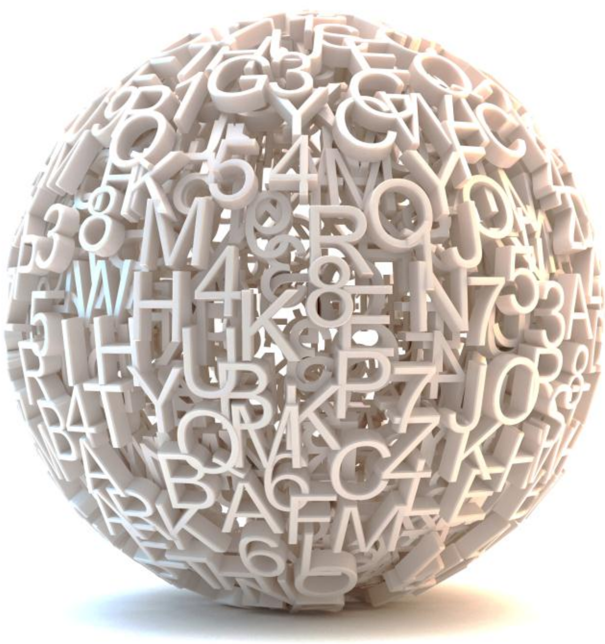
Ten technologies which could change our lives

Potential impacts and policy implications



IN-DEPTH ANALYSIS

EPRS | European Parliamentary Research Service

Authors: Lieve Van Woensel and Geoff Archer
Scientific Foresight (STOA) Unit

EN

Ten technologies which could change our lives: Potential impacts and policy implications

In-Depth Analysis

January 2015

PE 527.417

AUTHORS

Lieve VAN WOENSEL, Head of Scientific Foresight Service, DG EPRS
Geoff ARCHER, Scientific Foresight Unit, DG EPRS
Laura PANADES-ESTRUCH, IMCO Secretariat, DG IPOL
Darja VRSCAJ, Scientific Foresight Unit, DG EPRS

ADDITIONAL INPUT

Peter IDE-KOSTIC, Scientific Foresight Unit, DG EPRS
Nera KULJANIC, Scientific Foresight Unit, DG EPRS
Isabella CAMPION, Directorate for Legislative Coordination and Conciliations, DG IPOL
Andreea Nicoleta STEFAN, Legislative and Judicial Coordination Unit, Legal Service
Fernando FRECHAUTH DA COSTA SOUSA, Economic Policies Unit, DG EPRS
Maria Del Mar NEGREIRO ACHIAGA, Economic Policies Unit, DG EPRS
Veronika KUNZ, Economic Policies Unit, DG EPRS
Teresa LÓPEZ GARCÍA, Economic Policies Unit, DG EPRS
Alessandra DI TELLA, Structural Policies Unit, DG EPRS
Jonathan GUNSON, Structural Policies Unit, DG EPRS
Maria KOLLAROVA, Structural Policies Unit, DG EPRS

LINGUISTIC VERSION

Original: EN

ABOUT THE PUBLISHER

To contact STOA or to subscribe to its newsletter please write to: STOA@ep.europa.eu
This document is available on the Internet at: http://www.ep.europa.eu/stoa/

Manuscript completed in January 2015

PE 527.417
ISBN: 978-92-823-6490-1
DOI: 10.2861/610145
CAT: QA-01-15-027-EN-C

Ten trends to change your life...

This report acts as a 'taster' for those interested in understanding more about how today's emerging technology trends could impact upon society in ways yet to be fully considered by policy-makers and the public.

Europe in the 21st Century is a 'technological society'. Its citizens have seen rapid technological progress occur over a matter of decades; progress which has taken place at virtually every level of society and throughout the economy. As individuals and in groups we use a multitude of devices every day. These enable us to discover previously unexplored places, coordinate our activities at home and in the workplace, and communicate with each other instantaneously. Why do we surround ourselves with such technology? The answer is straightforward: technological advancement carries with it the promise of saving time, or doing more in the same amount of time. In short, innovation offers us the opportunity to 'do things more efficiently'.

Innovation is looked to for stimulation of the growth of new industries and the creation of new jobs, but the wider impacts of innovation and technological progress must also be acknowledged. Assessing such impacts has however been historically difficult and is often cited as a priority issue for policy-makers. The scientific foresight discipline offers hope for a range of new policy-making tools which aim to improve understanding of the possible long-term consequences of our actions, with particular reference to potential impacts arising from the development and deployment of technological innovations.

Approach

The ways in which the selected ten technology trends are set to transform European daily life are described as a series of two-page notes. Each trend has been chosen to reflect the diverse interests of stakeholders from across Europe and is aligned with the research priorities of the Parliament's STOA (Science and Technology Options Assessment) Panel: mobility; resource security; e-government and ICT; improving and maintaining public health.

An overview is provided for each trend followed by a summary of its key expected impacts. Each note also contains a section outlining some of the most significant unexpected impacts that could arise were the technology trend 'fully embedded' within society. This provides food for thought through posing a series of 'what if?' questions.

Each note also contains an analysis of some of the key legislative issues to stimulate thinking on how impacts of each trend could be better tackled with regulation. A consideration of the EU's competence in an area relating to a particular trend investigates whether a treaty change would be required whilst the possibility of amending already existing legislation, or creating new legislation, is also explored. The creation, or update, of the roles and functions of regulatory bodies in the light of particular trends is also considered, providing policy-makers with a holistic view of the legislative issues relating to each trend.

Scientific Foresight Unit in the European Parliament

Many of the issues coming before the European Parliament have a scientific or technological dimension. The Scientific Foresight Unit provides bespoke, expert and independent assessments of policy options for technologies in a variety of areas for policy-makers and legislators. It is at the forefront of Parliament's assessment of policy options for techno-scientific trends emerging across the EU and is spearheading the development of a methodological framework for scientific foresight in the institution.

Ten technologies which could change our lives:
Potential impacts and policy implications

List of selected techno-scientific trends

1. Autonomous Vehicles 1
2. Graphene 3
3. 3D printing 5
4. Massive Open Online Courses (MOOCs) 7
5. Virtual currencies (Bitcoin) 9
6. Wearable technologies 11
7. Drones 13
8. Aquaponic systems 15
9. Smart home technologies 17
10. Electricity storage (hydrogen) 19

1. Autonomous Vehicles

With thousands of Autonomous Vehicles (AVs) due to be on Europe's roads in a few years, will your child soon be driving you to work? Could the definition of a 'responsible driver' change forever?

The term 'autonomous vehicles' (AVs) covers a wide range of vehicle types, mainly operating on the ground but also the air and the sea. These have the capacity to be operated automatically, although in many cases real-time human control is still an option. The emergence of this technology has been most associated with the high-profile development of the 'Google Car', for which Google has taken advantage of the large amount of high-quality mapping data it possesses to programme travel routes. The technology for autonomous vehicles has developed to such an extent that the EU is focusing now on development of the infrastructure required to facilitate further deployment of this technology.

The 'V-Charge Consortium', together with €5.6 billion invested in it by the EU, is exploring ways in which autonomous vehicle technology can be integrated with existing parking infrastructure to produce 'driverless parking systems' accessible via existing personal electronic devices such as smartphones. The European CityMobil2 project is demonstrating the use of fully automated road transport systems in Europe and developing guidelines to design and implement such systems.

Expected impacts and developments

With some analysts predicting that by 2022 there will be around 1.8 billion automotive Machine-to-Machine (M2M) connections it is clear that a large amount of data will be generated by vehicles in the future. This level of communication between automated vehicles should make it possible for such vehicles to navigate to destinations and interact with other vehicles and objects more effectively than a human brain. The implications for a step-change in health and safety are significant with Google recently claiming that its cars could save almost 30,000 lives a year on highways in the USA and prevent around 2 million traffic-related injuries.

The increased connectivity required to facilitate automation of vehicles would significantly improve the degree of monitoring of the performance of such vehicles. Individual owners would be able to better maintain and enhance their vehicles with improvements in fuel efficiency and safety. An increased ability for vehicles to communicate with each other could also lead to vast improvements in terms of traffic flow, particularly at road junctions. This could also provide further benefits such as reduced pedestrian exposure to pollution and lower risk of road-traffic and pedestrian incidents occurring, particularly in urban areas.

The rise of autonomous vehicles is also likely to combine with continuing electrification of vehicles as telecommunications software and hardware are further integrated into vehicles. Whilst annual global car sales may remain low relative to conventional-fuel vehicles, Electric Vehicles (EVs) are expected to account for more than 5-10% of new car sales by 2025 alone. Rental-orientated business models for the EV market are likely to emerge from the telecommunications sector. An exponential increase in the use of telematics would likely also facilitate the use of AVs more widely, driven by their need to communicate through cellular networks.

Unexpected impacts that could arise from greater embeddedness in society

What if your child drove you to work, dropped you off, transported themselves to school and in the evening picked you up from your place of work? If this became a reality would restrictions, currently in place for operation of manually-controlled vehicles, such as age, competency, possessing a 'clean' licence, etc., still apply to the operation of an AV? Could sections of the population currently unable to drive manually-controlled vehicles, such as those under the minimum driving age or with a certain disability then be allowed to get 'behind the wheel'?

It is therefore useful to re-explore the definition of a 'responsible driver' in the context of AVs. At present, responsibility tends to lie with human drivers of vehicles but if AVs were to be operated by members of society such as young children, could this change the concept of 'responsibility' throughout EU society? How could this mean for responsibility for children in relation to other areas of everyday life? It is also important to consider the implications of AV use for personal driving skills and road safety. Could AV users be expected to have a new set of IT skills in addition to a practical ability to drive and operate a more 'digital' type of machine? How might this impact upon existing vehicle users in terms of requiring re-training, particularly those less able to learn a new set of skills so easily?

There could also be impacts upon our environment and our modes of transportation. How will our use of public transport change if we have individualised versions of public transport and how would this effect public investment in transport services? Moreover, given AVs are likely to be an electrified form of transport, localised vehicle-exhaust pollution could thus be significantly reduced. Could our future living habits change as a direct result of changing transport behaviours? Will autonomous transport simply become an interchangeable extension of our homes and workplaces? If distance from workplaces or transport hubs becomes a less significant factor for decisions on where to live then how should future development be planned?

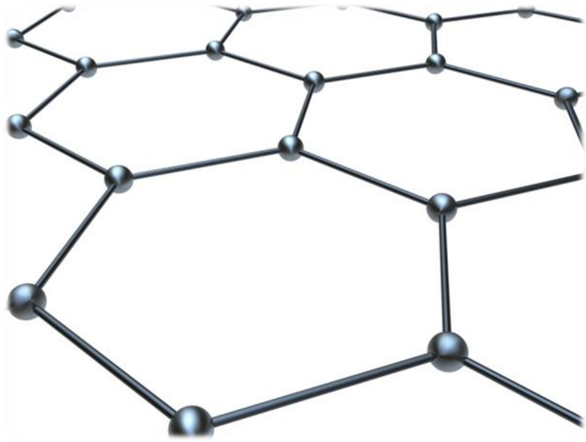
Anticipatory law-making

In considering the legislative issues of most relevance to the emergence of AV technology it is important to address topics such as liability for damages, data protection and quality standards. For example, who would bear responsibility in the case of a road accident involving an automatically-driven vehicle? Given that control of an AV could be via a third-party, would liability extend to such actors? Here, the interpretation of internationally applicable texts on this issue (such as the Vienna Convention which simply requires a 'driver to be in control' of a vehicle) could provide a useful starting point for policy-makers addressing this question. Would existing EU legislation on this issue be rendered obsolete if new laws were to be created in individual Members States. Moreover, how would such efforts be coordinated across Member State boundaries?

Should policy-makers strengthen existing regulations on specific issues, such as liability for damages, rather than create new legislation? For example, many Member States do not permit the use of handheld devices whilst operating a vehicle however the risks of doing so in an AV are significantly lower. Could existing legislation simply be updated to reflect these particular concerns as inserted articles? Similarly, to what extent would the data security and protection required for AV users demand the creation of new legislation? The TFEU already provides for protection of EU citizens' data but would this prove sufficient in the case of AVs? Finally, how could regulatory bodies ensure appropriate standards are adhered to for AVs and what should these standards be? What level of driving qualification would an AV user need? What would be the minimum age of use? Which authorities (EU or national) could be expected to enforce data protection standards, particularly wity data being used across multiple borders?

2. Graphene

As a material with many outstanding properties, could graphene revolutionise the way we innovate new technologies, and design tomorrow's products?



Graphene is the first 2D nano-material produced by scientists. It is processed from Graphite, a material that is abundant on the earth, and has a wide range of applications. It should allow the creation of potentially ultra-light and resistant composite materials with the potential to replace steel. Graphene is also extremely electrically and thermally conductive, has a high elasticity and is virtually impermeable to all molecules. There is significant potential for graphene to be used in high speed electronics and optic circuits, photovoltaic cells, bio-sensors, and in developing more sophisticated catalysing and filtering solutions for the chemical industry.

The 'Scotch Tape method' of producing graphene, discovered in 2004, resulted in graphene research growing exponentially since then with hundreds of laboratories around the world now dealing with different aspects of graphene research. Key amongst these is the 'Home of Graphene' at Manchester University in the UK which has received funding from the European Commission's Graphene Flagship. Significant challenges still remain to mass produce graphene with an adequate level of purity and in an eco-friendly way. In this regard, the production of graphene by using 'tame' micro-organisms to produce thin sheets of graphene has recently been discovered by researchers. This procedure makes use of a chemical process involving biological agents and could offer a low-cost route to mass production of graphene whilst minimising harm to the environment. Furthermore, the cost of graphene is expected to fall under current silicon prices within the next two years.

Expected impacts and developments

As mentioned, graphene's many advantageous properties, particularly its lightweight and flexible nature, make it an ideal material for use with many of the technological innovations of tomorrow. It has been foreseen that more flexible screens could be manufactured using graphene. There have also been proposals to use graphene to create night-vision contact lenses. In both case the thinness and light weight of graphene is the enabling factor in developing these technological applications.

Graphene will also enable further innovation of electronic circuits, particularly for its heat-conductive properties. The combination of a graphene coating on copper wiring in electronic circuits would make it possible for smaller computer chips to be developed that are more resistant to the concomitant increase in heat output. Graphene alters the structure of copper being used to allow heat to flow more readily and hence design faster circuits, making it possible to build more powerful computer systems using more transistors.

Researchers believe they will also be able to produce graphene-based transistors capable of operating at much higher frequencies than silicon. Graphene could also be used to produce more effective photo-detectors in high-powered supercomputers that make use of light, instead of electrons, to transmit data. Graphene could also modify the properties of other materials, for example developing 'nano-filtration' that exploits graphene's impermeability which would revolutionise the effectiveness of desalination and purification technologies and processes, particularly in less-developed countries.

Unexpected impacts that could arise from greater embeddedness in society?

Whilst the possibilities for technological innovation offered by graphene are significant, supply of the material is still far from adequate to be relied upon. World reserves of graphite are estimated to exceed 800 million tons with China, India and Brazil currently the most important graphite-producing nations. Although some graphite can be supplied from mines in Ukraine and Norway, as well as from synthesised and recycled sources, what would happen if supplies were threatened in the future? If the EU were dependent upon this material for a number of applications what might be the impact on its economy?

Graphene could be subject to strict regulation concerning its use in everyday life as well as for specific industrial applications. This is due to the fact that graphene is classified as a 'nano-material' ('nano-scale' in at least one dimension, between 1 and 1000 nanometres). Graphene could therefore be subject to regulation governed by the so-called 'precautionary principle'. Would this hinder or slow down industrial developments of graphene as a material of the future? How could this impact upon the competitiveness of Europe in comparison to less risk-adverse economic blocs?

Graphene could also have unexpected impacts upon the environment, particularly given that the dominant process for graphene production employs highly toxic chemicals. If large-scale production were to take place, would this be inside or outside of the EU and what could be the knock-on effects to the physical environment and human health of such production? It is also expected that graphene will be used successfully in combination with 3D printing and additive manufacturing. Could unforeseen health and safety issues arise from the widespread use of 3D printing? On the other hand graphene could also be used to deploy cheaper, more efficient and more versatile photo-voltaic (PV) cells on almost any surface. Could this 'democratise' the use of renewable energy and what would the implications be for decarbonisation of the EU power sector?

Anticipatory law-making

The 'precautionary principle', typically used to ensure a higher level of environmental protection, in policy-making, could be triggered for use in policy-making related to the use of graphene. Whilst primarily used in conjunction with environmental legislation, in practice the scope of this principle is far wider and typically covers consumer policy, such as food, and human, animal and plant health. A key issue for policy-makers to address here is therefore, would new legislation be required or would an amendment of existing regulations be sufficient? In particular, does graphene meet the threshold criteria for avoiding having the precautionary principle applied to it, for example does a satisfactory scientific consensus exists on the hazards of graphene?

Much of the EU's legislative work in the environmental area has been focussed on issuing 'command-and-control' regulation with strict limits on pollution levels from production processes. Will existing legislation be adequate for production of graphene on a large-scale if this takes place within the borders of the EU? If production takes place outside the EU, how can it be ensured that graphene is produced safely for both staff and consumers?

In terms of more immediate action, significant amounts of environmental protection or regulated at the national level through transposition of EU law, whilst the European Environment Agency supports the European Commission and other stakeholders in relation to this. With this in mind, policy-makers could consider how the regulatory powers of such bodies might be updated in relation to graphene. New competences might be required to monitor usage of graphene and graphene-based/containing products. Would additional labelling regulation be required and how could this be enforced effectively by such bodies?

3. 3D printing

From jewellery to weapon parts, 3D printing is throwing open the doors of manufacturing and design possibility. Are we on the verge of a new industrial revolution and who will benefit?

3D printing is an additive manufacturing technology for making three-dimensional objects of almost any shape using a digital model. The process is computer-driven with items being built up from nothing, typically through the deposition of successive layers of materials of plastic, metal, wood, concrete, etc. The technology is already in use in a number of sectors, most notably in prototyping and in various sectors as diverse as jewellery manufacturing and aerospace industries and the number of applications is rapidly increasing. In particular, the use of graphene as a material for 3D printing would open up the number of items able to be produced in this way, for example manufacturing entire computers and solar panels.

The use of 3D printing to produce organic items is also a possibility with 'bio-printing' having already produced artificial vascular systems and it is hoped that this will allow for complex, functional human tissues (for example a heart or liver) to be produced using cells from almost any organism. With the ability to produce items, such as guns, that were previously difficult to access, being extended to many more people, there are serious public safety issues.

Expected impacts and developments

A macro-level impact of 3D printing could be the way in which it shifts our consumer-based economy and the societal behaviours associated with this. There is the potential for a mass democratisation of buying habits as individuals are able to print their own products, to bespoke specifications, and in the comfort of their own homes. Activity would be shifted from traditional shopping methods, either by visiting shopping high streets or ordering goods online, to a tailored and highly personalised shopping experience.

The design of the product, rather than the manufacturing process itself, is what consumers will be paying for and thus there is the potential for a design-led cottage-industry of 3D printers to emerge. Perhaps most significantly, the widespread use of 3D printing could open the floodgates of creative innovation. For example, the ability to create more complex shapes for bespoke uses such as individual machine parts could drastically improve our ability to design and manufacture more effective machines and components.

The shortening of 3D printing supply chains could have multiple impacts on the economy, not least the reduction of labour costs to near-zero, potentially shifting manufacturing back towards 'Western developed countries'. The type and volume of waste produced from 3D printing is uncertain but is also likely to differ significantly compared with traditional manufacturing. The medical benefits offered by bio-printing are significant, for example there are predictions that we are only years away from being able to treat severe burns with a spray on substance, produced from a bio-printer making use of copies of a patient's own cells and collagen.

Unexpected impacts that could arise from greater embeddedness in society?

The implications of 3D printing for the make-up and behaviour of society could be significant, not least changing the shopping habits of citizens. For example, what will the implications be for the level of personal interactions between individuals in society if all of our products were to be manufactured at home? How would this change our typical buying habits and what would be the impact on our economy?

Online shopping already dominates the retail of many goods and services across the EU with retailers increasingly viewing the 'high-street' as more of marketing operation to simply promote their brand similar to the business model used by car dealerships. Would an increased use of 3D printing technology in the home accelerate this process and what would be the implications for local high-streets? Would economies shift towards being design-focused with digital design skills having a greater premium than traditional manufacturing methods?

If the ability to print everyday items at home becomes a reality, who in society would have the greatest access to such technology? Excluding a particular demographic section (age, gender, race, income level) from access to 3D printing presents economic risks, for example if the skills required to interface with a 3D printer are only represented in a younger demographic. Could this mean that older members of society would not be able to benefit from 3D-printed projects? Moreover, could a reduction in knowledge transfer between generations result in a slowing of the innovation of 3D printing technologies?

Uneven distribution of the costs and benefits of 3D printing is also an issue when considering 'bio-printing', for example 'printing' of organic material to create personalised 'bio-bandages'. How would access to this type of use of 3D printing disadvantage those with or without access to the technology? For example, if some members of society could return to work more quickly as a result than others, then what might be the impact upon their employability compared to others and what are the implications for equality and economic growth?

Anticipatory law-making

At present, unauthorised copying of a product, including by use of a 3D printer, would likely constitute an infringement of an intellectual property (IP) right. If this results in this type of infringement being easier to make, and thus more likely to happen, then perhaps the question of regulatory enforcement is more pertinent in relation to 3D printing. How do legislators ensure there is not a proliferation of such IP infringements and how could enforcement be stepped-up to successfully regulate 3D printing for commercial exploitation?

In terms of consumer protection and 3D printing, it may be difficult to determine who the 'manufacturer' would be in terms of fulfilling product safety requirements. Would the designer for a 3D printer be responsible for the malfunction of the goods? Should a product produced by a third-party 3D printer be classed instead as a 'service'? If so then the consumer-manufacturer relationship may need re-defining. Could this be achieved through updating consumer protection laws alone?

There are also existing legal issues surrounding ownership over biological materials such as discarded body parts (cells and tissues etc.). For example, who should have ownership over your cells and tissues when you die and who should, in theory, be able to profit from them? It is clear that the issue becomes significantly more complicated when considering a scenario in which medical products are no longer produced in a laboratory but in an industrial setting by a private company or individual. In this case would legislation governing informed consent, in relation to genetically-unique bio-printed material, need to be stricter or at least more strictly enforced?

4. Massive Open Online Courses (MOOCs)

Online education could be the future, unlocking access to education for more people than ever before. How will it change traditional education and how can we maintain high levels of achievement?

The world of education is changing through the proliferation of Massive Open Online Courses (MOOCs). These are educational courses accessed by participants through online means, typically via personal computers, and often hosted on bespoke platforms. These can be followed by thousands of students simultaneously in contrast to traditional methods of teaching with much smaller 'class sizes'. In principle the technology is based on the premise that the internet can be used for open education around the world and, at least in terms of accessing the course, is often free of charge. The emergence of MOOCs can be traced to around 2012 when tuition fee increases for higher education, most notably in the USA and the UK, drove interest in ways to make education more accessible. In Europe the use of MOOCs is less common, owing to greater public funding of higher education whilst interest in this technology has spiked in the US which dominates the global distribution of use of MOOCs.

Many of the private companies providing MOOCs are also located in the US, with companies such as Udacity, Coursera and FutureLearn being some of the front-runners. The technology is still in an experimentation phase and a 'basic MOOC model' has not yet been established although the MOOC model has evolved to some extent with 'x' and 'c' MOOCs being created. The latter are managed proactively by individual academics to generate ideas and understanding from a community of participants on open-source platforms, while the former are conducted in the style of Open University courses. In Europe, some higher education institutions have started using MOOCs as a way of 'flipping classrooms' and delivering core teaching online, making use of face-to-face teaching for in-depth material.

Expected impacts and developments

The emergence of MOOCs is expected to transform the way in which we both deliver and perceive education, particularly higher education. Whilst not a technology in itself, MOOCs combine existing forms of highly innovative communication technologies such as social media, and could disrupt education practices similar to the use of 'torrenting' for downloading music and film. A clear impact of MOOCs has been significant cost reductions for education, widening access to sections of the population who might not have previously availed of higher education. For example, last year at Georgia Technology University, a virtual MOOC for Computer Science was re-launched at less than 20% of its original cost to participants. A further effect would likely be to increase employability, both of students and working professionals, with increased access to education through MOOCs, and the resultant impact on a country's economic competitiveness. There are also questions around the quality of the education provided by MOOCs as highlighted by critics who point out that the potential for cheating is higher, and some courses are pointedly directed towards areas of interest that help providers to also sell other products whilst others simply promote passive learning.

Unexpected impacts that could arise from greater embeddedness in society?

There are several issues to consider when assessing the more uncertain impacts of the development of MOOCs. The increased use of MOOCs is often closely associated with an increased level of choice; this is seen as automatically beneficial for students who then have a free global education database. Would curbs on the provision of seemingly free MOOCs exist? Does low cost alone address low take-up of further education? Simply lowering cost barriers of access to education would not necessarily result in automatic take-up by consumers. Policy-makers may also need to think about how best to market MOOCs, particularly to disadvantaged groups such as older generations with lower computer and internet skills.

In addition, certain MOOC providers may rely upon collection of information from participants to use for marketing or advertising purposes as a way of reducing course costs, potentially to zero. Since MOOCs often operate upon the principle of collectivisation of information from a community of participants there are implications for consumer protection and data privacy to address. What type of 'knowledge economy' would the use of MOOCs shape? Who would be the winners and losers of an education market based upon such stronger principles of knowledge-sharing and how can the institutions employing the use of such methods be appropriately supported to maintain the integrity of further education?

Other potential impacts of MOOCs relate more to education 'going online' and a shift away from the more traditional forms of campus-based teaching in higher education. Would improving access to education have the effect of increasing numbers of participating students, not only in MOOCs, but in education overall? If so, this may have a positive impact in terms of widening take-up; of but how might this skew interest in education, in particular universities or certain subjects and courses? Will certain institutions attract more or less interest simply because they are already starting from a position of celebrity and will lesser-known institutions be unwittingly biased against as a result?

Anticipatory law-making

It is important for policy-makers and legislators to recognise the current limits to the EU's competences on education. The EU currently holds the competence of coordination in education as laid out in article 6 of the Treaty of the European Union with the majority of regulation determined by Member States. As a consequence, a treaty change could be required if the EU were to intervene more significantly in this policy area. Moreover, there are several issues which would need addressing were new or amended legislation to be produced in relation to MOOCs, such as data collection and protection, commercialisation of MOOC materials and MOOC-education quality standards.

First, the question of who would own MOOC materials is complicated. Would the organisation providing the course, be the 'legal owner', or the original author? What would the limits of their rights over such materials be, for example could access to materials be limited by different parties? In addition, how can the quality of such material be guaranteed once it passes out of the domain of the original MOOC provider? Furthermore, what obligations could reasonably be placed on data collection from MOOC participants and what could the restrictions on use of such data for commercial purposes be? If a new EU agency were to be created to address these concerns, how could quality standards be determined and how could such standards be enforced between different Member States? National agencies could assume this role of quality assurance instead but how could this be successfully harmonised across the EU - perhaps through existing means such as the 'ePassport'?

5. Virtual currencies (Bitcoin)

Virtual currencies such as Bitcoin are expanding the frontiers of our digital economy. How can their potential to stimulate a new form of economy be balanced with the cyber-safety needs of citizens?

So-called 'virtual currencies' have gained much attention in recent years and this emerging technology offers significant opportunities for policy-making. The European Central Bank differentiates between two categories of virtual currency, one being electronic money schemes using traditional units (such as Euros) and the other whose units are an 'invented currency' such as a virtual currency. Electronic schemes, linked to traditional money formats, have a clear legal foundation and basis in established institutions. They derive value through the implicit support of national and, increasingly, supra-national governments and institutions. A virtual currency such as Bitcoin relies instead upon records of transactions to be noted in an anonymous online ledger known as a 'blockchain'. This prevents double-spending of Bitcoins and removes the need for third-party verification of transactions, a function traditionally performed by financial institutions such as banks.

Bitcoin is a virtual currency simply representing an electronic 'peer-to-peer' (direct from sender to recipient) payment network. The system is operated by users sending Bitcoins to each other, stored in a 'digital wallet', in exchange for the sale of goods or services. A transaction is created by transmission via the Bitcoin network and recorded on the 'blockchain', grouped in 'blocks', which is completely accessible to all using the network. A transaction is then confirmed within a block of current transactions (subsequent transactions confirming the integrity of previous ones). This process is completed by 'miners' using substantial amounts of computing power to process increasingly lengthy blockchains and receiving a Bitcoin reward accordingly. The mining process is thus becoming increasingly complicated, and resource-demanding, because data chunks to be processed are now larger within the system. This is programmed so as to only pay operational costs to miners to maintain the system.

Expected impacts and developments

The key element of many virtual currencies, and in particular the Bitcoin system, is the anonymity of the users of the system. It is due to this level of encryption that a virtual currency such as Bitcoin is in principle much more secure than using cash, credit and debit cards or direct money transfers between traditional banks. Bitcoin is in fact the first global electronic currency to have even been developed.

The anonymity afforded to users of Bitcoins forms the basis for the major impact of Bitcoins: removal of the need for a 'third-party verifier' of transactions. Bitcoin usage would help to 'de-fragment' the global financial market, which has always been the preferred market model by banks around the world seeking to (thus far) prevent the emergence of a global electronic currency. This therefore offers a number of potentially highly-positive impacts stemming from the fact that use of virtual currency could be cheaper, easier and faster than existing methods of payments. For example, users of Bitcoins do not need to use bank accounts, with the associated credit and security checks that make their use complicated in comparison, simply accessing a 'digital wallet' via an internet connection.

Transaction costs of making payments for goods and services should fall dramatically were virtual currencies to be more widely used. This would help smaller business and 'start-ups' as this type of running cost can disproportionately impact upon their operating expenditure capacities. Not only this, but use of Bitcoins could vastly improve access of buyers with sellers. With an enlarging of markets for good and services, accompanied by faster personal and business transactions across international borders, the impacts for the EU's and the global economy are potentially massive. Furthermore, if virtual currencies were to be embraced by financial institutions this could usher in a new era of highly secure, cheaper, and easier to access means of payment.

Unexpected impacts that could arise from greater embeddedness in society?

The issue of the security of virtual currencies such as Bitcoin should also be one of concern for policy-makers alongside the positive benefits it could provide. For example, use of Bitcoins opens up the possibility of fraud and other criminal activities increasing alongside greater use of this virtual currency. This is because users can only be identified by unique numbers in comparison to existing bank customers who are typically identified through fixed details such as names, dates of birth, addresses, etc. As it is impossible to know whether a Bitcoin user represents an individual or a group, would regulatory and enforcement agencies be able to successfully follow transactions, beyond the blockchain?

By the end of 2014 many communications on the internet were still not encrypted, including email for instance, and it remains relatively easy for governments to tap information for massive surveillance purposes. If encryption were to be more widely used for virtual currencies such as Bitcoin, would this help protect the privacy and security of citizens (governments are still able to collect meta-data about virtual currency transactions with the aim of exploiting them in the future)? Moreover, the widespread use of quantum computing could render previously-unbreakable encryption obsolete. In this scenario, would the use of virtual currencies still be safe and secure for their users?

Anonymity has proven to be very successful with the use of Bitcoins as a form of digital currency and provides the basis upon which the Bitcoin system is run. This does, however, also make it very difficult to identify perpetrators of digital currency crime. What would this mean in terms of consumer wellbeing? Would a multi-tiered system of access and usage open up, particularly as a significant proportion of Bitcoins is thought to be owned by a relatively small number of users?

Anticipatory law-making

Law-making for virtual currencies will be particularly demanding of policy-makers and legislators given the highly innovative and esoteric nature of these instruments. A key question to address is the type of regulation that will be appropriate for virtual currencies. Should existing type of financial regulation be used, given it is already notoriously difficult to enforce financial regulation? There is no 'home country' for Bitcoin and thus raises further issues of which jurisdiction this system would fall under. For example, if Bitcoin fraud were carried out affecting multiple users from across the world, which jurisdiction would lead in prosecution of offenders (assuming perpetrators could be identified)?

Moreover, how should payments made in virtual currencies be taxed? Some governments are considering defining Bitcoin as a form of property and therefore applying laws on property taxation accordingly. However it is not known how successful this would be, given the anonymity of Bitcoin users. How would such taxation be monitored or even enforced, particularly in a world economy where transactions take place between countries with very different legal frameworks? With this in mind, it could be important for policy-makers to consider how such individual regulatory action would be harmonised across the EU.

6. Wearable technologies

From physical electronic devices to new types of 'smart fabrics', the reasons for wearing our clothes are changing. How will this change our data-sharing habits and the way healthcare is delivered?

The term 'wearable technology' applies to a wide range of technology types and materials being rapidly developed all over the world. One of the first pieces of technology that comes to mind when using the term 'wearable' would be Google's 'Glass' technology which represents the combination of eyeglasses with a miniaturised computer system and screen. Despite the media attention around this particular piece of technology there are several further types of 'wearable technology' groups, as outlined in an own-initiative opinion of the European Parliament's European Economic and Social Committee on 'Growth Driver Technical Textiles' in 2013.

Wearable technologies are described here in terms of being 'technical textiles' which comprise 'alternative materials' with new and advantageous properties such as being light-weight, flexible, heat-resilient, etc., and 'new technologies' that have been made to be more versatile and can be worn with ease, such as Google Glass; or 'functional components' of existing technological systems, such as the 'internet of things'. The importance of wearable technologies has also been recognised by the European Commission which is indirectly providing support for 'key enabling technologies', through its Horizon 2020 programme, vital to developing such wearable technologies, such as nanotechnology and micro-electronics,.

Expected impacts and developments

In terms of wearing specific pieces of technology, the trend in this area has leaned more towards continual miniaturisation of computing technology into a form that is unobtrusive enough to be worn by a user. Google Glass is one of the more obvious pieces of wearable technology in this regard, combining the existing functionalities of modern smartphones with a highly portable device for access 'on the go'. The company is also developing a device to improve detection of blood clots, whilst Microsoft has released details of a wristband fitness tracker monitoring vital body signs. Further products are also being developed which have the potential to deliver treatments more effectively. An EU-funded project, 'i-Care', has recently produced a wearable device to monitor the wound healing process which will enable clinicians to better personalise treatment.

Wearable technologies in the form of 'smart' or 'technical' fabrics are also being developed with highly specialised properties. Clothes which resist more extreme environmental stresses are already in development, for example from the EURIPIDES project. This has released details of a 'smart jacket' for firemen making use of a new, heat-resistant material developed in-house. Fabrics are also being developed with a view to embedding different types of sensors in them to allow for real-time monitoring of users' local environments. Dephotex, another EU-funded project, is at the forefront of innovating wearable renewable energy technologies. It has helped to develop methods for making photovoltaic materials light and flexible enough to be worn comfortably. This could increase the versatility of existing technologies, such as smart phones, for example by adding the ability to re-charge them 'on the go' and without using a traditional plug socket.

Unexpected impacts that could arise from a greater embeddedness in society?

The development of wearable technologies offers huge potential for both the type of medical care that patients receive and the way in which such care is delivered. Remote delivery of care could provide many benefits but who is likely to benefit from this widening of access? People for whom travelling to a medical centre is difficult, such as the elderly, would potentially benefit but how might this change the relationship between doctor and patient if face-to-face care is dramatically reduced?

Applications of wearable technologies, such as outlined for healthcare, will require a huge amount of data collection and assimilation. Everyday forms of wearable technology, such as 'smart' watches, would link automatically to social network accounts and potentially share personal data automatically. The concept of information privacy in this context could be placed under significant threat if such technologies could bypass user consent to data sharing so easily and subtly. For example, who may be collecting, storing, and analysing information obtained from wearable pieces of technology and for what purpose?

Some members of society may feel particularly uncomfortable in wearing clothing or technology that contravenes personal religious or cultural views or beliefs. What could be the disadvantaging or advantaging effects for them of wearable technologies in this regard? Could a consumer-base biased towards men or women, or perhaps children or adults, be inadvertently developed for such a technology? Could this have the effect of excluding certain parts of society from the benefits of wearable technologies?

Wearable technologies may also provide an opportunity to transform our fashion rather than simply transfer existing technology into it, with resultant implications for the emergence of new types of art and culture. In practical terms this has led to the development of 'fashionable', yet highly practical, pieces of technology such as the Hövding, an inflatable cycle helmet, being developed. Companies supporting the integration of different technologies with clothing could find a new market niche. What would this mean in terms of the skills that economies across the EU might need in the future to facilitate this?

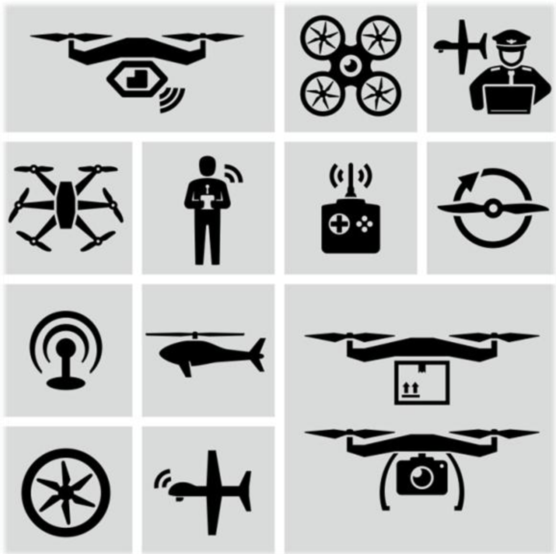
Anticipatory law-making

The use of wearable technologies, designed to monitor and analyse our personal information through the 'Internet of Things' (often surreptitiously) raises questions of data protection and privacy. This includes both privacy of the public, (what if a Google Glass-wearing user took unauthorised pictures you?), and of individual wearers for whom data may be automatically uploaded into 'the cloud' in a non-transparent way. Hospitals making use of wearable monitors would be likely to collect huge swathes of information but how would 'informed consent' be given in such situations where the volume of data collected is so high? Moreover, medical devices may be individually regulated but how should existing legislation categorise non-medical devices which also provide data intended for medical use (particularly invasive, heart-monitoring devices)?

There have also been debates over the use of wearable technology in the workplace, particularly in monitoring employee activity. Whilst there are data protection and privacy issues to consider, there are also ethical questions to answer: how much right should an employee have to privacy in the workplace? Where would the 'workplace' boundary be in this situation? Medical negligence is also of relevance to policy-makers and legislators if the delivery of patient care changes significantly due to greater use of wearable technologies. What would happen if the patient-doctor relationship became complicated by technology? Would a technological fault still lead to liability for negligence? How would technology impact upon the legal standard that professionals, such as doctors, should adhere to?

7. Drones

Drones have already started capturing pictures of our world like never before. How can privacy be preserved as falling technology costs allow the average consumer to become a drone operator?



Different terms for drones are ascribed in different types of literature, however two tend to dominate: Remotely Piloted Air Systems (RPAS), typically controlled from outside the aircraft; and Uninhabited Aerial Vehicles (UAVs), also controlled automatically. It should be noted that the term 'drone' can also apply to machines operating in other environments such as underwater. The addition of weapons to drones was first proposed in the late 1940s and since then drone technology has rapidly evolved with the innovation of constituent parts (batteries, on-board computers, fuel types, fuel tanks, lightweight materials, etc.) allowing more widespread use.

Drones are most visibly used for military purposes but there are also many other applications for drones, such as surveillance, as well as further civilian uses in areas such as mapping and logistics. Costs of drones have dropped sharply as the technology develops and are likely to continue to do so into the near future. There are significant legal and ethical issues associated with the increased use of drones however, particularly as the range of uses for drones diversifies into the future.

Expected impacts and developments

The key uses of drones by both military and civilian authorities in the immediate future is likely to be in discharging core duties of safety, security and policing, particularly in carrying out surveillance and intelligence gathering. The immediate impact of this will be to reduce the numbers of 'frontline' personnel being deployed in carrying out these activities and, in the future, could see drones carrying out the most dangerous of activities such as assisting in the fighting of forest fires.

The range of commercial applications for drones is yet to be explored. However, major delivery and logistics companies have already started investigating ways in which drones could improve the efficiency of their operations and widen the range of services they could offer. There have been predictions that 12% of a $98 billion cumulative global spend on aerial drones over the next decade will be for commercial purposes alone, illustrating the degree of expected growth in the short-term.

Drone technology costs are expected to drop in the short-term and this makes it likely that there will be widespread proliferation of drone use by the public more generally. Together, the increased commercial and public use of drones is expected to impact significantly upon the safety and security of the public as well as having serious implications for public privacy.

Unexpected impacts that could arise from greater embeddedness in society?

Many of the impacts of drone use revolve around practical applications and resulting impacts with many concerns regarding issues of privacy, which are well-documented and actively considered by intelligence agencies around the world. One issue that has not been fully investigated, however, is the potential impact of drones on a societal 'fear of being watched' which, although difficult to quantify, is subject to anecdotal reports from members of the public cited by media outlets, typically using language such as 'creepy' or 'unnerving'. Could this have implications for how citizens behave, at least publicly, in the future if they actively feel watched by drones?

Related to this are the implications for personal privacy of using drones, particularly as they allow for novel ways of taking photographs and film. Would the owner of the drone in question have sole access to such data? What could the impact be of unwittingly revealing personal details of subjects caught on film (for example address details)?

The use of drones to deliver commercial goods and services, such as transport of goods, is widely expected in the future. It may also be useful to consider how other types of service, for example as traditionally provided by government, could also be delivered by drones and how this might change the nature of that service. For example, what would be the impact of substituting community policing with a greater use of drones? What types of skills and character traits would instead be required for such 'remote policing'? Indeed, what types of new skills and knowledge will be needed in society to design, operate and maintain both drones, and related infrastructure, is important to consider when planning further innovation of drone technologies.

Interaction of drone-related infrastructure (telecommunications networks etc.) with other technologies is another issue to consider when assessing the impact of drone technology. Potential clashes in use of airspace between drones and both military and civilian aircraft has already been raised as a serious issue: how can such conflicts be resolved, and the safe use of drones safeguarded, whilst upholding military and commercial priorities? Similar conflicts may occur when considering how drones may use telecommunications networks to send and receive data. What will the impact be on safety however if such connections are not made secure, for example if a drone is taken over for malign uses?

Anticipatory law-making

Whilst many concerns may be similar for civil and military parts of society, it should be noted that Member States would be expected to retain regulatory powers over drones, used for military or defence reasons under their remit of competences. In terms of civilian use, there are several issues for policy-makers to consider. The TFEU provides all EU citizens with such a right, although this is mainly set as an exclusive responsibility of the Council, and the EU has already legislated in regards to data protection. Legislation specifically concerning drones may need to be developed in the future, addressing to what extent a drone operator's right to capture data can be upheld against the need to protect individual privacy. How could fair allocation of responsibility be achieved, particularly in relation to damages to 'third persons', such as scratching vehicles, hitting buildings, and drones injuring members of the public?

Competences on the use of drones for military purposes are likely to remain at the level of individual Member States, although it is interesting to note recent calls for at least a 'soft' form of regulation at the EU level. A recent study by the European Parliament's Directorate-General for External Policies made recommendations concerning the overseas use of drones. This articulated concerns that such drone use was not subject to any guidelines. For example, how could military drone use be harmonised in order to maintain high EU ethical and legal standards? Developing a 'Code of Conduct' was suggested to cover procedures for authorising and carrying out surveillance and attacks using drones. This raises interesting questions for policy-makers regarding European foreign policy. What should the standards be for Member States operating military drones outside of European borders? Furthermore, how could the promotion of law in relation to the development and proliferation of drone technology best be pursued by the EU at an international level?

8. Aquaponic systems

As the world's population continuing to expand rapidly, developing innovative and sustainable food sources is a key priority for Europe. How will spatial planning cope with greater use of aquaponics?

Aquaponic systems combine the farming of fish, typically freshwater, with the cultivation of plants. This takes place within a 'closed-loop' aquaculture system whereby fish are fed nutrients and their excrements are used as fertiliser directly into the water in which they are being kept. The water then feeds plants which use it for growth and filter the water so it is suitable for re-use with the fish in the system. Such a system can be said to be 'closed-loop' and hence a significant emphasis is placed upon the environmental and economic sustainability characteristics of aquaponics. At present aquaponic systems are only small-scale and therefore incur high costs of production relative to current methods of large-scale farming.

The popularity of this method of farming was recently recognised in an own initiative legislative report presented by the AGRI Committee, and adopted by, the European Parliament in March 2014. It is not clear, however, how funding for aquaponics development and innovation, sitting between both fisheries and agricultural policy areas, is covered within the EU. Aquaculture is covered by a number of provisions in the European Maritime and Fisheries Fund with enterprises being assessed using criteria such as 'reducing environmental impact' and 'improving sustainability'. It is possible that funding could also be directed towards aquaponics in the same way as such characteristics are also central to the discipline of aquaponics.

Expected impacts and developments

As mentioned above, the use of aquaponics could lead to the development of a more closed-loop system of agriculture wherein resource efficiency is prioritised, resulting in minimal economic throughput. This offers an opportunity to produce food in a more economically and environmentally sustainable way with produce being grown using a low level of resource-input. Aquaponics could also help to reduce carbon emissions from food production, and through shortening of supply chains could improve food security and food systems resilience.

Local economies could be further boosted through the use of aquaponics to reclaim some of the value of their outputs. This has been demonstrated recently by researchers who used domestic wastewater to grow tomato plants and found that harmful chemicals in the water, such as ammonium nitrate, were reduced to non-toxic levels so as to be useful in agricultural and industrial systems. Furthermore, an aquaponic system could significantly reduce the amount of water used for food production compared to existing methods of agriculture.

In addition, the versatility of many aquaponics systems means that they would potentially allow for the growing certain food-types in atypical locations, such as urban areas. As mentioned, this could help to improve the resilience of food supply-chains as food would then be produced much closer to where it would be consumed. While this has already started happening, it has proved difficult due to the small-scale of production and high cost of food production from aquaponic systems.

Unexpected impacts that could arise from greater embeddedness in society?

What would the implications be for our diets with increased use of aquaponic systems? At present the technology can only be used with a narrow range of conditions (pH, temperature, etc.) and thus can only be used to produce a limited range of plants. If a larger proportion of our diet were provided from such a source, what would the impact be upon our diet? Could certain minerals, vitamins and other nutrients be missing from diets in the future and how would the healthiness of populations change?

Aquaponic systems are small in comparison to traditional methods of farming and require less space, although they are expensive to operate. Cities are therefore ideal locations for the use of aquaponics and policy-makers may need to consider what the effect of a shift towards more decentralised forms of food production might be on both rural and urban landscapes. For example, how could new and existing buildings be configured to accommodate aquaponic systems? Aquaponic systems integrated into everyday architecture could also help to reconnect populations with food production. This could have further implications in terms of the acceptance of policies related to cities and food production.

The economic impacts of using such a method should also be considered. Would use of more expensive, smaller-scale systems increase food prices and change the level of access to food? Communities not able to implement aquaponic systems could perhaps face higher food prices and rely instead on 'old, inefficient and unfair' forms of agriculture. What would the impact on employment be if a more labour-intensive form of food production such as aquaponics were to be used more widely and what workforce-skills would be needed in the future? If aquaponic systems could reduce water consumption from food production, would water prices fall with demand? What would the economic and environmental costs and benefits of shifting water use around the economy be?

Anticipatory law-making

As mentioned, the European Union (EU) has not yet legislated on aquaponics and, as such, it is not clear how policy-makers might legislate for funding to be directed towards this technology. Would new legislation need to be produced specifically for aquaponics or would existing legislation relating to food production be sufficient in this case? One aspect that is clear is that aquaponic systems are a relatively complex and technical area, and, policy-makers in the European Parliament might consider regulating this area of technology through delegated or implemented acts as a result. Similarly, it may be necessary for policymakers to consider the regulation of other products and technology areas relating to aquaponics, for example how should policy makers regulate the use of genetic engineering to improve aquaponic system yields?

Given that aquaponic technology is newly emerging and as yet relatively undeveloped, it may become a strong focal point for research in the future by individual Member States. As such it could receive significant amounts of funding by national governments and this would require careful monitoring by the EU to ensure such funding kept within the State Aid rules. Finally, planning policy and legislation may have to change in the face of an embeddedness of aquaponic systems in society. Would the technology be incorporated into urban or rural areas? Where will populations move to as a result? Either way there would be an impact on urban planning, which currently remains an area of national competence. If the EU wished to more directly regulate the provision of aquaponic systems in the future then here a treaty change could be on the horizon if such regulation further intervened in urban planning at the national level.

9. Smart home technologies

The Internet of Things now increasingly includes electronic devices operating in our homes. How will our everyday behaviours and personal relationships change as a result?

The Internet of Things (IoT) describes the increased level of connectivity between digital devices in society, for example smart phones and televisions. With the number of such devices having surpassed the number of people on the planet, Smart Homes are a practical application of the IoT in the buildings we live in. Smart Homes consist of a number of electrical devices which are communicating with each other via an internal network that is also connected to the Internet. Such a 'house of the future' would be built around an intelligent monitoring and control system that provides the user with greater flexibility in managing their daily energy and water consumption.

Smart homes are usually equipped with sophisticated multimedia systems that can deliver personalised content in each room. These are either designed as 'built smart' or 'made smart' later, through the use of appliances such as 'smart plugs' that control other appliances that are not connected to the IoT (non-smart electrical appliances). Around 13% of (US) consumers are predicted to own an in-home IoT device by the end of next year, illustrating the importance of this technology trend.

Expected impacts and developments

With more homes becoming 'smart' there is a great potential for efficiency gains both in terms of resource and time savings to consumers and to energy suppliers. Smart Homes could provide homeowners with increased flexibility of energy consumption, both directly and indirectly. For example, a smart home user could control home energy usage and environmental conditions remotely by connecting through a smartphone. When combined with 'smarter' building materials, such as thermal insulation and LED lighting, the future energy performance of homes could improve dramatically.

Smart homes not only manage energy consumption but also offer opportunities to store it, thereby helping to facilitate wider use of domestically-generated renewable power. Whilst this is crucial in helping such technologies to respond to fluctuations in local power supply, this would also have the ability of adding extra demand-response capacity to the wider energy grid within a building, city or country. Another side-benefit of this would be to aid deployment of Electrical Vehicles (EVs) through facilitation of charging networks for EVs as homes are developed into mini-charging stations.

Smart homes also contribute to energy demand-response strategies across the EU as less flexible, renewable, energy sources make up an increasingly larger share of energy supplies. Remote adjustment of energy consumption by individual properties would help regulators to reduce the load on electrical grids at peak times, for example by temporarily turning off air-conditioners, avoiding the need to use expensive 'standby power-generators'.

Unexpected impacts that could arise from greater embeddedness in society?

The main driver for take-up of smart home technologies would seem to be the potential for cost-saving efficiency, alongside a perceived improvement in quality of life. However, it has also been suggested that particular social challenges will arise from the adoption of smart home technologies. The impacts on social behaviours, both within and outside of private home lives, individual privacy and security and the universality, or not, of smart home technologies represent just some of such concerns which have yet to be fully addressed by policy-makers.

Debate about smart homes often assumes a stylised vision of a 'home'. In urban areas however, non-apartment-style blocks comprise a significant portion of residence buildings where environmental conditions are typically controlled by building managers or landlords. This raises questions about how much control smart home technologies would provide to such residents particularly if a landlord bundles utility charges into a tenant's lease. How might conflicts over settings for shared smart home technologies impact upon relationships between residents of multi-occupier properties? How could residents know that data being transmitted by smart home technologies would not disadvantage them in their relationship with landlords?

Smart homes may also alter our everyday behaviours and relationships. If 'managing' homes more efficiently can be achieved remotely, would this result in longer working hours? Moreover, if housework were to be increasingly delegated to a smart system this could impact the way homes are physically constructed and thus the allocation of social responsibilities. Would people feel 'liberated' to leave their homes and, for example, make greater use of public spaces? Would these therefore become more valuable to policy-makers?

Could delivery of the more practical side of healthcare delivery, operating equipment such as boilers for elderly patients, be revolutionised by take-up of smart home technologies? Would this change the nature and effectiveness of service delivery? Smart homes could enable patients to lead more independent lives and transfer more care into homes and out of the clinic. What might the impact of this be upon the required skills and training needed by medical workers for this form of service delivery?

Anticipatory law-making

Given the multitude of devices involved in smart homes, data protection and the privacy of 'smart home users', is a pressing issue. How would the privacy policies for each device apply and how could a user be expected to keep track of these? EU legislation limits the collection of data to what is required for the 'primary purpose' of a product however with multiple devices interacting with cross-cutting purposes; how would this be defined and who would be the 'owner' of such data? Furthermore, how would such data be protected in the face of increasing attacks through the internet, many of which would originate outside of the EU? Similar to trends previously described in this report, could new legislation be required here that provides specifically for data collected so ubiquitously in the home?

Determining the apportioning of liability in the case of smart homes could also be challenging. For example, who would be liable for a particular malfunctioning 'smart home' product, the user of the supplier? If a 'smart fridge' were to automatically order food, how would existing contract law be applied and what would the terms of the order be? Could such products be easily returned and who would be responsible if a problem arose? Moreover, questions remain as to the ownership of components of the 'Internet of Things', for example would software enabling a fridge and a food sensor to communicate be patentable? A key characteristic of 'smart homes' is for them to make use of standardised technologies and excessive use of Intellectual Property Rights law could provide a barrier to this.

10. Electricity storage (hydrogen)

With renewable energy technologies being deployed throughout Europe, 'smart energy use' is now upon us. How can electricity storage improve Europe's energy resilience and will we live 'off-grid' in the future?

Research into new storage technologies is booming with the objective to attempt to store excess electrical energy produced from renewable generation efficiently during low consumption periods (for re-use during peak times). There are several dominant types of energy storage currently in active development, typically grouped into four categories: electrical, mechanical, thermal and chemical. Chemical storage systems, particularly those that produce Hydrogen via electrolysis, are considered as the most promising technology type. The stored gas can be used to drive a combustion process to re-generate electricity or power a fuel cell, for example in a 'hydrogen car'.

Renewable energy technologies are being deployed throughout the EU alongside which storage technologies can be utilised at various locations depending on where electricity is produced, consumed, transported, as well as held in reserve. Depending on the location and the nature of the energy generation, the type of storage system used can be very large-scale (measured in terms of Giga-Watts), medium-sized (Mega-Watts) or in the form of small, highly localised systems (Kilo-Watts). Public investment in energy storage research and development has led to significant reductions in cost. However, increasingly there are calls for further EU subsidies to be allocated to research in this area.

Expected impacts and developments

Development of electricity storage technologies is beginning to match an increasing trend of energy being generated from renewable sources, such as wind and solar power. This is driven significantly by a desire to electrify power generation and consumption as Europe's policy-makers seek to reduce carbon emissions driving global climate change. A shift away from energy sources such as oil and gas is also seen as necessary to ensure a secure and lower-cost energy supply in the future, hedging against political instability in fossil-fuel producing regions and long-term rising energy costs.

The inflexibility of renewable energy sources is, however, making it increasingly difficult to secure such energy even as the proportion supplied from such sources increases (from 2011 - 2012 electricity generated from wind power in the EU increased by just over 12% from 181.3TWh to 203.1 TWh). Greater electricity storage would help to 'smooth' energy demand, for example by releasing energy when demand is high (but supply from renewable sources relatively low), therefore making greater deployment of renewable energy much more feasible.

Electricity storage technologies are also thought to be vital in developing so-called 'smart grids' for electricity generation and supply. The combination of electricity storage technology with smart grids offers a significant opportunity to optimise the consumption of energy through such systems. This would add a significant degree of flexibility to demand-management and demand-response which become increasingly dependent on generation of energy from renewable sources. Furthermore, being better able to go 'off-grid' with greater options for electricity storage could also offer a solution to unexpected black-outs in the future and drastically improve energy resilience at the local level.

Unexpected impacts that could arise from greater embeddedness in society?

The combination of electricity storage technologies with other technologies offers significant potential for the impact of this technology. Electricity storage could enable homes and businesses to more easily go 'off-grid', contributing to their future energy and economic resilience. Could this provide a more sustainable energy supply for inhabitants in local areas? It is likely to be more efficient to have 'local grids' that are separate from a national grid, making use of 'off-grid clusters' of habitations and businesses. If so, how could this impact upon future locations of population centres? Will this change the general trend of population moving to increasingly built-up and urban areas?

In addition, there are costs associated with going off-grid and these could be higher relative to more traditional 'gridded' types of infrastructure due to difficulty in achieving economies of scale, higher installation costs and so on. The issue of who pays for going off-grid is therefore extremely relevant in this context. First, who would pay? Will it be the individual energy consumer or the public taxpayer? If the majority of the cost were to be borne by consumers then would going off-grid be limited to those with the private means to pay? Furthermore, what would the distribution of benefits of doing so be and would this be fair?

Electricity storage technologies could impact the development of other technologies, for example hydrogen-fuelled vehicles. If a number of households and businesses had hydrogen storage facilities could this aid the development of networks for hydrogen-fuelled vehicles? If this occurred, would such vehicles become the dominant form of road transport? It would appear that the electrification of transport has already taken place to a significant extent, with rail electrification accelerating and electric cars already in final testing phases. For this reason, greater deployment of hydrogen storage could be more likely to aid in the general electrification of energy generation.

Anticipatory law-making

Although competences for energy generation and supply remain mainly at the national level, the EU has an obligation under Directive 2005/89/EC to safeguard the safety and security of electricity supply investment. This is achieved through ensuring a functioning market for both electricity generation and supply. Should the EU also fund hydrogen-based electricity storage projects using the same mechanisms and would this require new Directives to govern such investment? Should this instead remain the preserve of individual Member States?

Questions also remain as to the level of innovation needed for technologies such as hydrogen-based electricity storage. Whilst the technology has developed significantly over the last few years, more work may be needed to scale this up into commercially viable projects. Again, should European policy-makers provide the funding for this and if so what legislative actions would be required? Policy-making at the EU-level has been instrumental in setting targets for reductions in carbon emissions, increases in share of renewable energy and levels of energy efficiency deployed. Would similar targets for electricity storage also be appropriate and at what level could this be set at by EU policy-makers and legislators if necessary?

Finally, the legislative areas of health and safety (both consumer and third-party) are of relevance to electricity storage technology, especially using hydrogen. If such technologies were to become commonplace in communities throughout Europe, how can policy-makers ensure that those living and working nearby to such technology are protected? In the case of an 'off-grid community', how can the rights of all community members be maintained with fair access to energy? Would storage technologies such as this present a physical risk to local wildlife? How could existing legislation be updated to reflect this and to what extent would Member States have competences for this?

This study was undertaken in support of the Scientific Foresight Unit's ongoing work to develop a methodology for carrying out foresight studies within the European Parliament. Ten different scientific and technological trends are investigated which reflect the interests of citizens, policy-makers and legislators drawn from across the European Union. A summary of each trend is provided followed by an overview of both the 'expected' and 'unexpected' impacts associated with the trend. A legal analysis is then provided which highlights procedural and legislative issues for policy-makers and legislators to consider when tackling policy-making in the EU in relation to each trend.

This is a publication of the
Directorate for Impact Assessment and European Added Value
Directorate-General for Parliamentary Research Services, European Parliament

PE 527.417
ISBN:978-92-823-6491-8
DOI: 10.2861/803452
CAT: QA-01-15-027-EN-N