors.

"Assuming an average excess hospital stay of 4 days (i.e. 16.4 million extra hospital days a year) and an average hospital bed cost of Euro 334 per day (not including post-hospital costs), the resulting healthcare cost for the EU can be estimated conservatively at Euro 5.48 billion per year"[14].

In the UK alone, the estimated cost for people that acquire a healthcare associated infection is over GBP 1 billion per year[15]

It is estimated that 20-30% of HAIs can be prevented through improved cleanliness, compliance with good hand hygiene and the implementation of novel and innovative new solutions, such as antibacterial materials, coating and surfaces and air sterilisation technologies.

2.5 Workforce Shortages and Skills Gaps

It is estimated that by 2020 there will be a shortfall of almost 1 million health professionals in the European Union. This doubles to 2 million if long term care and ancillary health professionals are included[16]. Forecasts predict a shortage of almost 600,000 workers in nursing alone by 2020 and a shortage of 230,000 physicians. This could mean that almost 14% of demand for care will go unmet, as shown in the table below.

Health Professional	Estimated Shortage by 2020	Estimated % of Care Not Covered
Physicians	230,000	13.5%
Dentists, pharmacists, physiotherapists	150,000	13.5%
Nurses	590,000	14.0%
Total	***970,000***	***13.8%***

Figure 3: Estimated Workforce Shortage in Healthcare Sector by 2020[16]

As the population in Europe ages so does the workforce and there are insufficient numbers of younger people entering the system to replace those that are retiring.

"In 2009, about 30% of all doctors in the EU were over 55 years of age and by 2020 more than 60 000 doctors or 3.2% of all European doctors are expected to retire annually. Based on data collected by some Member States the average age of nurses employed today is between 41-45 years"[16].

The sector suffers from low retention levels, believed to be because of relatively low pay in some healthcare professions, long working hours, stress and the difficulty in maintaining a healthy work-life

[14] Questions and Answers on patient safety, including the prevention and control of healthcare associated infections, MEMO/08/788, Brussels, 15th December 2008

[15] Reducing Healthcare Associated Infections in Hospitals in England, National Audit Office, June 2009

[16] Commission Staff Working Document – on an Action Plan for the EU Health Workforce, European Commission, April 2012

balance. The latter issue is a particular concern in the healthcare sector as the proportion of women working in this sector is high and continuing to increase.

Increasingly, healthcare professionals require a relatively high level of technical know-how in addition to clinical knowledge in order to operate new medical appliances and diagnostic techniques. They also need to utilise, to the fullest, emerging solutions such as eHealth, including electronic patient records and telemedicine.

Health professionals will need to develop new skills and competence required for new treatments and new care delivery models, particularly associated with increasing numbers of elderly people with multiple chronic conditions.

2.6 Rising Cost of Resources

The healthcare sector (including its supply chain) is a major consumer of energy, water, food, materials and chemicals, amongst many other resources and is estimated to create at least 5% of total EU carbon dioxide emissions, which is equivalent to its international aviation and shipping industries combined[17]. In England, the National Health Service (NHS) is believed to generate 25% of total public sector emissions at 18 million tons of CO_2 each year[18].

The major areas of concern are energy consumption, water consumption and waste management:

- Energy consumption in hospitals can be broken down into fuel applications, such as space heating and hot water, and electricity applications, such as ventilation, lighting and cooling
- Water consumption can be broken down into sanitary; HVAC (Heating, Ventilation and Air Conditioning); medical processes; food services and laundry
- Waste management, where solid waste such as paper, organics and plastics, accounts for the majority of the sector's pollution and disposal costs

There is now increasing impetus to improve the sector's environmental profile. EU leaders have committed to transforming Europe into a highly energy-efficient, low carbon economy. The EU has committed to cutting its greenhouse gas emissions to 20% below 1990 level and offered to increase its emissions reduction to 30% by 2020 if other major emitting countries in the developed and developing world commit to undertake their fair share of a global emissions reduction effort. Additional EU targets to be achieved by 2020 include: raising the share of EU energy consumption produced from renewable resources to 20% and a 20% improvement in the EU's energy efficiency[19].

2.7 The Impact of Climate Change

Climate change is considered by some as possibly the biggest global health threat of the 21st century[20]. The World Health Organisation estimates that climate change already contributes to 150,000 deaths every year. In Europe the threat centres mainly on higher temperatures, increased risk of flooding, the spread of vector-borne diseases (such as malaria) and possible changes in air and water quality.

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17 LCB-HEALTHCARE State of the Art Report, Low Carbon Buildings in Healthcare Sector

18 Saving carbon, improving health: NHS carbon reduction strategy, National Health Service, Sustainable Development Unit, Cambridge, January 2009.

19 The Climate and Energy Package, http://ec.europa.eu

20 Adaptation to Climate Change for Health and Social Care organisations, NHS Sustainable Development Unit

The European heatwave of 2003, thought to be the warmest period of extreme heat in Europe for up to 500 years, resulted in more than 20,000 premature deaths[21]. It has been projected that the number of heat-related hospitals admissions in a future period (2021-2050 compared to reference period of 1981-2010) could more than double in Europe with southern Europe facing a three-fold increase[22].

Hotter and longer summers, warmer winters and increased rainfall could enable arthropods that transmit vector-borne diseases to shift their habitats and potentially introduce diseases to regions that were previously unaffected. However, it should be noted that conclusively demonstrating the link between climate change and vector-borne disease spread is difficult as many other factors can have a significant influence, such as land use, human and animal population and increased travel between regions.

Clearly climate change is driving the need to develop strategies and implement appropriate mitigating systems so that the healthcare sector can ensure continuity of care, particularly for the most vulnerable group of patients, robustness of infrastructure and supply chains, and reliability of equipment.

[21] The Met Office

[22] Heat-related respiratory hospital admissions in Europe in a changing climate: a health impact assessment, BMJ Open 2013, Volume 3, Issue 1, Astrom C et al.

3 Priority Areas of Need

There is clearly a need to explore new and innovative solutions in order to help address the many significant challenges Europe's healthcare sector is currently facing. These solutions can range from relatively minor operational changes such as improved cleaning to reduce HAIs, to innovations in medical procedures, including robotic surgery and robot-assisted rehabilitation, to new models of healthcare delivery such as facilitating home-based care to reduce the number of hospital admissions.

A reorientation of Europe's healthcare systems has been proposed, from hospital-centred care to preventative, community and home-based care. This would enable the sector to optimise resources, delivering care on a one-to-many basis where appropriate and hospital admission would only be necessary in far fewer cases. There can, however, be significant resistance to change within the healthcare sector leading to long, expensive processes that may not address the real quality issues and leave the public and staff feeling unhappy[23]. Indeed it is often difficult to provide clear evidence of the benefits of reconfiguration and to ensure that all the drivers for change are given equal consideration.

Technologies that might facilitate changes in healthcare models could be used to increase patient empowerment, enabling the elderly, for example, to remain in their own homes for longer and provide patients (and physicians) with much more data on health conditions.

In addition there is a growing need to improve the continuity of care, particularly for patients suffering from multiple chronic diseases. Solutions such e-prescribing and electronic health records have the potential to improve this situation.

In this section, we highlight specific areas of need in which new technologies have significant potential to improve efficiency and quality of care whilst reducing the cost of care. Examples of specific solutions to address these needs are discussed in the subsequent sections of this report.

3.1 Reduce Burden on Hospitals (New Healthcare Models)

3.1.1 Prevention rather than treatment

Solutions are required to keep people healthier for longer, to maintain a healthy lifestyle, prevent the onset of illness and better manage disease before complications arise that then require hospital admission and costly care and treatment. Involving patients and healthy individuals in self-care and health maintenance is now vital and could range from self-testing and self-management to fully-autonomous prevention and care. It is clear from the literature that:

- Prevention requires solutions that can facilitate the maintenance of healthy lifestyle, including for example monitoring and guidance on nutrition and tools that encourage physical activity
- Early diagnosis is a key element in preventing the onset of serious conditions that then require acute care
- Chronic disease management, particularly for the elderly and very old patient, requires special emphasis. More and better technologies are required that monitor conditions on an on-going basis with built-in triggers and alerts to help both the patient and the healthcare provider better manage conditions and coordinate care

[23] Briefing - Reconfiguring Hospital Services, C. Imison, The Kings Fund, 2011

There is certainly scope for healthcare systems across Europe to spend more on the prevention of disease; it is likely that hospital admissions could be avoided if patient care was better managed. [It is noted, however, that spending on public health has been curtailed somewhat in the aftermath of the financial crisis].

Solutions that improve access to diagnostic facilities and capabilities are needed, as well as tools that encourage or facilitate patients to undergo preventative health check-ups are required.

3.1.2 Community-based and home care

There is a need for healthcare delivery models that facilitate a shift from hospital-based care to delivery of primary care closer to the home. This is required to better manage the increase of elderly patients with multiple chronic diseases, such as heart disease and diabetes, and to make better use of limited healthcare resources.

This area includes technologies, such as telehealth and remote robotics, which enable the elderly to live longer in their own home and more independently, despite being chronically ill or disabled in some way. Examples of potential solutions include alarm and safety systems, daily living support, fall prevention and social interaction services.

Dramatic efficiency improvements are possible through the implementation of one-to-many services. For example, using advances in telehealth and robotics to offer remote rehabilitation for patients that would enable a therapist to treat, remotely, many more patients than would be possible by the traditional model of out-patient appointments (and associated lowering of the carbon footprint of patient travel to hospitals). An example of this in action is in Norrbotten, Sweden, where patients suffering from long term or chronic illnesses can monitor and report values to their district healthcare centres, or via video link, receive help with physiotherapy or 'meet' specialist for consultations[24].

3.1.3 New solutions to improve efficiency of healthcare professionals

Currently, health and social care services are usually delivered independently, leading to inefficiencies, duplication of resources or reduced levels of quality or care. Integrating care and improving continuity of care would both improve efficiency and increase quality of care. Patients with multiple chronic diseases often see several physicians, sometimes at different healthcare facilities.

Elderly patients are particularly affected by the discontinuity in healthcare services and for them integrated healthcare will need to extend beyond health systems and into long-term social care. According to the OECD, between 10% and 20% of West Europeans over 65 require some form of long-term care.

Implementing electronic health records would vastly improve the efficiency of coordinating this type of care.

3.2 Reducing Operational Costs/Impact

There is significant potential for healthcare facilities to implement a range of efficiency measures to reduce the environmental impact of operational procedures and associated costs. The main areas of opportunity are energy, water and waste management as well as a reduction in the use of hazardous substances.

[24] 'A Part of Your daily Life, City Council of Norrbotten

3.2.1 Energy Efficiency Technologies

The main energy-saving opportunities in hospitals are in the domains of lighting, heating, ventilation and air-conditioning (HVAC) systems. There are a number of energy-efficient intelligent technologies already commercially available that could be introduced as feasible permanent measures (rather than temporary demonstration projects). For example, presence detection control combined with intelligent software that tracks how a room is used and occupant behaviour (such as opening windows) can be utilised to greatly reduce energy consumption for lighting and HVAC.

To reduce their carbon footprint, healthcare facilities need to switch energy supply to low carbon non-fossil technologies, such as solar PV and solar thermal, biomass boilers and heat pumps to name a few.

Hospitals are particularly suited to a range of renewable energy options – they operate 24/7, are highly energy intensive, based on large sites with large roof areas, are powered by fossil-based energy and were built at a time when energy costs where low. To increase investment in renewable energy systems, healthcare facility decision makers need to be made aware of the various options, including the technical risk and benefits of implementation; funding support is required; and a move away from the traditional approach to capital investment is required.

Transportation is responsible for about a quarter of EU greenhouse gas emissions. Healthcare facilities make heavy use of transportation systems to move patients, workers and supplies. There may be an opportunity to further introduce fuel efficient technologies, alternative and hybrid fuel technologies into ambulances and shuttle buses. Additionally, local providers could be prioritised when selecting suppliers to reduce transportation distance and associated emissions.

3.2.2 Resource Efficiency Technologies

Improving water efficiency is a priority area of need. As discussed earlier, hospitals are large consumers of water and there is a pressing need to implement water-efficient technologies and practices that lead to reduced water consumption.

To begin with, healthcare facilities need to establish a comprehensive water management programme and this will require analysis of current water consumption practices. In general, priority areas are usually sanitation, HVAC, medical processes, food services and laundry services. A range of technologies could be adopted to reduce water consumption, such as electronically controlled valves that switch off automatically after use, shorter hand-wash cycles, reduced-flow showerheads, waterless urinals, etc. We provide examples of FP7 projects where innovative solutions are being developed in some of these areas later in this report.

With regard to waste, the majority of medical waste, up to 85%, is similar to normal municipal waste and so is of low risk. Healthcare facilities need to develop suitable waste management strategies and operations that:

- Avoid waste generation, for example by implementing electronic and not paper data systems
- Consider re-useable products rather than disposable single-use items
- Look to segregate and recycle whenever possible
- Seek to employ environmentally sustainable treatment and disposal methods, such as non-burn treatment technology

3.2.3 Reduce Use of Hazardous Substances

The healthcare sector consumes significant amounts of chemicals, including those that are documented to cause serious impact on health and the environment. Examples of potentially hazardous substances handled in hospital environments include:

- Fixer and developer baths from X-ray departments
- Hazardous microbiological cultures, dyes and solvents
- Substances from nuclear medicine/radiology (including radioactive substances)
- Concentrates of disinfectants and cleaning agents, bleaches and detaching agents
- Substances used in chemotherapy treatments

Less hazardous alternatives should be used instead where possible. Certainly, with regard to cleaning chemicals, a number of alternative methods are under development (as discussed later in the report).

3.3 Reducing the Occurrence of HAIs

3.3.1 Improved cleaning technologies and tools

Regular facility cleaning and good hand hygiene practice may not be sufficient to combat the growing problem of HAIs. Improved methods of disinfecting the hospital environment are required to ensure high-touch surfaces and equipment items are free from pathogens and contaminations. A range of solutions have been developed or are under development both in industry and via collaborative research projects with academic institutions. Examples include development of antibacterial materials and surface coatings, novel sterilisation technologies that destroy airborne pathogens, and nano-enabled solutions. These solutions must be environmentally sustainable, for example water consumption and the use of hazardous chemicals need to be minimised.

In addition to technology solutions, improved training of cleaning personnel is required, to ensure compliance with key prevention practices. Novel cleaning management tools have been developed to aid cleaning personnel, such as marking gels on high touch surfaces to indicate whether or not a surface was effectively cleaned and fast turnaround microbiological tests (as discussed below).

3.3.2 Microbiological sensors

Rapid tests and handheld devices have been developed to monitor the cleanliness of key surfaces. The most common systems used today are ATP-based monitoring devices that measure the amount of adenosine triphosphate (ATP), an enzyme present in all living cells, remaining on a surface after cleaning.

There is however a need for further development of new technologies in this area as current systems may not be robust enough for quantitative analysis on bacterial concentrations, particularly at low levels[25].

3.3.3 Demand-led ventilation systems

Poor indoor air quality is contributing to the problem of HAIs and new solutions are required to deal with air contaminants, which include fungus, mould, bacteria, inorganic and organic matter that can cause problems from nuisance colds to fatal pneumonia.

[25] Ideal Method for Detection of Bacteria on Hospital Surfaces Still Elusive, Researchers Say, Infection Control Today, May 2011

Inadvertently, the drive to reduce heating loads and save energy by shutting windows could be making the problem worse. And in some hospital areas, such as offices, ventilation systems may be operating above the levels necessary and, therefore, wasting energy.

There is, therefore, a clear need for improved systems that can deliver the required ventilation as and when required in a similar fashion to demand-led lighting. It may be that sensors and intelligent control technology could be combined with infection control systems to deliver high quality air, free of contaminants.

4 Innovative Solutions for Healthcare

The previous section highlights the main areas of need for innovative solutions to address healthcare challenges. This section considers some of the current and emerging technologies that could address these needs. This includes some examples of European R&D projects. Further details of these are included in Appendix A.

4.1 ICT for Healthcare (eHealth)

Information communication technologies (ICT) are expected to play an increasingly important role in future healthcare operational performance and delivery of services. There is an enormous range of possible applications of ICT in healthcare. Broadly, applications can be grouped under four categories of objectives[26]:

- Increasing quality of care and efficiency – accurate collection and exchange of health data, ready availability of individual patient medical information, online access to clinical guidelines or drug databases, monitoring systems and prevention of medication errors
- Reducing operating costs of clinical services – integration of electronic patient management tools, such as electronic medical records (EMRs) or electronic health records (EHRs) into clinical workflows. This includes e-prescriptions and picture archiving and communications systems (PACS)
- Reducing administrative costs - which could include electronic payment methods, possibly with links to private healthcare insurance policies and other healthcare payment/funding systems
- Enabling entirely new modes of care delivery – exploring new primary health services and improving access to care through telehealth innovations, primary care centres that make use of electronic access to patient records and mHealth services that make use of mobile connectivity and smart phone to enable better disease diagnosis and management

In the UK alone, at least £200 million has been spent since 2006 supporting pilot projects in the area of 'remote care' and has been highlighted in over 20 official reports and government white papers[27].

A selection of some possible ICT applications in healthcare is discussed further below.

4.1.1 Electronic Health Records

Many organisations across Europe have been implementing electronic health record (EHR) systems at an organisational and, in some cases, at a regional healthcare level. There is no universally accepted standard definition for the term EHR but broadly speaking it refers to a shared, integrated or interlinked (virtual) record of patient health data and is independent of when, where and by whom the data was recorded.

The European Commission's Seventh Framework Programme (FP7) has funded a number of projects in this area. In general, these projects have been centred on interconnecting EHR with innovative delivery solutions and making better use of data for early detection and prevention.

[26] Improving Health Sector Efficiency – the roles of information and communication technologies, OECD, 2010

[27] http://www.james-barlow.com/page_2810036_remotecare.html

Some examples of FP7 projects, where innovative healthcare solutions are being developed that are either based on or make use of EHR, is provided here:

- SMARTPERSONALHEALTH – this Support Action sought to promote interoperability among Personal Health Systems and between eHealth systems in the landscape of continuous care, across multilingual and multi-cultural environments in Europe
- iCARDEA – was aimed at developing an intelligent platform to semi-automate the follow-up of CIED (cardiovascular implantable electronic devices) patients with context-aware, adaptable computer interpretable clinical guideline models, with EHR interoperability
- DECIPHER – is seeking to deploy Pre-commercial Procurement (PCP) to generate a portfolio of interoperable applications to enable a patient to use a secure mobile device safely to gain 24/7 access to their prescription data, emergency data, examination results and other health information. Deployed on a pan-European platform, the portfolio will improve existing healthcare services by supporting mobility of patients and healthcare providers
- LINKED2SAFETY – will facilitate the scalable and standardized semantic interlinking, sharing and reuse of heterogeneous EHR repositories
- ALERT - The overall objective of this project was the design, development and validation of a computerized system that exploits data from electronic healthcare records and biomedical databases for the early detection of adverse drug reactions

In addition, examples of EHR-type systems already implemented in Europe include:

- The Emergency Care Record (ECR) systems deployed in Scotland since 2007
- The IZIP system in the Czech Republic
- The personal health record (eLAK) systems in Bulgaria
- The National Patient Summary (NOP) pilot in Sweden

Regional Deployment of Electronic Health Records in Spain

The DIRAYA EHR systems in Andalucía, Spain, is a good example of the first true regional EHR system, covering a significant populations (over 8 million) fully integrating all patient information from primary to tertiary care including emergency and in-patient care, also connecting all pharmacies, their logistics and billing.

4.1.2 Electronic Prescriptions

The term ePrescription is generally understood as the electronic transfer of a prescription by a healthcare provider in a primary care or community health centre setting to a pharmacy for retrieval of the drug by the patient. More sophisticated systems could include the use of decision support tools, such as an integrated medication management solution that has additional safety features such as allergy lists and automatic alerts to warn of potentially harmful drug interactions.

It has been suggested that electronic prescribing could be a way of improving the monitoring and tracking of HAIs if the prescribing of antibiotics in hospitals could be linked to patient records[14].

Countries that have implemented full ePrescription processes at a national level include Denmark, Estonia, Iceland, and Sweden. Others such as the Netherlands have established routine use of

ePrescription in some regions, and there are pilots underway in the Czech Republic, Finland, Italy and Poland.

ePrescribing in Denmark

Demark has a long history of ICT adoption in healthcare and electronic prescribing has existing in the country since the early 1990s and is now widely adopted. Primary care providers routinely prescribe drugs electronically with ePrescribing and implementation rates at close to 100%[28]. The system enables patient access via web-based services, allowing patients to view medication profiles and even to re-order certain repeat medications.

ePrescribing at Doncaster and Bassetlaw Hospital, UK

ePrescribing systems provided by JAC Medicines Management. First phase of the project began in 2002 with a trial at Montagu Hospital and was followed by a roll-out to three further wards during 2003. The systems was then updated to link to patient's medical records[29].

4.1.3 Telecare, Telehealth and Telemedicine

Telehealth is an umbrella term that is sometimes interchanged with telemedicine or telecare and there are many different definitions of the term used across Europe by Member States, networks and trade representative bodies. Broadly speaking it encompasses personalised health systems and services such as disease management services, remote patient monitoring, teleconsultation, telecare, telemedicine, and teleradiology.

Amongst many other benefits, telehealth will help address the issue of shortages of health workers as well as improve access to specialist services, particularly for patients with limited mobility or for those in remote locations.

Telehealth services can be segmented into services between doctors (D2D) and services direct to the patient (D2P), where:

- Teleservices between health professionals/doctors includes teleconsultation, teleradiology and telepathology
- Teleservices directly offered to patients includes telemonitoring and telehomecare, emergency care, care of mobile patients and internet based patient consultations

Some examples of FP7 projects in this area are shown below. These projects range from remote patient guidance systems and digital avatars, to wearable sensor networks and creation of intelligent home environments to facilitate home-care.

- MOBIGUIDE - will develop a patient guidance system that integrates hospital and monitoring data into a Personal Health Record (PHR) accessible by patients and care providers and provide personalized secure clinical-guideline-based support also outside clinical environments

[28] eHealth Strategies, Country Brief:Denmark, European Commission, October 2010

29 Review of the Potential Benefits from the Better Use of Information and Technology in Health and Social Care, PricewaterhouseCoopers LLP, January 2013

- SWAN-ICARE – the core of the project is the fabrication of a conceptually new wearable negative pressure device equipped with Information and Communication Technologies for the management of wound healing; mainly diabetic foot ulcers (DFU) and venous leg ulcers (VLU) treatment
- FALLWATCH DEMO - a new generation of practical, easy to use and install, reliable fall detectors
- WEEG - this research will focus on the microelectronic related issues of: a) reducing power to enable long term monitoring; b) reducing the size of electroencephalography (EEG) systems; c) reducing the amount of specialist time required to interpret the signals. These are key stepping stones for achievement of a truly wearable ambulatory EEG system (WEEG)
- HEATWEAR –the aim of the project is to to develop a novel wireless product for preventive screening and monitoring of ischemic conditions
- PSYCHE – sought to develop a personal, cost-effective, multi-parametric monitoring system based on textile and portable sensing platform for the long and short term acquisition of data
- BRAVEHEALTH - a patient-centric vision to CVD (cardiovascular diseases) management and treatment, providing people already diagnosed as subjects at risk with a sound solution for continuous and remote monitoring and real time prevention of malignant events. The solution will include a wearable sensor unit for continuous monitoring, a remote management unit for clinical interface and remote support, and a gateway unit with real time communications, education and support
- MOBISERV – to design and evaluate a system and service to support independent living of senior citizens by means of a proactive personal companion robot integrated with smart textiles, innovative sensors, and a smart home environment
- MYHEALTHAVATAR - a proof of concept for the digital representation of patient health status. It is designed as a lifetime companion for individual citizens that will facilitate the collection of, and access to, long-term health-status information
- USEFIL - developing advanced but affordable in-home unobtrusive monitoring and web communication solutions, using low cost "off-the-shelf" technology to develop immediately applicable services that will assist the elderly in maintaining their independence and daily activities

There are many examples of innovative eHealth technologies entering the market place. An indicative list, based on a competition as part of eHealth Week 2013 (the largest annual eHealth event in Europe) is provided below[30], where the “Promise” category refers to innovations from SME with turnover less than Euro 500.000 and "Champion" refers to SMEs with turnover above Euro 500.000.

- "Promises" category winners:
  - Sense Observation Systems (The Netherlands) developed "Goalie", a context-aware, personal health assistant to improve cognitive behavioural therapy for mental care
  - Biovotion (Switzerland) offers continuous, non-invasive, wearable concepts for accurate physiological monitoring embedded into mHealth.
  - BrainControl (Italy) gives disabled people the ability to control objects with their minds.

[30] Commission Awards Prizes to Best eHealth SMEs, Press Release 14/05/2013

- "Champion" category winners:
  - Medisana AG (Germany): VitaDock, a free, medically-certified “app” for smartphones and tablets to compare blood pressure, blood glucose, weight and temperature data.
  - Vivago (Finland): VivagoGlobal, personal security system calling for help when the patient cannot, offering preventive care and reduced costs
  - qUK Preventive Medicine (UK) offering The Prevention Plan - A Comprehensive Care Co-Production System

There were a total of 212 applications for the competition and a selection of the other finalist includes:

- "Promise" category finalists:
  - Cognuse (Estonia) radically improving mental rehabilitation accessibility.
  - DNAlytics (Belgium): RheumaKit, an early online diagnostic solution for patients with arthritis.
  - Mood Institute (France): an easy-to-use tool to monitor depression and bipolar disorder.
  - Saludnova (Spain): home tele-monitoring solutions for multi-pathologic chronic disease patients with real-time detection of alarm situations.
  - TedCas Medical Systems (Spain): handling of information in hospital environments, developing touch-free natural user interfaces.
  - WINMedical (Italy): a wireless physiological multi-parameter monitoring system designed for general medical wards and home monitoring.
- "Champion" category finalists:
  - C4U Technologies (Denmark): a web-based personal health record and secure messaging system between patient and physician.
  - Mediconsult (Finland): Medinet service, providing necessary health status data and engaging users through remote self-reporting and treatment.
  - Medisana AG (Germany): VitaDock, a free, medically-certified app for smartphones and tablets to compare blood pressure, blood glucose, weight and temperature data.
  - SaludOnNet (Spain): 360º eHealth cloud platform to connect patients, clinics, doctors and health insurance

Telehealth in Kent, UK

Kent County Council has invested £1 million in a telehealth pilot scheme that involves 250 patients across the county with long-term conditions. Each teleheath patient has a range of self-monitoring devices covering four main functions, depending on each individual’s particular condition: blood pressure; weight; blood glucose; and pulse oximetry. The system includes an electronic hub, which patients use to upload their readings each day and receive messages and advice back from their nurse. Results are reported to have been better than expected, with the prevention of unplanned hospital admissions for less complex cases; patients with complex co-morbidities have stayed in their homes and away from hospital for longer; and acute care costs are down by more than 60 per cent in some patient groups[31].

4.2 Innovative Materials and Devices for Healthcare Delivery

[31] Telehealth in Kent: What’s Behind the Success?, NHS Institute for Innovation and Improvement

4.2.1 Smart Fabrics and Interactive Textiles

Smart textiles for healthcare applications can be segmented into two areas:

- Clothing with sensors or devices embedded within the fabric or attached to the garment, such as fall detectors, data loggers and activity detectors
- Clothing with sensors close to or in contact with the skin for body sensing and monitoring where the fabric itself can be used as the sensor

We list below, projects in the field of smart fabrics and interactive textiles, co-funded by the European Commission, Information Societies Technologies, in the 6th and 7th Framework Programmes:

- MYHEART - integration of system solutions into functional clothes with integrated textile sensors for continuous monitoring of vital signs, making diagnoses, detecting trends and to react on it (feedback devices, able to interact with the user as well as with professional services)
- BIOTEX - The project was aimed at developing dedicated biochemical-sensing techniques compatible with integration into textile. The approach was aims at developing sensing patches, adapted to different targeted body fluids and biological species to be monitored, where the textile itself is the sensor
- PROETEX – development of integrated smart wearables for emergency disaster intervention personnel, improving their safety, coordination and efficiency and for injured civilians, optimising their survival management. Amongst other proposed functions, the smart garment sought to integrate continuous monitoring of life signs (biopotentials, breathing movement, cardiac sounds) and continuous monitoring biosensors (sweat, dehydration, electrolytes, stress indicators
- STELLA – development of stretchable and soft-touch substrates, including electronic assembly on theses substrates, to enable high comfort body monitoring sensor networks
- OFSETH – investigations into the use of optical devices embedded into textiles for the measurement of as cardiac, respiratory rates, oximetry pH and glucose concentration
- CONTEXT – the objectives of the project were to create a system where different types of contactless sensors are incorporated into textiles to be used in continuous monitoring of individuals, with particular focus on textile sensor electrodes that pick up the muscle and heart electric signals and miniaturized pre-processing sensor electronics connected to a textile substrate which contains conductive yarn structures for data and power transmission
- MERMOTH – project aims were to create a comfortable, wearable monitoring prototype unit, based on a "wearable interface" and implemented by integrating smart sensors, advanced signal processing techniques and new telecommunication systems on a textile platform
- SYSTEX – wearable electronics embedded in or transformed into textile systems are a new generation of products that contribute to economy as well as to society. SYSTEX wants to bring partners involved in European projects in this area together in order to group the results of numerous efforts that are currently going on

4.2.2 Nanotechnology-based Products

Nanotechnology already provides many different medical solutions, including therapeutics and diagnostics. The technology scope is very broad, encompassing for example nanofluidic devices and

lab-on-chip devices as next generation diagnostic tools, material developments to aid healing and nanoengineered antimicrobial functionality to combat the spread of HAIs.

Examples of FP7 projects in healthcare related applications are provided as follows:

- BACTERIOSAFE - development of a wound dressing that involves the sophisticated design of nanocapsules that release signalling molecules and antibiotic/antimicrobials in the presence of pathogenic bacteria
- CAMINEMS - aims at developing new tools based on microfluidics and nanotechnologies, to improve cancer diagnosis and prognosis
- EMBEK1 - Development and analysis of polymer based multifunctional bactericidal materials
- FABIMED - aims to use nanoscience research to develop advanced manufacturing techniques for medical devices. Nanoscience has the potential to vastly improve medical devices resulting in smaller, more sophisticated medical implants, e.g. heart stents, rapid point-of-care diagnostics, and efficient, painless drug delivery
- LIGHT.TOUCH.MATTERS - product designers and material researchers will collaborate to jointly develop a fully new generation of smart materials that combine touch sensitivity with luminosity, based on latest developments in polymeric piezomaterials and flexible OLEDs
- Nanobond – this project has resulted in the development of durable antimicrobial textiles with a polymeric coating in the nano range in thickness that can withstand industrial laundry cycles. The aim of project was to develop easy-to-clean textiles that last long, use few chemicals, keep patients healthy and avoid cross-contamination
- NANODIARA - the main objective of this project is the development of modified superparamagnetic iron oxide nanoparticles (SPION) as a diagnostic tool for the detection of early stages of rheumatoid arthritis and osteoarthritis. In addition to research, the project will consider the social, ethical and legal aspects of applying nanotechnology for medical purposes
- NANOFOL – folate-based nanobiodevices for integrated diagnosis/therapy targeting chronic inflammatory diseases

4.3 Technologies to Improve Medical Procedures

4.3.1 Novel Surgical Tools

Robotics for healthcare is an emerging field and applications can range from robotised surgery, robotised patient monitoring systems and robotised motor coordination analysis and therapy. Of course there are many other novel, non-robotic, instrument innovations such as tools (bone reamers, for example) that have been redesigned for ease of cleaning and sterilisation and novel materials, such as shape memory alloys, are being explored to enable greater functionality and efficiency in surgical procedures.

Examples of FP7 projects in this area are:

- SAFOS - aimed at demonstrating that a properly controlled robotic surgery carried out in accordance to our safety criteria can improve the level of patient safety currently achievable by traditional surgery

- I-SUR - the project will demonstrate that an autonomous robotic surgical action, carried out with the developed technologies, can be as safe as currently achievable by traditional surgery
- CLEANTOOLS - will provide a method for the manufacture of surgical instruments containing Shape Memory Alloy (SMA) materials though the use of rotary friction welding (RFW). RFW is a low heat input solid phase welding technology that will preserve the properties of the materials in question. CleanTools will improve the function of flexible surgical instruments, reduce the required cleaning and disinfection effort, improve reliability and reduce the cost of manufacture within Europe
- URALP - to create an advanced augmented micro-surgical system through research and development of real-time cancer tissue imaging, surgeon-machine interfaces, assistive teleoperation, intelligent (cognitive) safety systems, and augmented-reality
- STREAM - the overall goal was to create a breakthrough in microsurgery by supplying innovative robotic tools to enhance the surgeon's manipulation accuracy

4.3.2 Rehabilitation Robotics and Systems

Robotic systems can be used to help patient recovery within the field of rehabilitation treatment and can facilitate home treatment, especially when the treatment involves repetitive activities.

Examples of FP7 projects in this area are provided below.

- MONARCH - develop and introduce a fleet of robots that collaborate with medical personnel and interact with patients
- REWIRE - develops, integrates and field tests an innovative virtual reality based rehabilitation platform - to assemble off the shelf components
- SCRIPT - robot-mediated rehabilitation has shown the potential of robotic devices for delivering repetitive training thus allowing for a large number of repetitions to be delivered during acute and chronic phases of stroke rehabilitation.
- STROKEBACK - StrokeBack will combine state-of-the-art monitoring devices forming a wireless Body Area Network that enable simultaneous measurement of multiple vital parameters and currently executed movements that are particularly of interest from a Stroke rehabilitation point of view

4.3.3 New Measurements / Diagnostic Technologies

A range of new measurement and diagnostic technologies are being developed to improve operational efficiency and enable improved patient care. These can range from point of care diagnostics, which allow early and quick disease detection, to more detailed assessment tools that will enable personalised care.

Some examples of FP7 projects in this area are:

- ISA - providing web-based diagnostic and/or therapeutic support for complex medical cases requiring specialized opinions in different health areas (initially adults and paediatrics Oncology as well as Infectious Diseases)
- CD-MEDICS - the overall concept of the project was to develop a technology platform for point-of-care diagnostics, capable of simultaneous genomic and proteomic detection, with embedded communication abilities for direct interfacing with hospital information systems

- PYTHIA - the project aims at developing a novel integrated optoelectronic biochip for the early diagnosis of diseases. These biochips are envisioned to "prophesise" potential predisposition to, or diagnose the early onset of human diseases, paving the way for advances in personalised health care
- SPIDIA – aimed at developing quality guidelines for molecular in-vitro diagnostics and standardising the pre-analytical workflow in related procedures, as well as developing modern pre-analytical tools for diagnostics improving the stabilisation, handling and study of free biomolecules within blood, plasma, serum, tissues and tumours
- CEED3 - the development of diagnostic tools to differentiate specific subgroups of diabetic patients to allow individualization of patient care
- NANOTRYP - development of new and innovative diagnosis and treatment tools, using the nanobody technology
- DIATOOLS – development of an integrated instrument that combining a broad range of groundbreaking technologies to enable minimally invasive diagnostics, prognostics, and follow-up of treatment of cancers.
- PARCIVAL – the project aims to develop a multi-analyte lab-on-a-chip platform for simultaneous detection of resistance patterns, biomarkers for severity of infection, and infectious pathogens from patients and air samples. It will enable point-of-care testing for immediate evidence-based therapy thereby reducing unspecific use of antibiotics
- INFACT – developing the means to convert wound dressings into a diagnostic tool capable to inform both patient and therapist about the wound status, thus directing towards the following therapeutic step. The proposed functional materials include a real time diagnostic reaction that positively influences the wound healing due to the timely intervention to treat infection or proteolytic stasis in the wound
- NADINE - development of fully integrated lab-on chip instruments able to perform elaborate multimodal biomarker analysis on a routine basis and at the ultrasensitive level required to allow minimally invasive tests

4.4 Technologies to Improve Operational Procedures

4.4.1 Infection control and innovative cleaning solutions

A number of solutions have been proposed to tackle the problem of rising HAIs and to address the growing need to reduce both water consumption and use of hazardous cleaning chemicals. The development of antibacterial materials and imparting antibacterial functionality to surfaces is a particularly active field of research and innovation.

Some examples of relevant FP7 projects are shown below. These projects range from the development of antibacterial cleaning cloths to novel air sterilisation solutions, which destroy airborne biological agents, and nano-structured antibacterial copper coatings.

- CuVito - antibacterial coatings represent a huge market in healthcare and food sectors. CuVito™ brings together Mexican mining products and European product development, to produce a state-of-the-art copper nano-structured coating
- CLEANWARD – the project will develop titanium dioxide coated ultra-microfibre fabric where the coating will react with water and UV to produce a highly reactive environment, killing all harmful micro-organisms without the need for chemical disinfectant and with low water usage

- SELFCLEAN – the development of antibacterial coatings consisting of Sn-Ni matrix with doped TiO2 nanoparticles and applied to commonly touched objects in healthcare facilities
- PROHIBIT – the project aims to understand existing guidelines and practices to prevent healthcare-associated infections in European hospitals with focus on central line associated bloodstream infections
- CLEANCLOTH - the development of a superior cleaning cloth with constant and continuous antibacterial effect was proposed and was accomplished by a unique technology where the antibacterial agent is integrated into the microfiber of the cloth
- SONO – the development of a pilot line for the production of medical antibacterial textiles. The pilot line will be based on the scale-up of a sonochemical process developed and patented at one of the partners' laboratories
- HAIFREE – the design of a new method and device for purification of indoor pollutants (VOCs - volatile organic compounds, microbes, spores, and fungi). The purification unit will be able to sterilize airborne biological agents contained in a moving air stream at high airflow rates

The appeal is the promise of surface coatings that can self-decontaminate after a bio-contamination event. A Broad spectrum of antimicrobial activity can be provided by metal-containing antimicrobial surface materials via the controlled release of metal ions. Silver coatings are commercially available but their use in healthcare facilities is limited because of their high costs. The development of alternative, cheaper and more suited-to-healthcare options, therefore, are of particular interest - for example the above FP7 CuVito project in which low cost copper based coatings with antibacterial functionality are to be developed.

Plasma Field, Airborne Infection Control Technology

Novaerus, a US company, has developed an air sterilisation system that emits a plasma field that generates particles to kill harmful microbes in a patient's room or common area. The technology has long been used in aerospace and semiconductor industries. The company claims the device kills 99.99 percent of airborne microbes and reduces microbial surface counts by up to 68 per cent.

4.4.2 Improved procedures and systems

Solutions being developed in this area range from the implementation of lean principles (a set of "tools" that assists in the identification and steady elimination of waste) into healthcare procedures, to best practice in handover of patients and even medical equipment that improves patient management. This area can also include solutions that automate processes, as highlighted in the case example here.

Fully Automated Laboratory System at Copenhagen's Hilleroed Hospital

The hospital has installed a flexible and fully automated blood sampling system that utilises world-class robotic technology and enables the laboratory to communicate results directly with the clinical word or the general practitioner.

Hospitals staff realised inefficiencies in their blood sampling procedures and, after reviewing state-of-the-art options, consulted with industry and agreed specifications for the new laboratory.

Cutting time from sample taking to results delivery (by at least 50%) has meant quicker patient treatment and fewer errors.[32]

Some relevant examples of FP7 projects include:

- ORCAB - benchmarking organisational and individual factors that impact on quality of care and patient safety and designing bottom up interventions that increase both quality of care and well-being
- QUALICOPC – assessment of the performance of health care systems via two surveys across 32 countries: one of GPs and the other of users in primary care
- HANDOVER - identified and studied best practices and created standardized approaches to handoff communication at the primary care hospital interface and measured the effectiveness of these practices in terms of costs and impact
- LEAN – developing better understanding of Lean production implementation in hospitals and R&D units, and specifically, identify conditions that explain why and how Lean production would have a positive effect on hospital
- EPOSBED-DEMO – the development into commercial stages of a speciality bed for hospitals that assists patients with limited mobility

4.5 Technologies to Reduce Environmental Impact

4.5.1 Low Carbon Energy Solutions

Low carbon energy solutions include:

- Options that reduce energy demand (energy efficiency) – such as thermal insulation, low energy lighting, electrical controls on pumps and motors and energy management systems
- Non-fossil fuel energy generation technologies (renewable energy systems) – such as biomass boilers/CHP, solar PV, solar heating, heat-pump technologies, etc.

Improved lighting includes replacement of existing luminaires with energy efficient fittings and installation, were appropriate, of ceiling mounted illumination detectors and controls to reduce electrical lighting when daylight is available.

There is great potential in the installation of energy saving software that enables a 'sleep' mode when equipment is not used for long periods of time. Timer controls in hospitals kitchens for example could be used to turn off extraction hoods after a set time.

Some relevant examples of FP7 projects in this area include:

- HERCULES – this project aims to produce a step-change solution for LED-based illumination systems for an extended range of applications. It is based on an original concept that combines the light from different LED sources to produce near-perfect colour rendition, variable colour temperatures at the same time with high energy efficiency
- GREENERBUILDINGS - will investigate how buildings can dynamically adapt their operations according to actual use, aiming at substantial energy savings. The project aims to realise an integrated solution that addresses the challenge of energy-aware

[32] Denmark's Top-Class Robot Technology, European Hospital, 20th May 2013

adaptation from basic (energy harvesting) sensors and actuators, up to the embedded software for coordinating thousands of smart objects with the goals of energy saving and user support

- SMILES - it was the purpose of the project to design the Smart Laundry-2015 through research, further development and adaptation of 16 key technologies (combined for green sites or individual for existing plant augmentation). These include water reduction, energy savings, green fuel substitutions for CO_2 reductions, new energy systems and improved sequencing of the processes, greater textile hygiene

A number of projects in this area have also been funded by the Intelligent Energy (IEE) Programme, which is part of the EU Competitiveness and Innovation Framework Programme (CIP). One of these is the RES-Hospitals project[33], which has been carrying out pilot project in 18 hospitals in seven EU countries. Each of the hospitals are developing an investment plan to produce at least 50% of their energy needs from renewable energy sources by 2020 and exploring options to become zero carbon sometime in the future. The pilot projects, and evidence from case examples in other hospitals, clearly indicate a tendency to focus on options that are well proven. Since the majority of energy consumption in a hospital is for heating and/or cooling then the most popular renewable energy investments at present are biomass systems and ground source heat pumps. Many hospitals have invested in solar energy systems (for electricity and/or heating) but in most cases these only provide a relatively low proportion of the energy demand. Depending on geographic locations there are also some examples of wind turbines and hydropower systems as well as integration within community energy systems.

For the future, technologies such as deep geothermal, hydrogen fuel cells and energy-from-waste systems are seen as potentially very important but most hospitals regard these as high risk at present. Security of energy supply is absolutely vital for a hospital and so there is much interest in dual options that include both on-site energy production and procurement of renewable electricity, gas and hot/cold water from energy utilities. Hospital energy centres would also be an ideal environment for innovative energy storage systems such as hydrogen produced from renewable energy, pumped-hydro, fluid phase-change and electro-magnetic systems.

HosPilot – Intelligent Energy Efficiency Control in Hospitals[34]

This is also a CIP/IEE project, which finished in February 2012. It was aimed at assessing energy saving potential in hospitals and providing an ICT-based scheme to reduce energy consumption. Three pilot projects were executed in hospitals:

UMCG Hospital, Groningen (NL) – an average of 23% was saved on electricity for lighting. Technologies demonstrated: BMS for dimming and controlling of lights according to time schedules, presence detection for switching LED downlights, advanced HVAC management with windows sensors, carbon dioxide sensors, radiator valves and air valves.

San Pedro Hospital, Logrono (ES) – an average of 49% was saved in energy bills. Technologies demonstrated: occupancy schedules of the room, presence detection strategies and windows status monitoring, optimization of ventilation based on presence detection and CO2 control, T5 lighting

33 RES-Hospitals Project: Towards Zero Carbon Hospitals with Renewable Energy Systems, http://www.res-hospitals.eu

34 www.hospilot.eu

technology and LED downlights, daylight and occupancy sensors for lighting adjustment, dynamic temperature set point adjustment (winter / summer set points)
EPSHP Hospital, Seinajoki (FI) – more than 21% of energy was saved. Technologies demonstrated: electronic radiator valves, demand-based VAV ventilation (CO2-control), LED downlights and LED linear tubes, dimmable lighting in corridors, presence detection information shared for lighting and HVAC, LonWorks room controllers (all information is collected via the BMS)

4.5.2 Water Management

Some relevant examples of FP7 projects in the area of water management and treatment related technologies for the healthcare sector are listed below.

- AQUA-PULSE - aims to realise a low-power, low-maintenance water purification solution based on high-brightness UV Light Emitting Diodes (LEDs) and a photocatalysis method. Such a system would be effective against viruses, bacteria and organic compounds, and would provide an attractive and innovative alternative to current technology utilising mercury-based UV lamps
- LEGIOTEX-DEMO - the aim is to install the product prototype for the prevention of Legionella contamination in a demonstration installation of a representative facility in risk of becoming a source of legionnaire's disease
- CERAMPOL - project is to achieve a new generation of smart and low-fouling nano-structured membranes based on ceramic and polymeric materials with enhanced affinity to heavy metals and drugs

4.5.3 Waste Management

Medical waste has typically been treated by incineration and autoclave but concerns regarding emissions from incinerators and occupational hazards associated with medical waste have led to the development of alternatives such as:

- Microwave treatment of medical waste – where the waste is first shredded then mixed with water and subjected to microwaves. The microwaves internally heat the waste into high temperature steam, the combination of which effectively neutralises all biological. Both on-site and mobile treatment systems are available
- Macrowave treatment – waste is again first shredded and mixed with water, but this time low-frequency radio waves are applied, over an extended period of time, to generate the heat and steam that inactivates all microbes
- Pyrolysis technologies – this methods involves high temperature treatment of waste in the absence of oxygen
- Plasma technologies – here an electric current is used to ionise an inert gas which creates an electric arc of very high temperature and medical waste is converted into a glassy rock or slag, ferrous metal and inert gas.

An example of a commercially available alternative medical waste treatment solution is Sterilwave.

STERILWAVE – developed by Bertin Technologies (FR), Sterilwave is an easy-to-use biohazard waste treatment system designed for direct use on waste-producing sites. The system transforms regulated medical waste into ordinary solid waste. This is a microwave-based solution.

Another example of innovation in this area is the Pharmafilter:

Pharmafilter – An Innovative Waste and Waste Water Management Concept for Hospitals

The Pharmafilter is a novel collection system in which all waste and wastewater streams in hospitals are combined and optimisation of handling and hygiene is achieved by the use of bio-plastics for bed-pans, urinals and other disposable. The solid waste is processed by a shredder and particles are flushed through to a central liquid/solid separation unit and fed into a digester tank and for the production of biogas. The wastewater is treated by a membrane bioreactor, followed by ozonation and an activated carbon phase.

5 Pre-Workshop Conclusions

This paper has highlighted priority areas of need for new solutions that will have a direct impact on key healthcare sector challenges. It has then identified five main thematic areas where there are likely to be a wide range of unmet needs for new solution, namely:

- ICT for Healthcare
- Innovative Materials and Devices for Healthcare Delivery
- Technologies to Improve Medical Procedures
- Technologies to Improve Operational Procedures
- Technologies to Reduce Environmental Impact

These provide a potential framework for a collective European group of healthcare organisations that are interested in being more proactive about creating the market demand for next generation solutions.

The paper has highlighted the main priority areas of need for new solutions but what is clearly missing is an analysis of their relative importance and the barriers to exploitation of new technologies. A parallel stakeholder survey was therefore launched during the summer, to complement this paper, and the interim feedback will be presented at the workshop.

Appendix A: Examples of FP7 Projects by Application Area

Area of Application - Electronic Health Records

Acronym	Project Title	Start	End	Coordinator	Number of Partners	Overall Budget (M€)
ALERT	Early detection of adverse drug events by integrative mining of clinical records and biomedical knowledge	01/02/2008	31/07/2011	Erasmus Universitair Medisch Centrum Rotterdam	15	€ 5,880,600.00
SMARTPERSONAL-HEALTH	Interoperability of connected personal health systems (phs) with the wider ehealth domain promoting the smart delivery of health services	01/01/2010	31/01/2011	Edelman Public Relations Worldwide Sa	5	€ 426,963.00
LINKED2SAFETY	A next-generation, secure linked data medical information space for semantically-interconnecting electronic health records and clinical trials systems advancing patients safety in clinical research	01/10/2011	30/09/2014	Intrasoft International Sa	11	€ 4,411,644.00
ICARDEA	An intelligent platform for personalized remote monitoring of the cardiac patients with electronic implant devices	01/02/2010	31/01/2013	Srdc Yazilim Arastirma Ve Gelistirme Ve Danismanlik Ticaret Limited Sirketi	8	€ 3,613,448.00
DECIPHER	The decipher project (distributed european community individual patient healthcare electronic record)	01/02/2012	31/01/2015	Baxi Partnership Limited	8	€ 4,036,658.00

Area of Application - Tele-Health

Acronym	Project Title	Start	End	Coordinator	Number of Partners	Overall Budget (M€)
MOBIGUIDE	Guiding patients anytime everywhere	01/11/2011	31/10/2015	University Of Haifa	12	€ 7,061,625.00
SWAN-ICARE	Smart wearable and autonomous negative pressure device for wound monitoring and therapy	01/09/2012	31/08/2016	Exodus A.E.	11	€ 8,079,179.00
FALLWATCH DEMO	Optimization of process, quality and cost as well as clinical tests of the wearable miniaturized fall detection system for the elderly	01/10/2012	30/09/2014	Vigilio S.A.	5	€ 1,447,598.00
WEEG	Chips on the go: towards truly wearable eeg systems	01/01/2010	13/12/2014	Imperial College Of Science, Technology And Medicine	2	€ 1,775,713.00
HEATWEAR	Wearable wireless kit for detection and monitoring of ischemic conditions	01/01/2013	31/12/2014	Axio Consulting As	7	€ 1,587,512.00
PSYCHE	Personalised monitoring systems for care in mental health	01/01/2010	30/04/2013	Universita Di Pisa	10	€ 3,920,603.00
BRAVEHEALTH	Patient centric approach for an integrated, adaptive, context aware remote diagnosis and management of cardiovascular diseases	01/03/2010	28/02/2014	Labor S.R.L.	16	€ 10,382,905.00
MOBISERV	An integrated intelligent home environment for the provision of health, nutrition and mobility services to the elderly	01/12/2009	31/08/2013	Stichting Smart Homes	9	€ 3,600,742.00
MYHEALTHAVATAR	A demonstration of 4d digital avatar infrastructure for access of complete patient information	01/03/2013	29/02/2016	University Of Lincoln	7	€ 3,364,588.00
USEFIL	Unobtrusive smart environments for independent living usefil	01/11/2011	31/10/2014	National Center For Scientific Research "Demokritos"	8	€ 4,625,210.00

Area of Application - Nanotechnology

Acronym	Project Title	Start	End	Coordinator	Number of Partners	Overall Budget (M€)
BACTERIOSAFE	Active wound dressings based on biological mimicry	01/07/2010	30/06/2014	Max Planck Gesellschaft Zur Foerderung Der	11	4,629,000.00
CAMINEMS	Integrated micro-nano-opto fluidic systems for high-content diagnosis and studies of rare cancer cells	01/07/2009	31/12/2012	Institut Curie	9	4,599,999.52
EMBEK1	Development and analysis of polymer based multi-functional bactericidal materials	01/08/2008	31/07/2011	Max Planck Gesellschaft Zur Foerderung Der	11	3,953,777.00
FABIMED	Fabrication and functionalization of biomedical microdevices	02/09/2013	01/09/2016	Asociacion De Investigacion Metalurgica Del Noroeste	12	4,133,747.13
LIGHT.TOUCH. MATTERS	Design driven development of touch sensitive luminous flexible plastics for applications in care & well-being	01/02/2013	31/07/2016	Technische Universiteit Delft	17	5,463,750.68
NANODIARA	Development of novel nanotechnology based diagnostic systems for rheumatoid arthritis and osteoarthritis	01/02/2010	31/01/2014	Wissenschaftlich-Technischer Entwicklungen	15	12,247,052.20
NANOFOL	Folate-based nanobiodevices for integrated diagnosis/therapy targeting chronic inflammatory diseases	01/12/2009	30/11/2013	Universidade Do Minho	14	6,635,409.43

Area of Application - Surgical Tools

Acronym	Project Title	Start	End	Coordinator	Number of Partners	Overall Budget (M€)
SAFOS	Patient safety in robotic surgery	01/04/2010	01/03/2013	Universita Degli Studi Di Verona	10	€ 4,983,486.00
I-SUR	Intelligent surgical robotics	01/03/2011	31/08/2014	Universita Degli Studi Di Verona	6	€ 3,929,667.00
CLEANTOOLS	Crevice-free, high reliability bi-metallic surgical instruments manufactured from shape memory alloys	01/02/2012	31/01/2014	Corin Limited	7	€ 1,442,078.00
URALP	Micro-technologies and systems for robot-assisted laser phonomicrosurgery	16/01/2012	15/01/2015	Fondazione Istituto Italiano Di Tecnologia	5	€ 3,559,363.00
STREAM	Scaled telerobotics for enhanced microsurgery	01/09/2008	31/10/2011	Katholieke Universiteit Leuven	1	€ 79,166.00

Area of Application - Rehabilitation Robotics

Acronym	Project Title	Start	End	Coordinator	Number of Partners	Overall Budget (M€)
MONARCH	Multi-robot cognitive systems operating in hospitals	01/02/2013	31/01/2016	Lisbon's Instituto Superior Técnico (Ist),	9	€ 4,426,216.00
REWIRE	Rehabilitation wayout in responsive home environments	01/10/2011	30/09/2014	University Of Milan	13	€ 3,558,902.00
SCRIPT	Supervised care & rehabilitation involving personal tele-robotics	01/11/2011	31/10/2014	The University Of Hertfordshire Higher Education Corporation	8	€ 4,643,983.00
STROKEBACK	Telemedicine system empowering stroke patients to fight back	01/10/2011	30/09/2014	Ihp Gmbh	8	€ 4,300,561.00

Acronym	Project Title	Start	End	Coordinator	Number of Partners	Overall Budget (M€)
ISA	Inter support action (international network of teleconsultation excellence & referral)	01/09/2009	29/02/2012	Servei De Salut De Les Illes Balears	10	€ 855,805.00
CD-MEDICS	Coeliac disease - management, monitoring and diagnosis using biosensors and an integrated chip system	01/02/2008	31/07/2012	Universitat Rovira I Virgili	20	€ 12,702,594.00
PYTHIA	Monolithically integrated inter-ferometric biochips for label-free early detection of human diseases	01/05/2008	31/10/2011	National Center For Scientific Research "Demokritos"	8	€ 3,519,782.00
SPIDIA	Standardisation and improvement of generic pre-analytical tools and procedures for in vitro diagnostics	01/10/2008	31/03/2013	Qiagen Gmbh	17	€ 13,823,601.00
CEED3	Collaborative european effort to develop diabetes diagnostics	01/12/2008	30/11/2012	The University Of Exeter	12	€ 3,830,004.00
NANOTRYP	Exploiting nanobodies in development of new diagnostic tools and treatment methods for trypanosomiasis	01/01/2009	30/06/2013	Vib	6	€ 3,407,256.00
DIATOOLS	Tools for minimally invasive diagnostics	01/11/2010	31/10/2014	Uppsala Universitet	7	€ 6,550,538.00
PARCIVAL	Partner network for a clinically validated multi-analyte lab-on-a-chip platform	01/01/2012	31/12/2014	Erasmus Universitair Medisch Centrum Rotterdam	9	€ 4,132,600.00
INFACT	Functional materials for fast diagnosis of wound infection				11	6,117,244.00
NADINE	Nanosystems for the early diagnosis of neurodegenerative diseases	01/09/2010	31/08/2015	Danmarks Tekniske Universitet	16	11,649,237.88

Area of Application - Procedures

Acronym	Project Title	Start	End	Coordinator	Number of Partners	Overall Budget (M€)
ORCAB	Improving quality and safety in the hospital: the link between organisational culture, burnout, and quality of care	01/11/2009	30/04/2014	Aristotelio Panepistimio Thessalonikis	8	€ 2,480,640.00
QUALICOPC	Quality and cost of primary care in europe	01/03/2010	28/02/2013	Netherlands Institute For Health Services	6	€ 2,637,052.00
HANDOVER	Improving the continuity of patient care through identification and implementation of novel patient handoff processes in europe	01/10/2008	30/09/2011	Universitair Medisch Centrum Utrecht	9	€ 3,443,100.00
LEAN	Integrated model of lean production concepts, practices, and climate as a tool for improving efficiency and effectiveness in hospitals and r&d units	01/09/2010	31/08/2013	Technion - Israel Institute Of Technology	3	€ 97,200.00
EPOSBED-DEMO	Demonstration action for an easy positioning for patients with reduced mobility	01/09/2011	31/08/2013	Industrias Tobia S.A.	4	€ 569,770.00

Area of Application - Cleaning Solutions

Acronym	Project Title	Start	End	Coordinator	Number of Partners	Overall Budget (M€)
PROHIBIT	Prevention of hospital infections by intervention & training	01/01/2010	31/12/2013	The University Of Geneva	9	€ 3,866,349.00
HAIFREE	A novel filtration technology targeted at enhancing the european healthcare system's efforts in restraining the spread of the hospital infection	01/01/2011	31/12/2012	Vimansa S.L.U.	8	€ 1,280,781.00
SONO	A pilot line of antibacterial and antifungal medical textiles based on a sonochemical process	01/10/2009	30/09/2013	Bar Ilan University	17	€ 12,038,142.00
SELFCLEAN	Novel self-cleaning, anti-bacterial coatings, preventing disease transmission on everyday touched surfaces	01/03/2013	28/02/2015	National Technical University Of Athens	9	€ 1,524,044.00
CUVITO	Nano-structured copper coatings, based on vitolane technology, for antimicrobial applications	01/10/2010	30/09/2013	Twi Ltd	7	€ 1,993,334.00
CLEANWARD	Safe, chemical-free, cleaning of hospital ward surfaces	01/12/2012	30/11/2014	Scot Young Research Ltd	9	€ 1,449,594.00
CLEANCLOTH	Development of an antibacterial cloth based on microfibre	01/12/2009	31/03/2012	Norwex Holding As	10	€ 1,432,405.00

Area of Application - Energy

Acronym	Project Title	Start	End	Coordinator	Number of Partners	Overall Budget (M€)
HERCULES	High efficiency and rendered colour using led solid state lighting	01/01/2012	31/12/2013	Brandon Medical Company Limited	6	€ 1,358,250.00
GREENERBUILDINGS	An ubiquitous embedded systems framework for energy-aware buildings using activity and context knowledge	01/09/2010	31/08/2013	Technische Universiteit Eindhoven	8	€ 2,975,191.00
SMILES	Sustainable measures for industrial laundry expansion strategies: smart laundry-2015	01/09/2008	30/11/2011	Federatie Van De Belgische Textielverzorging	14	€ 3,168,400.00
ENTENTE	European network of knowledge transfer in health	01/09/2012	31/08/2015	Inserm - Transfert Sa	7	€ 2,256,645.00

Area of Application - Water

Acronym	Project Title	Start	End	Coordinator	Number of Partners	Overall Budget (M€)
AQUA-PULSE	Photocatalysis with uv led sources for efficient water purification	01/09/2011	31/08/2013	Epi-Light Limited	5	€ 1,415,933.00
LEGIOTEX-DEMO	Demonstration installation of a legionella preventive bactericide water filtration for large public and industrial facilities	01/09/2011	31/08/2013	Logrotex Sa	3	€ 633,987.00
CERAMPOL	Ceramic and polymeric membrane for water purification of heavy metal and hazardous organic compound	01/02/2012	31/01/2016	Acondicionamiento Tarrasense Associacion	9	€ 4,851,255.00