THE FUTURE OF CITIES

ELLEN MACARTHUR FOUNDATION

The Ellen MacArthur Foundation works with business, governments and cities, and academia to accelerate the transition to an economy that is restorative and regenerative by design: a circular economy. Our learning resources are designed to actively engage students in thinking about the economy and exploring alternative models for the future.

Subjects: Geography, Business Studies, Design and Technology, ICT, Environmental Sciences, Engineering, Citizenship, Sociology

Age range: 15 +

Time: Approximately 10 hours worth of content (excluding suggested extension activities)

Skills: Communication & collaboration, critiquing, creativity, pitching and presenting, critical thinking, systems thinking

Preparation: Ideally students would have access to computers or tablets so they can easily explore the interactive content. A central smartboard is helpful but not essential. Students can capture notes and ideas in exercise books or in a digital format.

HOW TO USE

This course has been designed to be highly adaptable; it could be a series of lessons, form the basis of a week-long project or - by incorporating the many suggested extension activities - a unit of work lasting 4-6 weeks. We have intentionally not been prescriptive to allow for flexibility of use. The course lends itself to whole-class or group activity or a combination of the two, and is ideally suited to students aged 15 and above.

If you would like to expand this resource, you can find a number of useful lesson plans and activities relating to the circular economy **here**. Alternatively, the last page of this course provides some useful links to other courses, case studies, podcasts, news stories and more.

To get the most from the course, we recommend that a teacher or facilitator leads students through the content, encouraging group work and discussion; however, individuals can work through the content by themselves or at home if needed. In the spirit of participation, the course does not demand that the teacher be well-versed in the concept of a circular economy beforehand or familiar with trends in the urban environment. This is more of an exercise in exploring a new idea together than getting to ‘right’ answers.

The course comprises several articles outlining some of the major innovations and trends associated with modern cities, both in terms of what is happening now and what is in store for the future. We recommend working through each of the articles and videos consecutively, either as part of a learning project relating to cities, technological innovation or to the circular economy specifically. Topics covered include:

- The built environment
- Mobility
- Energy
- Food & wastewater
- Digital technology
- Society

Embedded within each article is a selection of short videos taken from the Ellen MacArthur Foundation's **Disruptive Innovation Festival**. In each video, you will hear from experts in their field as they share their insights on how these changes are shaping the future of our cities, what that means for citizens, and what role the circular economy can play.

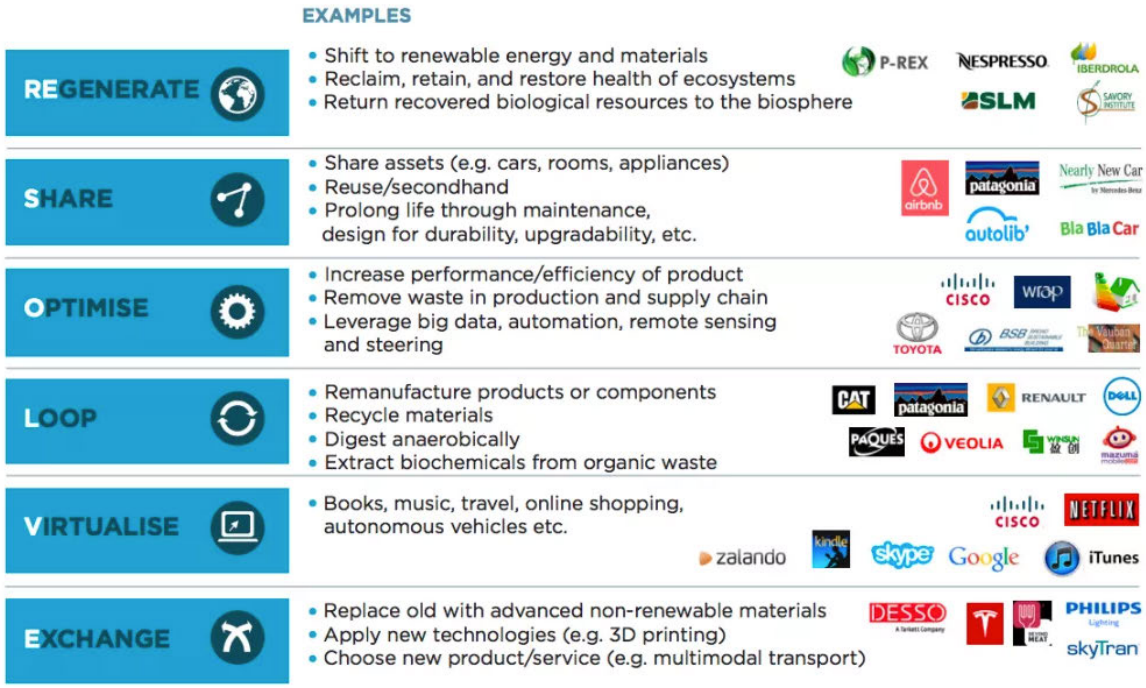
Each article and its accompanying videos provide an excellent stimulus for discussion with students. Embedded throughout, you will find prompts and considerations to deepen the learning as well as challenge your own and your students' thinking.

We have also provided a city map which students can use to capture their vision of the future city as they progress through the course.

Lastly, you may like to introduce an element of **Flipped Learning**, in which students cover some of the content (the videos or the articles) outside of the classroom, allowing for discussion and deep dives into the content during class time. (You may also wish to use **Playposit** to build in your own questions and activities to the videos for an interactive online experience.)

Suggested extension activities:

- If you were to build a city from scratch what would it look like? Throughout this course, students add to their vision of a future city using the provided map. Why not create a more sophisticated, large scale reproduction? This could take the form of a model, large poster, wall display, or digital 3D model.
- Once you have finished the course, you may want to spark some entrepreneurial flair in your students. In groups, ask students to identify potential business opportunities in their future city (this could be a product or service) and develop a proposal to be pitched to the rest of the class. The winning concept receives investment from you the investor. Students could use the Resolve framework below, which identifies six ways businesses can become more circular, to guide them. Get inspiration by researching some exciting circular business models on our **case studies** page



Source: Company interviews; Web search. S. Heck and M. Rogers, *Resource revolution: How to capture the biggest business opportunity in a century,* 2014.

- After completing the course, students should have a clear picture of what the future could look like for cities. Get students imaginatively engaged with the content by asking them to show what life is like in a city in 2050.
  Students can bring this to life by using a medium of their choice e.g. film, poem, short story, play script etc. Students then share or perform their creations.

- Throughout this course we refer to the importance of systems thinking as a vital skill for tackling complex challenges. Explore this topic further through a variety of case studies in this **Complexity Module** developed by the **Ellen MacArthur Foundation** in collaboration with the **International Baccalaureate** and **United World Colleges**.

FUTURE OF CITIES: INTRODUCTION

At the heart of creativity, innovation and growth, cities play a central role as motors of the global economy. 54% of the world's population live in urban areas with this figure set to rise considerably over the coming decades. Cities account for 85% of global GDP generation and are also huge collectors of materials and nutrients, accounting for 75% of natural resource consumption, half of global waste production, and the large majority of greenhouse gas emissions.

As urban areas continue to grow, our cities will have to build more housing, deal with greater pressure on road and rail networks, and work out how to cope with a growing demand for resources.

Where will those investments be made? One place to look is at existing infrastructure currently being underused. Let's look at the transport system as an example. Cars are parked for 91% of the time, yet roughly half of a city's land is used for roads, car parks, driveways and service stations. On top of that, traffic congestion in cities is detrimental to our health and well-being as well as to the environment and economy. Then take buildings: the average office is used only 35–50% of the time, even during working hours.

We clearly need to find better ways of managing our cities more effectively. Fortunately we have never been in a better position to do so, thanks to technological advances and a wave of innovation sweeping across many sectors.

This course looks at some of the latest ideas and technologies that have the ability to reshape how we design and experience our cities. This course is put together by the Ellen MacArthur Foundation, a charity working with business, government and academia to build a framework for an economy that is restorative and regenerative by design.

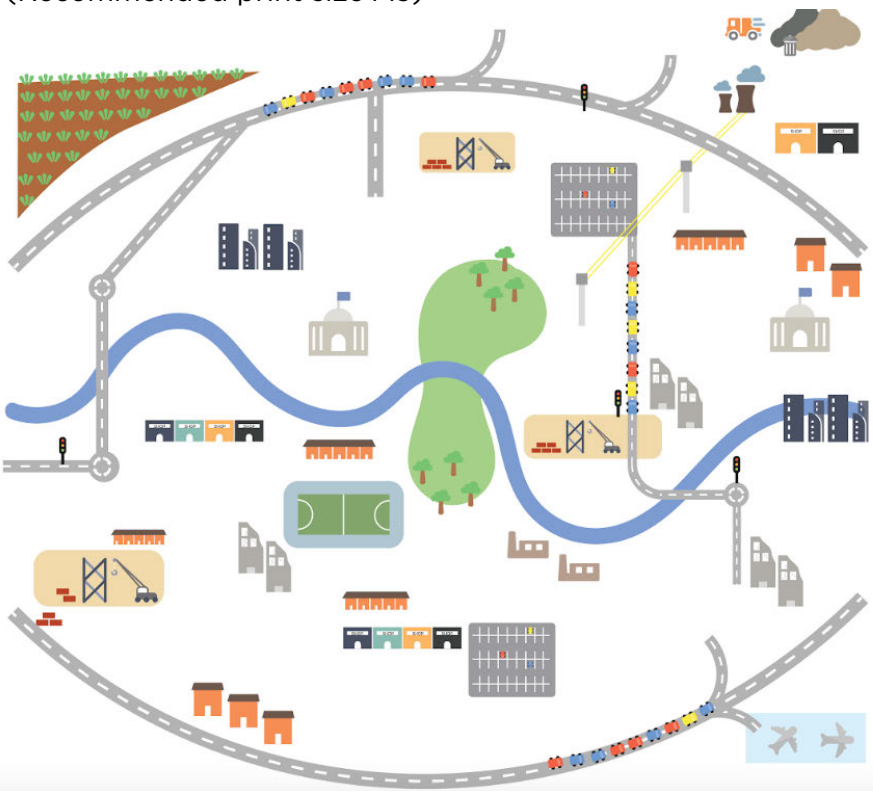
That framework is the **circular economy**. In a circular economy, products are made to be made again, digital technologies allow us to track materials and take advantage of access to products over ownership, nutrients are returned to the soil, structural waste is put to effective use, and the whole system is powered by renewable energy. The circular economy promises to generate benefits for business, society and the environment.

Cities are uniquely positioned to drive a global transition towards a circular economy, with their high concentration of resources, capital, data, and talent over a relatively small geographic area. This course explores the potential benefits such a shift could have on the economy, society and environment as well as some of the challenges that will have to be overcome.

Before you begin, let's find out some more about the circular economy and circular cities...

Rethinking Progress (3:48) The Butterfly Diagram (2:26) What is a Circular City? (1:59)

Use this map at the end of each section of the course to add your thoughts, make new connections, and generally map your vision for the future city. Add more of your thoughts that cannot be captured on the map in the corresponding boxes. (Recommended print size A3)



Mobility

Digital

Energy

Built environment

Society

Food & wastewater

Anything missing?

SECTION 1: THE BUILT ENVIRONMENT

Think of a city and what do you picture? No doubt your mind will conjure up images of skyscrapers, busy streets, retailers, sports stadiums...in other words, you most likely think of the built environment, i.e. our human-made surroundings. Nowhere is the built environment more obvious than in a city. After all, a city is a centre of population; a place where we live, work and play. Our cities are dynamic, constantly evolving environments. A growth in population means the built environment grows. This section takes a look at how we have built our cities and how we perhaps should build them.

This section contains six videos (approximately 45 mins viewing time total) and one article including question prompts and action points (allow approximately 1 hr 15 mins). **Suggested total time for this section is approximately 2 hours.**

Growing better buildings, featuring Guglielmo Carra from Arup (6:10)

Applying circular economy principles to buildings, featuring David Cheshire from AECOM (6:05)

Park 20/20: Circular case study, featuring David Cheshire from AECOM (5:19)

Google: Circularity and human health, featuring Robin Bass from Google (10:04)

Circular business models in construction, featuring David Corbey from the Alliance for Sustainable Business Products (8:56)

Smart buildings, featuring Futurist Nikolas Badminton (8:19)

Photo 1: The Bullitt Center in Seattle - designed to show what's possible in the movement toward high performance buildings and resilient cities
Photo credit: Bullitt Center on VisualHunt/ CC BY-NC

One surprising thing to learn about our cities is just how wasteful they are. One might think that because we have designed them and lived in them for centuries we might have perfected many processes, yet there is a lot of room for improvement. Look at Figure 1 below: the average European city wastes significant volumes of construction material, energy and demolition materials. As well as that, the Figure shows we waste space: 60% of European offices are not used even in working hours. Imagine if we were able to make better use of space in a city.

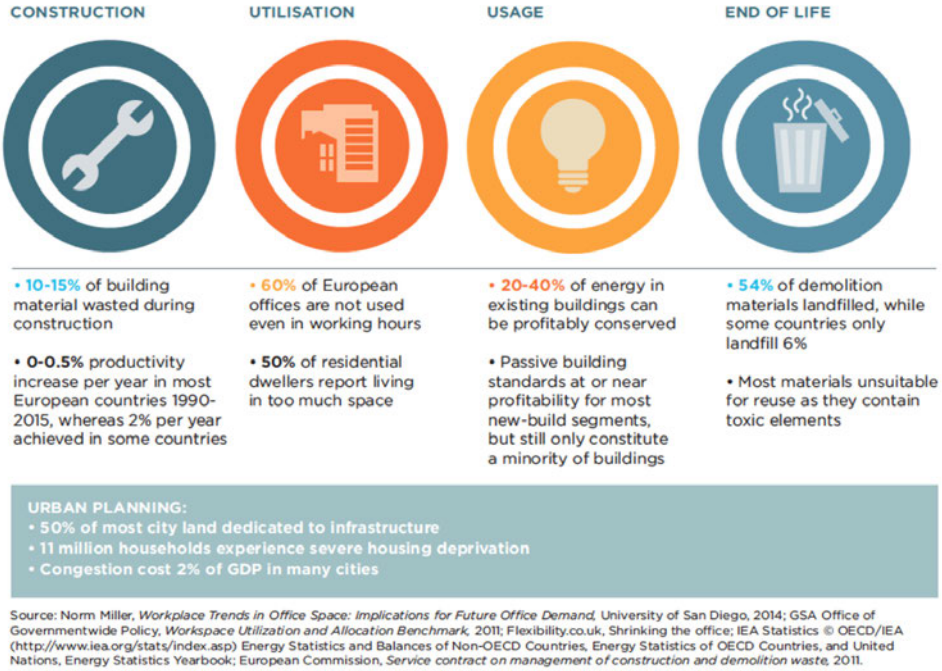


Figure 1 - Structural waste in the Built Environment
Credit: Ellen MacArthur Foundation (2015)

The UK generated 202.8 million tonnes of total waste in 2014, the majority of which goes to landfill. Over half of this (59.4%) was generated by construction, demolition and excavation, with households responsible for a further 13.7%[1] Of all industries in the UK, the construction industry is the major consumer of resources.

Redesign

One means of addressing waste in the built environment is by changing the way we design and construct buildings. Imagine if we designed buildings in a modular fashion, like a Lego model: this allows for components to be easily maintained and renewed, buildings to be repurposed, expanded or reduced in size according to need, as well as disassembled and moved to other sites. In London, for example, with over 40,000 new units of housing required

each year over the next ten years to keep up with population growth, this type of fast and flexible housing has obvious benefits.

Yorkon is one of the UK's leading modular building manufacturers. This off-site manufacturer of buildings pieces together the final building in situ, having done the

1. Department for Environment, Food and Rural Affairs, UK Statistics on Waste (2016)

majority of the work elsewhere. In itself, this can be a money and time-saver, as there is less disruption than would be the case for an on-site build. Yorkon say that labour and material efficiency is greater in the factory environment in comparison with a typical on-site construction. Noise and air pollution are also minimised due to the speed of installation, when compared with traditional practices, thereby improving city life.

Photo 2: Construction work at PLACE / Ladywell.
Copyright: Mark Gorton / Rogers Stirk Harbour + Partners

One existing example is **Place/Ladywell in Lewisham**, a temporary housing development planned and constructed in just nine months that will remain on site for between 1-4 years. The development will provide 24 homes for local people who need homes, as well as non-residential units for community and business use whilst more permanent new builds are being developed to meet demand. The buildings have been designed to be fully demountable, meaning they could be moved to another derelict site awaiting development where there is a housing shortfall. This approach understands that encouraging the flow of resources is vital for a healthy economy, and there's idling capacity in empty space that should be providing value. This flexible approach to construction ensures materials can be kept in use for as long as possible, thereby reducing waste as well as the need to extract new resources.

WATCH: David Cheshire from AECOM share his thoughts on applying the circular economy to construction in this short video (video: Applying circular economy principles to buildings)

WATCH: Simon Corbey from the Alliance for Sustainable Business Products share more circular building case studies in this short video (video: Circular Business Models in Construction)

In Amsterdam, **Park 20/20** is a 28-acre business park built on **Cradle-to-Cradle** design principles (a key component of the circular economy framework). Construction materials are leased from suppliers who retain ownership and can recover and reuse materials when buildings are disassembled. In this way, Park 20/20 acts as a **materials bank**: the materials are 'withdrawn' at the end of life and reused again at high quality. As well as the cycling of materials, energy is produced from solar panels, water is recycled, and waste is converted to biogas to provide an alternate source of energy. Nestled among the buildings are also greenhouses and vegetable gardens used to grow organic fruit and vegetables served in the on-site cafe. Imagine the benefits to people's health, the environment, and the economy if the Park/20/20 concept were replicated on a large scale!

Photo 3: Dutch internet travel booking company Fox Vakanties' building was the first to receive a BREEAM Excellent environmental rating.
Credit: Delta Development Group

WATCH: David Cheshire from Aecom discussing the Park 20/20 project in detail in this short video (video: Park 20/20: Circular case study)

3D printing also has the potential to revolutionise the built environment. Chinese construction company WinSun demonstrated how far 3D printing has advanced by printing full-sized houses and apartments. In 2014, WinSun printed and assembled ten houses in 24 hours. Each house was approximately 195 square meters, at a cost of EU 5000, and used 30-60% less material than traditional construction[2]. The 'ink' used in their 3D printers is a mixture of dry cement and construction waste that would otherwise be landfilled.

Materials

Advancements in materials technology will also play a vital role in the development of cities. Sourcing renewable, non-toxic materials will minimise virgin material use, increase reusability/recyclability, and ultimately allow for materials to be safely returned to the biosphere at end of life, thereby acting as 'nutrients' to grow new materials. In this model, buildings will generate, rather than consume, power and food. And they will have fully closed water, nutrition, material, and energy loops[3].

Arup's Biobuild project, featured in the accompanying video series, is one such example of material innovation in buildings. Using natural fibres from hemp, jute, and flax, and natural resins derived from sugar cane and corn, the project aims to create entirely non-toxic building facades known as 'biocomposites'. **Arup's 2017 report, The Urban Bio-loop: Growing, making and regenerating,** states that,

> *"biocomposites can reduce the embodied energy of building components when compared to conventional construction materials, and produce no increase in cost. At the same time, they increase the thermal performance of the building."*

WATCH: Guglielmo Carra from Arup describing how the Biobuild Project used natural materials to build high performing buildings in this short video (video: Growing better buildings)

Other innovations to date include the use of micro-algae in facade panels to generate heat and biomass as renewable energy sources. Even mushroom-based materials have been used in buildings such as in the Mushroom Tower installation for the MoMa in New York City. The material used is mycelium, a 'microscopic, fibrous fungus that binds itself to its food source to create a strong, resilient matrix in any shape desired[4].'

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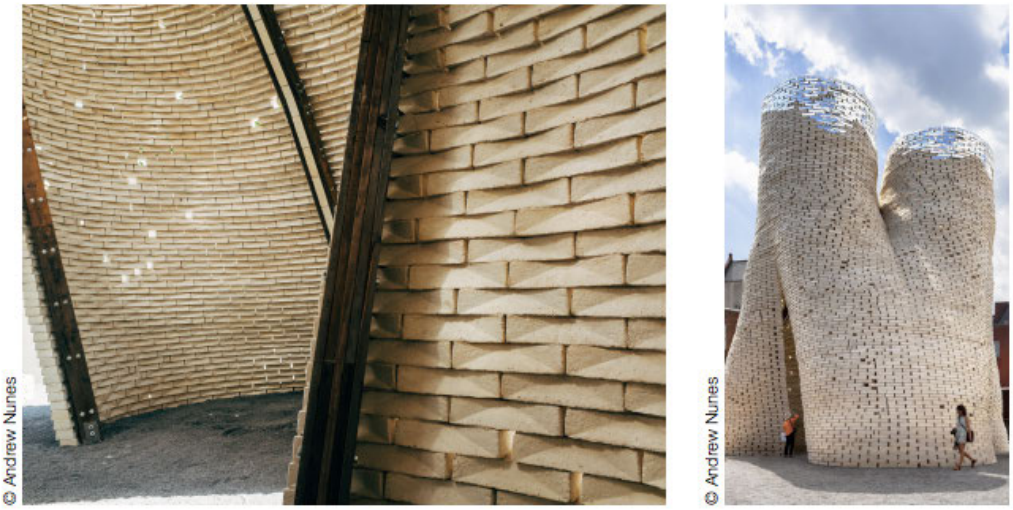
2. **Ellen MacArthur Foundation, SUN and McKinsey Center for Business and Environment, Growth Within: a circular economy vision for a competitive Europe (2015)**
3. **Ellen MacArthur Foundation, SUN and McKinsey Center for Business and Environment, Growth Within: a circular economy vision for a competitive Europe (2015)**
4. **Arup, The Urban Bio-loop: Making, Growing and Regenerating (2017)**

Photo 4: From micro-algae to mycelium, companies are exploring a range of new materials that provide multiple benefits for the environment, society and economy

BIQ HAMBURG

Facade panels filled with algae contribute to net-zero energy buildings



MUSHROOM TOWER

Mushrooms can grow from organic waste and be used for building purposes

Source: **Arup, The Urban Bio-loop: Making, Growing and Regenerating (2017)**

WATCH: Robin Bass from Google talking about the health implications of the materials we use in the built environment in this short video (video: Google: Circularity and human health)

Consider:

- **What are the key benefits associated with some of the construction techniques and approaches outlined in this article?**
- **Given the social and environmental benefits of these techniques, why do you think relatively few buildings are built this way?**

Space

There is a huge opportunity to reap additional value from underutilised space in cities. In Europe, 60% of office spaces are not used, even during office hours. But this picture is changing rapidly. Flexible seating, desk sharing, office hoteling, teleworking, and audio/video conferencing are major trends that are winning acceptance from workers who appreciate flexibility and adaptability. A forecast of employment trends by the World Economic Forum reports work flexibility, including telework (working via tele-communication tools from somewhere outside the office), as one of the "biggest drivers of transformation" in the workplace[5].

New business models are emerging to capture this opportunity. For example, 39% of IBM's 300,000 staff members worldwide work remotely, which has provided global real estate savings of around 1 billion Euros over the last ten years. Platforms like ShareDesk are allowing businesses to create additional revenue from renting out their office space, and co-working spaces are fast becoming hubs for innovation and the exchange of ideas.

Looking at the built environment as a whole, the introduction of a circular mobility system could have far-reaching implications for cities and the future of urban planning. Driverless cars, for example, remaining largely in transit rather than idle (the average European car is parked 92% of the time) won't require car parking space. This has the potential to unlock a huge amount of inner city land currently used for this purpose. In this circular scenario, urban sprawl could be reduced, and reclaimed land used for new housing projects or turned into shared green areas for recreation.

The city of Shanghai is implementing an unorthodox approach to the issue of urban sprawl. The project, known as Shanghai 2035, aims to 'shrink' its centre by capping its permanent population to 25 million by 2035 and limiting construction to within 3,200 square kilometres. A clear target of limiting private vehicle use to below 15% of the central city's transportation, has also been set[6]. One of the main purposes of the initiative is to create a very liveable 'human-centric' city that will attract highly talented workers and encourage healthier lifestyles for all.

New technologies impacting the built environment

Coupled with more efficient and cost-effective forms of construction, much progress can be made through the integration of 'smart' technology. Examples include responsive heating, ventilation, and air conditioning (HVAC) systems, as well as smart meters that can provide greater transparency on energy consumption and cost. Solutions for retrofitting existing buildings such as improving insulation and incorporating smart meters are estimated to reduce energy consumption by 20-30%.

5. **World Economic Forum, Employment Trends (2016)**
6. Yuchen, Z., **Shanghai Aims to Become Global Metropolis with New Blueprint (2018)**

Other more established technologies such as solar PV (photovoltaic) are dropping considerably in price, helping in the transition towards buildings as producers of energy rather than mere consumers. Water is moving in a similar direction with green roofs able to filter and capture rainwater. Recirculation of water within homes (e.g. using shower water to flush the toilet) is another way to reduce a home's resource consumption. More on the impact of digital technology in cities can be found in the 'Digital' section of this course.

WATCH: Futurist Nikolas Badminton describing how technology will change our buildings in this short video (video: Smart Buildings)

Figure 2 below illustrates some of the ways technology can unlock the circular potential in the built environment.

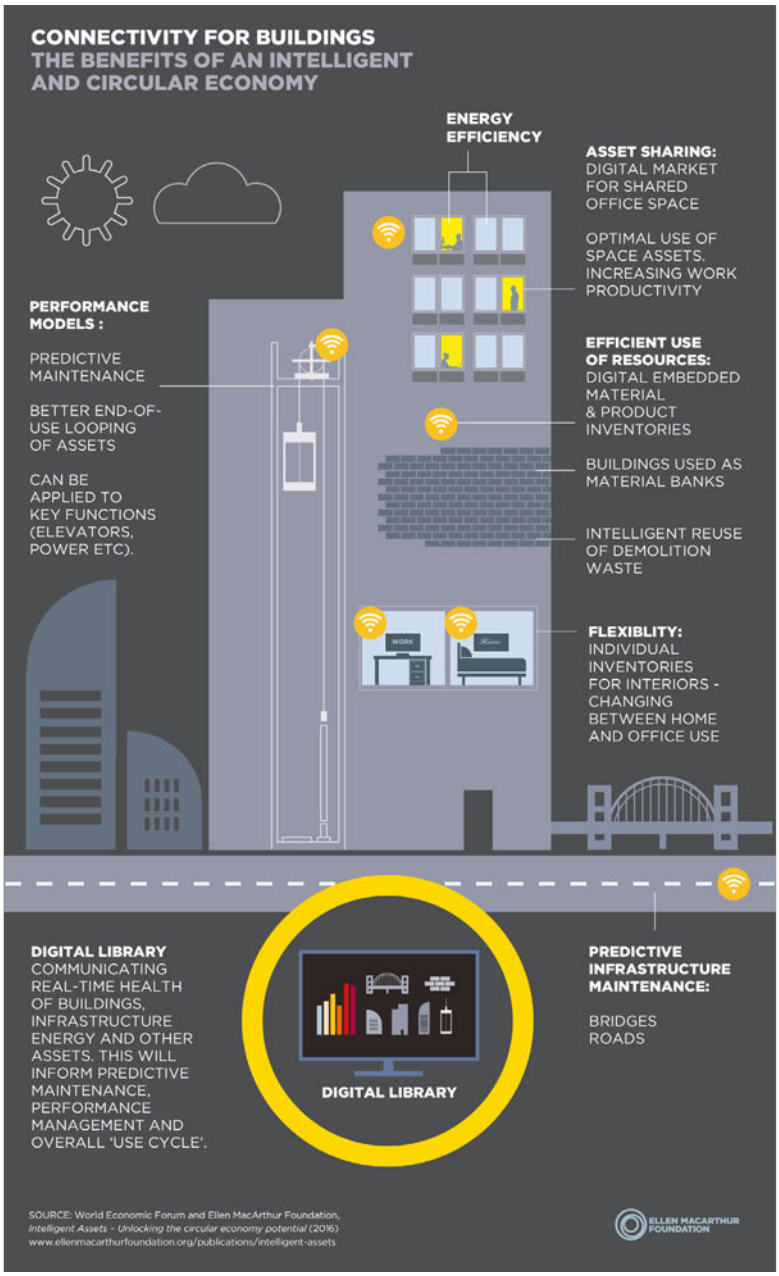


Figure 2: Connectivity for Buildings
Credit: Ellen MacArthur Foundation

Many of these changes are already underway, especially in new builds, but it is worth noting that in developed countries many of the buildings we will use in the next 30 years have already been built. In the UK, this is true for about two-thirds of the building stock that will be around in 2050[7]. Therefore, it is important that new technologies are able to be retrofitted to existing building stock and not just reserved for new ones. For developing nations, the need for retrofitting these technologies is clearly less of an issue as they have the opportunity to implement them from the outset.

The increasing move towards 'smart' home technology does, however, pose a security risk - companies will have access to data showing the movements of occupants, and precise information on how people use their homes or offices. Anything that is connected will be gathering personal data. Inevitably, there are big questions around rights, use and ownership of this information.

Figure 3 below provides a visual summary of the circular built environment.

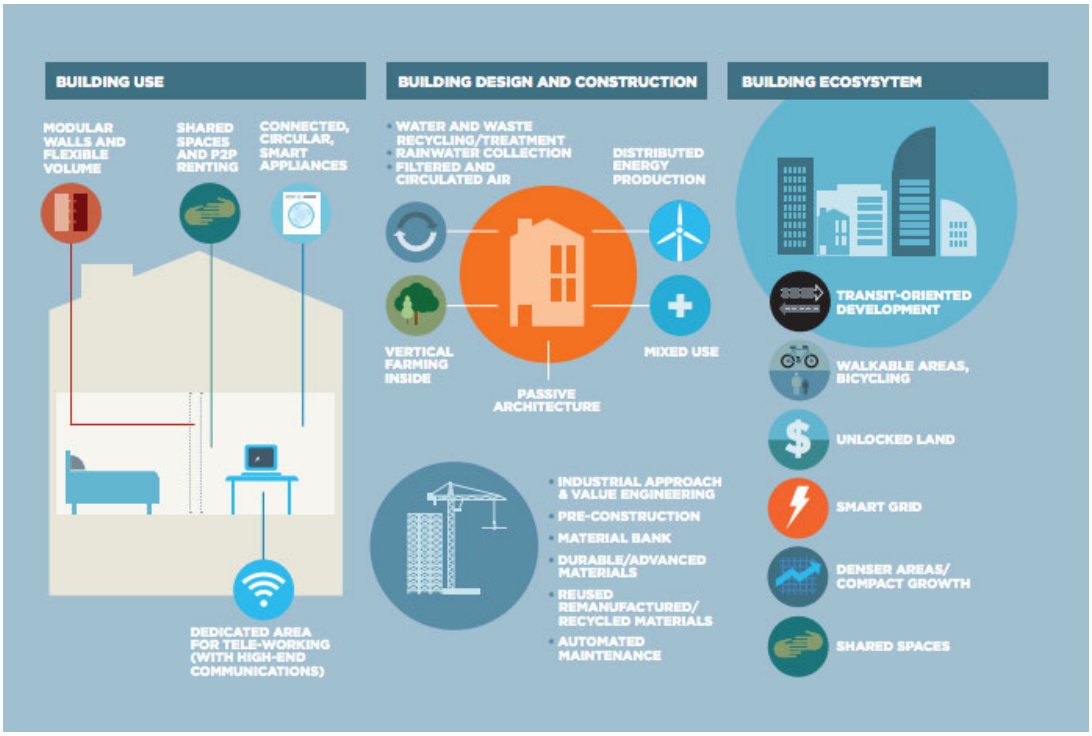


Figure 3: A Circular Built Environment
Source: Ellen MacArthur Foundation

Consider:

- **What benefits could businesses get from sharing their workspace with others?**
- **What advantages are there for people to remotely connect with their devices at home? Give two examples.**

7. Osborne Clarke, Smart Cities in Europe: The Future of the Built Environment (2016)

Action:

- **After you have read the article and watched the accompanying videos, show on the city map how your city would change if it adopted some of the ideas and technologies referred to here.**

Further Reading:

Smart Cities in Europe: The Future of the Built Environment - report by Osborne Clarke

The Urban Bio-loop: Growing, Making and Regenerating - report by Arup

Future of Cities: The Circular City - How will it Actually Look? - article by Julia Vol

The Circular Building; Arup's Project Director Speaks to Circulate - article by Joe Isles

Shanghai Aims to Become GlobAL Metropolis with New Blueprint - article by Zhang Yuchen

Future of Cities: A New Approach to Urban Space - article by Lena Gravis

SECTION 2: DIGITAL TECHNOLOGY

3D printing, the Internet of Things, driverless cars, intelligent robots, genetic editing; these are just some of the technologies that promise to shape our lives in the future. Hailed as the 'Fourth Industrial Revolution', our present times are set to see changes equal in scale and disruption to those borne of the Industrial Revolution of the 18th century. Driving these significant changes is the exponential growth of digital technology.

Professor Klaus Schwab, Founder and Executive Chairman of the World Economic Forum, describes this revolution as a "range of new technologies that are fusing the physical, digital and biological worlds, impacting all disciplines, economies and industries, and even challenging ideas about what it means to be human."[8]

In economic terms, digital technology allows for new business models, reduced resource consumption, and greater transparency on the way we use products and materials. In short, this digital revolution is enabling unprecedented levels of innovation, efficiency and convenience for a growing proportion of the planet. With their unique proximity of skills and resources, cities are central hubs for technological innovation and change.

This section contains three videos (approximately 30 mins viewing time total) and one article including question prompts and action points (allow approximately 1 hr or 1hr 30 mins to include the 'Extension' task). **Suggested total time for this section is between 1 hr 30 mins - 2 hrs.**

Technology in circular cities, featuring Dave Ward from Cisco (8:20)

The impact of evolving technologies, featuring Nikolas Badminton (9:24)

What is a smart city? featuring Nikolas Badminton (11:47)

Transformative technology

Imagine the possibilities for cities if products, components and materials - from car parts to steel frames - could be located, and their condition and quantity revealed at the click of a button. This information could help extend the life of an asset, find secondary uses for it, and help reduce the flow of waste materials. For example, monitoring a car's usage patterns and condition through sensors can trigger alerts about problems as they appear, to allow for an easy and quick fix, thereby prolonging the life of the car. This technology is known as **asset tagging**. Taking this a step further, **Artificial Intelligence** can enable predictive maintenance, meaning that any failures of equipment are predicted and repaired automatically before a problem occurs.

8. Schwab, K., The Fourth Industrial Revolution, World Economic Forum

What if we could not only see where things are located, but also how they are connected? Combined with asset tagging, geo-spatial information can provide visibility on the flow of materials and people across the city (including patterns of optimal transport routes, energy demand peaks and dips, congestion, and waste generation). This can be helpful for urban planners deciding on the best place to build a new hospital, for example.

Now imagine all of this information could be combined and over-layed with general patterns of human behaviour. This would allow us to monitor and predict energy consumption patterns or suggest transport options that avoid peak hour traffic flows in real-time. This is known as **big data management**.

All of the above technologies can be further enhanced through increased **connectivity**. Access to the internet via smartphone technology creates more connections between people, and between people and products. This enables circular business models such as leasing and sharing platforms (e.g. car2Go), take-back systems (getting materials back to the company), and distributed remanufacturing. For example, business models such as Fat Llama, Airbnb or BlaBlaCars are made possible through an app that connects assets on offer with people looking to use them.

The number of web connected devices is expected to grow to 25–50 billion by 2020, from around 10 billion today[9]. A growing body of research indicates that this **Internet of Things** (IoT) offers a trillion dollar opportunity, brought about by improved production and distribution processes, and a significant shift in the way products are used. Building on from IoT technology, we are likely to see the evolution towards an **Internet of Everything** (IoE), which can be defined as the networked connection not just of things, but also of people, process, and data.

WATCH: Dave Ward from Cisco share his insights on the future of technology for cities in this short video (video: Technology in circular cities)

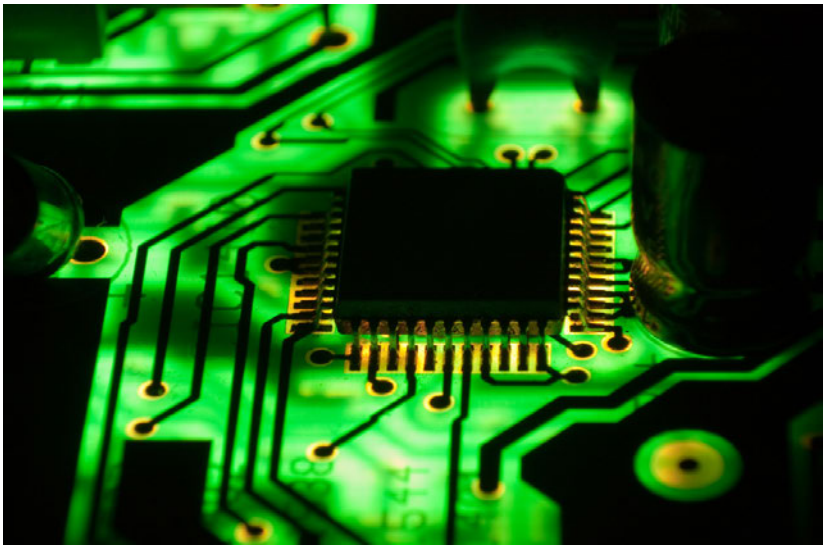


Photo credit: Skley on Visual hunt / CC BY-ND

9. Ellen MacArthur Foundation, Intelligent Assets: Unlocking the Circular Economy Potential (2016)

Figure 1 below identifies seven benefits associated with IoT technology.

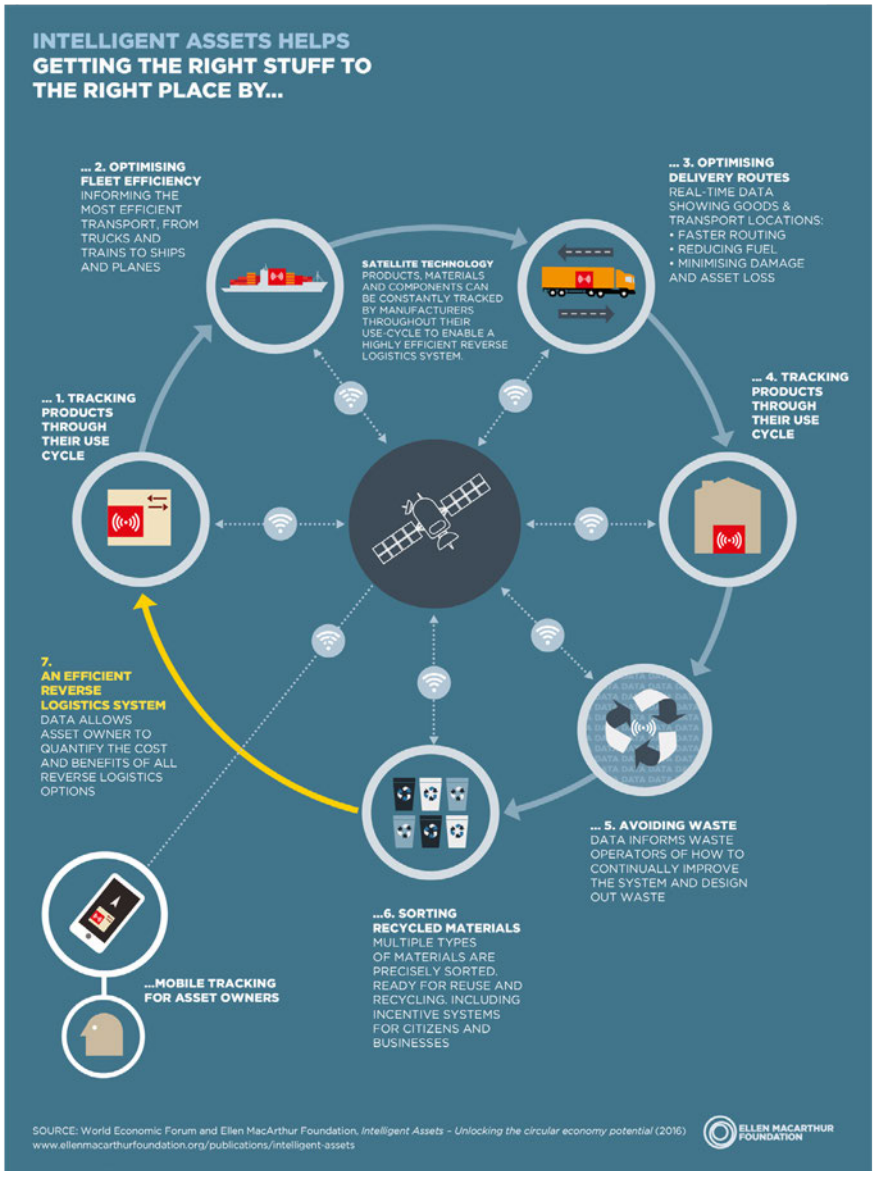


Figure 1: How the Internet of Things can optimise some processes
Credit: Ellen MacArthur Foundation

Consider:

- **Why would cities want to incorporate some of these technologies?**
- **What are the potential risks for a city that doesn't incorporate these technologies?**
- **Are there any other benefits that haven't been outlined in this article?**

Harnessing the Potential

As our ability to capture data increases, so too does our ability to analyse and observe patterns within that data - from the quality of the air we breathe to the amount of energy we consume in our homes.

Google, for example, is able to integrate data sources such as high-resolution imagery, GPS movements, sunlight capture, and intelligent sensors with a global user community to contribute to the circular city. This can provide the foundations for collaborative projects between public and private organisations, such as the **Waze Connected Citizens Program**. This program maps data in real time from a large network of drivers and volunteers who provide updates on things like traffic congestion and accidents. The resulting information has been used to inform new strategies for urban planners looking to ease traffic in city centres as well as help emergency services take vital minutes off their response times. Effective capture and use of this data is only possible through collaboration between people, organisations and sectors. Such collaboration will be essential in the transition to a circular economy, as its success will depend on finding creative solutions to challenges that cannot be achieved by a series of 'parts' acting in isolation from the 'whole'. This is where a 'feedback-rich' circular economy, enabled by digital information flows, takes a very different direction to a 'feedback-starved' linear economy.

Examples of how these technologies are supporting the vision for a circular city are layered onto Figure 2. For more information on the projects, read the full report **Cities in the Circular Economy: The Role of Digital Technology**

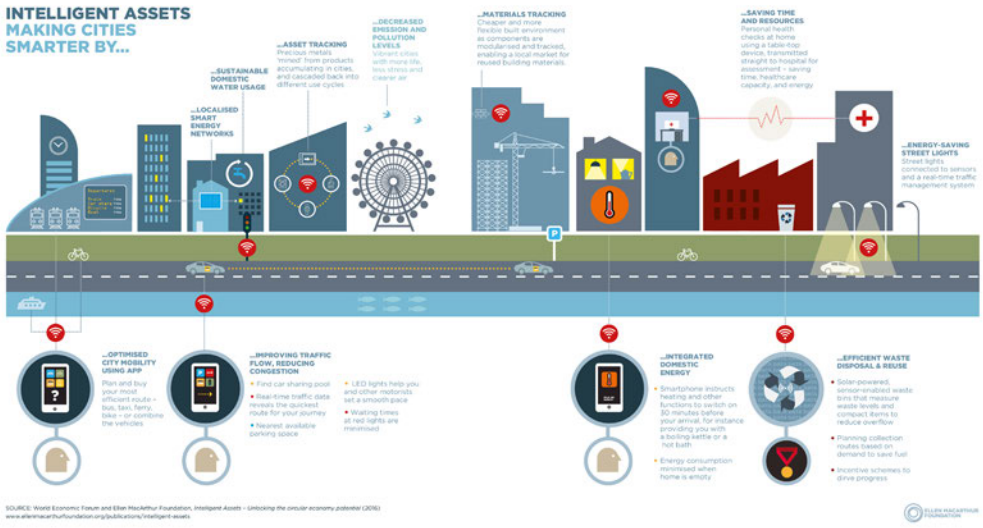


Figure 2: Making cities smarter
Credit: Ellen MacArthur Foundation

Sharing platforms

Mobile internet, in combination with high population density in urban spaces, has allowed the 'sharing economy' to flourish. The sharing economy allows people to exchange goods and services through an internet platform. For owners, this means you can earn money from an asset (e.g. a bicycle, or home) when you aren't using it, or from a particular skill that is in demand. For users, it means quick and easy access to things for a fraction of the price of buying them new and without any of the maintenance or storage worries.

The more we share, the less we need to buy new goods. Or so the story goes. There are associated issues, however. For one thing, the shared goods will need to be more durable, which might mean they have to be designed to be shared. What's more, fewer purchased goods leads to a fall in profits for manufacturers and retailers. This will undoubtedly have an impact on jobs in these areas. Will the jobs created in the new sharing platforms outweigh those lost?

However, in a best case scenario, shared goods can lead to the use of fewer resources (including the energy required to produce them), and a sharing economy can help generate new jobs and create new entrepreneurial opportunities.

AirBnB and Uber are two of the most famous examples of platforms disrupting mature sectors but there are others and there will be more. AirBnB began in 2008 and has already outgrown many of the large hotel chains that have been operating for decades. As of 2017, the company was valued at USD 31 billion, making it nearly twice as valuable as Hilton Hotels[10]. These new business models - referred to by some as 'platform capitalism' - are reshaping people's lives, but not always in a positive way. In essence, platform capitalism is when a company provides the platform (usually an app) for others to operate on. Value can be extracted either from the users who must pay to use the service (as with Uber) or through advertising (as with Facebook).

In a Guardian article entitled **Where Uber and Amazon rule: welcome to the world of the platform**, Evgeny Morozov writes:

> *Instead of the tired conventional model, with individual firms competing for customers, we are witnessing the emergence of a new, seemingly flatter and more participatory model, whereby customers engage directly with each other. With a smartphone in their pocket, individuals can suddenly do things that previously required an array of institutions.*

Morozov goes on to explain the subsequent impact this is having on the economy: "taxi companies used to transport passengers, but Uber just connects drivers with passengers. Hotels used to offer hospitality services; Airbnb just connects hosts with guests. And this list goes on."

10. **Lunden, I., Airbnb $31B Valuation, Techcrunch (2017)**

For many, platforms like Uber and Airbnb are seen as cheaper and more convenient than traditional service providers, which allow people to earn additional income from underutilised assets (things they own that aren't being used that much). However, critics argue that these platforms are able to monopolise sectors, killing competition and diversity, as well as exploit a variety of regulatory loopholes around areas such as taxation and workers' rights. Because Uber doesn't actually 'employ' its drivers, it doesn't have to adhere to the same laws as in the traditional employee/employer relationship, leaving workers in a more vulnerable position. What's more, these services tend to displace locally-run services. The profits from Uber head to the investors in San Francisco, while the profits from local taxi services typically make their way into the hands of local business owners.

One means of addressing these issues - as some countries are already doing - is to adapt regulation to ensure that a company cannot gain unfair competitive advantage. However, legislation has generally struggled to keep up with the pace of technological change.

In the city of Amsterdam, in 2015, there were approximately 17,000 rentals listed on AirBnB[11]. Short stay rentals in the city have proved so popular that entire neighbourhoods are being transformed as more and more homes are purchased for commercial purposes, pushing up real-estate prices and driving out locals. In turn, this has led to a reduction in neighbourhood businesses that create ties between residents, and an influx of businesses catering mainly to tourists.

Sito Veracruz, an urban planner interviewed for the **Guardian** by Renate Van Der Zee, has witnessed the side-effects of AirBnB first hand. In response, he has created his own alternative platform called **Fairbnb**, which is "a platform that really complies with the principles of a fair, non-extractive and collaborative economy." Fairbnb aims to contribute positively to city life by making sure that hosts are registered with the council, have met local authority standards, and neighbours are involved in the management of the platform.

These types of platforms - referred to as 'platform cooperativism' - provide an alternative to 'platform capitalism'. They are owned and governed democratically by the people who use them most, such as workers and users instead of by a single company. 'Value' is not extracted via a sleek platform app, it is circulated within the community of users.

Other examples include **Fairmondo**, an online marketplace for ethical goods and services and **Loconomics**, an online and mobile marketplace that allows customers to find freelance skills and labour for everyday tasks such as babysitting or pet care.

WATCH: Futurist, Nikolas Badminton, on the impact of new technology in this short video (video: The impact of evolving technologies)

11. **Morgan Stanley Research, Airbnb's Impact on Hotels, 2015**

Consider:

- **Some hotel chains have complained about how AirBnB have reduced their customer base. On balance, do you sympathise with hotels or sympathise with AirBnB?**
- **What is the key difference between platform capitalism and platform cooperativism? Which one do you think is more beneficial to society and to the economy?**

Security Concerns

The circular economy provides a framework for making better use of resources, creating new jobs, and reducing our environmental impact, but it is the increasing prevalence of digital technologies that is enabling circular economy principles and practices to become a reality in cities.

Yet despite the obvious advantages of technology, there are concerns around the protection of data that companies must take seriously. Many consumers are still cautious, especially given that 'smart' or IoT technology is relatively new with only basic security features.

Edith Ramirez, chairwoman of the Federal Trade Commission in the US, said in a 2015 **speech** that the "risks that unauthorized access create intensify as we adopt more and more devices linked to our physical safety, such as our cars, medical care and homes."

In an experiment carried out to gauge the threat of being hacked via everyday appliances, a fake 'smart' toaster was connected to the internet and made to look like an unsecured web device. One hour later the toaster had been hacked. This experiment demonstrated just how quickly unsecured devices can be compromised, providing a gateway into your home network where a range of personal data can be accessed. Just imagine the potential problems once millions of everyday devices are connected.

WATCH: Futurist, Nikolas Badminton, share his thoughts on what a smart city looks like in this short video (video: What is a smart city?)

Action:

- **After you have read the article and watched the accompanying videos, show on your city map where digital technologies are likely to have the most significant impacts.**

Extension:

- **Have a debate using the following statement as a prompt:**

There are positive and negative sides to our increasing reliance on digital technology; however, the potential benefits to our economy, society and environment far outweigh the threats.

Further reading:

Intelligent Assets: Unlocking the Circular Economy Potential - Case Studies

The Internet of Things: industry's digital revolution - article by Ed Crooks

Platform Cooperativism vs. the Sharing Economy - article by Trebor Scholz

How Platform Coops can Beat Death Stars like Uber to Create a Real Sharing Economy - article by Neal Gorenflo

The Inevitability of Being Hacked - article by Andrew Mcgill

How Can Cities Leverage the Potential of the 'Sharing Economy'? - article by Yann Zopf

The IoT, Performance Based Business Models and the Circular Economy - article by Matt Wright

Top Ten Urban Innovations - report by World Economic Forum

Growth within: A Circular Economy Vision for a Competitive Europe - report by Ellen MacArthur Foundation

CES: Security Risks from the Smart Home - article by Molly Wood

SECTION 3: ENERGY - HOW WILL WE POWER AND HEAT THE CITY OF THE FUTURE?

The energy market is anticipated to undergo considerable transformation between now and 2040. The cost of generating electricity from coal (in particular) and wind continues to fall, and now it is easier than ever for citizens to generate, purchase and sell renewable energy with very little complication. This means it is likely that one day our cities will generate a large percentage - or all - of their own electricity needs. Some people argue that heat could go the same way. Should this happen, the city might look and be experienced quite differently.

This section contains three videos (approximately 15 mins viewing time total) and one article including question prompts and action points (allow approximately 1 hr). **Suggested total time for this section is approximately 1 hr 15 mins.**

Solar: the next ten years, featuring Marty Neese, the COO of Sun Power (3:09)

Will rivers heat our cities? featuring David Pearson, Director of Star Renewable Energy (5:43)

Denmark: wind and district heating, featuring Jakob Lau Holst from the Danish Wind Industry Association (5:34)

Rate of change

History teaches us that when change comes it can often come at an exponential rate. Note the speed of adoption of various technologies in Figure 1 below.

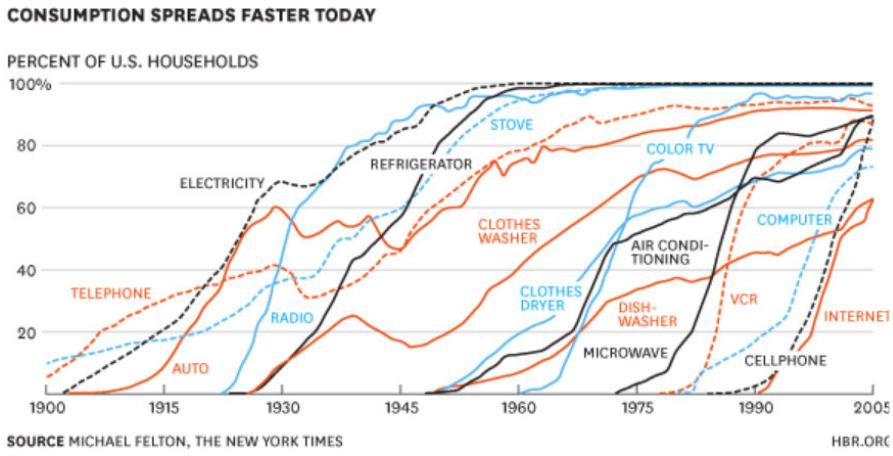


Figure 1: Consumption Spreads Faster Today

Source: https://hbr.org/2013/11/the-pace-of-technology-adoption-is-speeding-up

Will renewable energy technologies be adopted at a similar, sudden pace? Bloomberg believe they will. They say that by 2040, wind and solar will account for 48% of installed capacity and 34% of electricity generation worldwide. This is compared with just 12% and 5% today. This is partly due to cost: more efficient wind turbines, lower maintenance costs, and the continuing fall in the cost of solar PV production (priced per kilowatt hour (kwh)). The cost of wind and solar will be below the cost of coal by the mid 2020s, say Bloomberg.

Figure 2 below shows how the cost of generating a kilowatt hour of electricity from solar power has fallen sharply since 1977. Costs are anticipated to continue to fall.

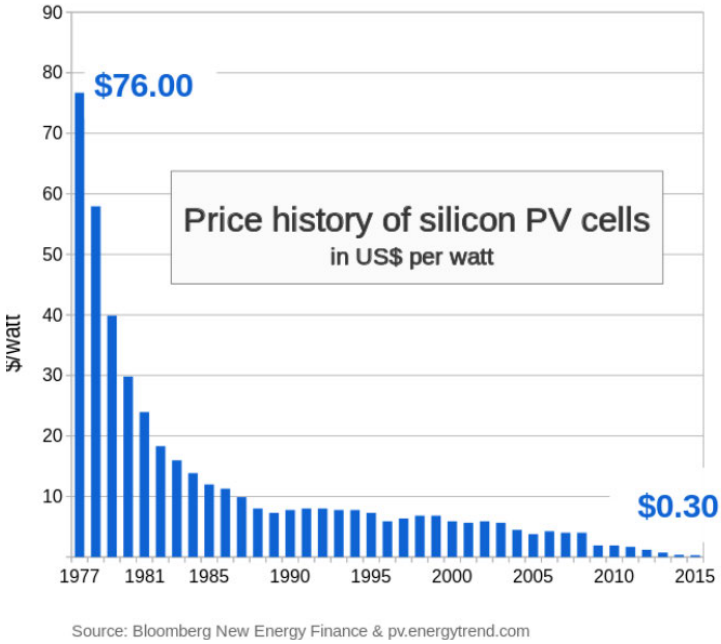


Figure 2: Price history of silicon PV cells
Source: https://commons.wikimedia.org/wiki/File:Price_history_of_silicon_PV_cells_since_1977.svg

While the price might be falling, the question persists: given their intermittent output, can renewables meet demand? The management of a city's power supply is in the hands of the **grid operator**. This person is in constant communication with power plants in order to ensure supply and demand are constantly balanced. Because the wind can suddenly drop, or clouds can appear, the electricity supply from renewables can fluctuate and cause problems for the grid operator. However, as **Robert Fares points out in the Scientific American**, if a city spreads its renewable load out across a wide enough area, it is unlikely that a sudden change to local conditions will disrupt supply. With that said, the grid operator needs to be forever planning ahead - hour to hour and day to day - in order to estimate where and when supply from renewables is predicted to fall. At present, the grid requires a mix of sources that complement each other in order to continually meet demand.

Perhaps at some point in the future the position of 'grid operator' will become unnecessary as electricity generation becomes increasingly decentralised (i.e. produced by citizens, rather than produced by giant power stations).

Rent a roof case study

The Indian state of Gujarat has managed to create enough clean energy for around 19,000 people while lowering greenhouse gas emissions. The state teamed up with private property owners to have their rooftops fitted with solar panels, thereby bypassing one of the most expensive elements in setting up a solar farm: purchasing ground space. The roof owners are paid for each unit of electricity generated by the energy company, who are themselves paid by the state for each unit fed into the grid.

In a clever use of technology, satellite images were used to scope out the most attractive roof space available within the city. The end result was that a variety of buildings, including state government buildings, libraries, government residential spaces, commercial buildings, and private housing and apartment blocks were used. Due to its success, plans are being considered to scale the concept across India.

WATCH: Solar panels are not a new idea, but their popularity is. Watch as Marty Neese - Chief Operating Officer of SunPower - speculates what the next ten years will bring for the industry (video: Solar the next ten years)

WATCH: Denmark has a great track record in renewable energy. In this short video you'll hear from experts in wind power and district heating as they tell us why the country is embracing these technologies (video: Denmark wind and district heating)

Consider:

- **If a large-scale switch is made to renewable energy, who will benefit and who will lose out? Explain how and why.**
- **If not renewable energy, then what?**
- **Why do renewables add additional complexity to the grid operator's job?**
- **What's the key advantage of district heating and how does it relate to a circular economy?**

Energy efficiency

When it comes to rethinking energy solutions for our cities there are two considerations to make: how we generate the energy and how we use it. Until now, this article has dealt with generation, so what of use?

Energy generation often comes with costs - economic, social and environmental - so it is sensible to work out how to minimise or eliminate these. The analysis suggests we can reduce energy demand by design. Given most of the buildings we'll use in our cities in the decades to come have already been built, to make better use of energy we might need to reconsider **retrofitting** them. **The Rocky Mountain Institute** (RMI) have concluded "that by 2050, U.S. buildings can triple or quadruple their 2010 energy productivity, saving $1.4 trillion net present value with a 33% internal rate of return. The savings are worth four times their cost"[12].

But there are barriers. For example, properly insulating a home can considerably improve energy efficiency; however, many homeowners rent out their properties and therefore have no financial incentive to pay for things like double glazing, as the tenants - not the owners - pay the energy bill.

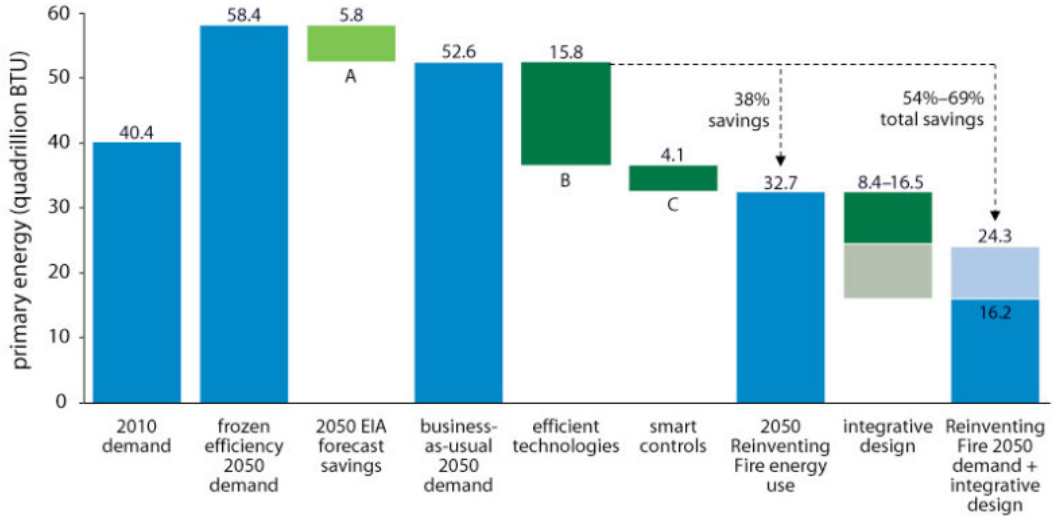
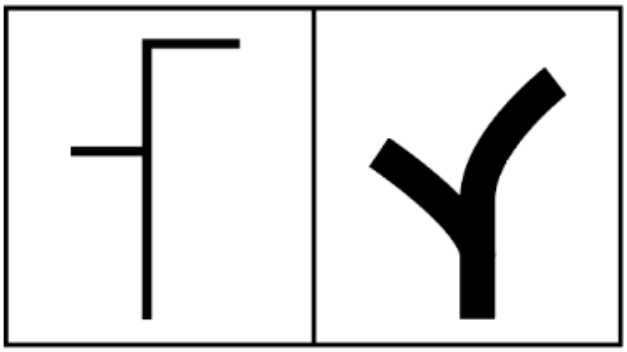


Figure 3: Retrofitting

Source: **https://www.rmi.org/wp-content/uploads/2017/05/AIP_RF.pdf**

12. Lovins, A., **Reinventing Fire: Physics + Markets = Energy Solutions (2017)**

Figure 4: Pipe design. Long, thin pipes with 90 degree angles (left) are not as efficient as short, thick pipes with junctions that mimic blood arteries (right)



WATCH: Dave Pearson is a Director with Star Renewable Energy, who produce river source heat pumps. The pump generates heat from rivers (video: Will rivers heat our cities?)

Consider:

- **Will a switch to renewable energy make us more or less wasteful of our energy use? Discuss.**
- **Do river source heat pumps fit with the idea of a circular economy?**

Externalities

Environmental costs are often described as 'negative externalities', i.e. the cost of dealing with them are not borne by those who produced the problem, they are instead dealt with by 'external' parties. The climate costs of fossil fuel use are already measurable and will increase in the future. As well as causing environmental problems, acid rain, mercury, and arsenic pollution are economic costs the public (often cities) bear. Fossil fuel power plants are a typical example of where such types of externalities are generated.

Some people argue that nuclear power should be a part of any energy solution, because it is a reliable producer of electricity and generates no emissions while they operate. While this is true, there are certainly downsides to nuclear power, not least the question of how to store the toxic waste they generate. There are other arguments for and against nuclear power - why not **watch this TED debate** which covers both angles?

While it is true that there are currently some negative externalities related to the start of life and end of life for renewable technologies, their operating cost is almost zero. This gives them a significant **competitive advantage** over fossil fuel plants. Some people argue against renewables on the basis of another externality: they don't like how they 'spoil' the landscape. This is clearly a subjective matter, but it is certainly one that wind farm operators, in particular, frequently come up against.

Consider:

- **Given the falling cost of renewables and the associated health and environmental benefits, are you surprised there is still resistance to their use? Explain why/why not.**
- **What shifts in regulation and policy might have a positive impact on the issue of negative externalities (such as air and water pollution)?**

Action:

- **After you have read the article and watched the accompanying videos, use the city map to show where you would see renewable energy technologies being adopted in your city.**

Further Reading:

100% clean and renewable wind, water, and sunlight (WWS) all-sector energy roadmaps for the 50 United States - report by Jacobson et al. Stanford University

New Energy Outlook 2017 - report by Bloomberg

The Pace of Technology Adoption is Speeding Up - article by Rita McGrath

Reinventing Fire: Physics + Markets = Energy Solutions - report by Amory Lovins

Integrative Design: A Disruptive Source of Expanding Returns to Investments in Energy Efficiency - report by Amory Lovins

All Renewables to Compete on Cost with Fossil Fuels by 2020, says IRENA - article by George Ogleby

Gujarati Cities Go Green with "Rent a Roof" Solar Power - article by Apolitical

SECTION 4: MOBILITY

The entire mobility sector is on the verge of one of the fastest and most significant disruptions in the history of transportation. Over the next two decades, electric vehicles, shared car schemes, autonomous vehicles, and better connected services will become commonplace.

These changes could ease congestion, improve air quality, reduce energy and materials demand, and lead to huge economic savings - all of which can improve the lives of citizens. On the other hand, if cities don't react quickly enough to the emergence of these technologies, they could become more congested, more polluted, and rife with illegal 'taxi' services. Embedding any new technology successfully into a city relies on understanding how it fits in and interacts with other key elements that comprise the overall 'system' of the city.

This section contains four videos (approximately 30 mins viewing time total) and one article including question prompts and action points (allow approximately 1 hr). **Suggested total time for this section is approximately 1 hr 30 mins**.

Mobility as a service, Rasmus Lindholm from Ertico-ITS Europe and Paul Godsmark from CAVCOE (8:40)

Growth in autonomous vehicles, featuring Paul Godsmark from CAVCOE (6:21)

Energy savings in the future of mobility, featuring Jeffery Greenblatt from Lawrence Berkeley National Laboratory (10:53)

The Future of Autonomous Vehicles, featuring Robin Chase, co-founder and former CEO of Zipcar (3:52)

The combustion car

Despite their obvious usefulness, there are numerous well-understood environmental and societal problems related to cars, namely: CO2 emissions, road accidents, and road congestion. Of course, cars also come with an ongoing maintenance and use cost to the owner.

It is estimated that there are over 1 billion cars in use in the world. Given they have been the prime mode of transport in the developed world for more than half a century, one might imagine that many of the detrimental aspects of cars may have been designed out, yet they remain surprisingly underutilised, wasteful, and dangerous. Consider the detail found in Figure 1 below:

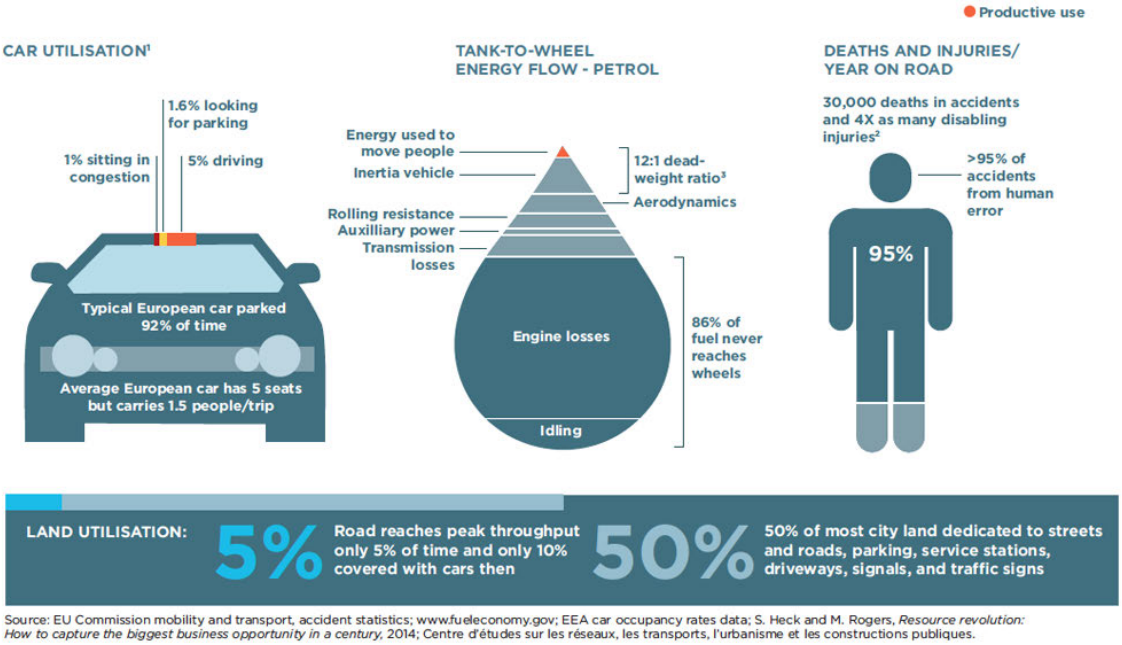


Figure 1 - Structural waste in the mobility system
Source: Ellen MacArthur Foundation

Note that Figure 1 refers to structural waste, i.e. wasted potential throughout the entire system, not just waste related to the vehicle itself. For example, Figure 1 shows that 50% of most city land is dedicated space for vehicles, yet roads only operate at their peak throughput 5% of the time.

The car cannot operate without the correct **system conditions**, i.e. roads, parking spaces, petrol stations, rules of the road, and so on. Therefore, it is only right that any consideration regarding the shortcomings of the car – or any discussion about how mobility might change – must also take into consideration the existing system conditions and the potential system conditions (i.e. the changes that could be made). For example, if a city wanted more citizens to cycle, then a system condition change could be to create more cycling lanes, or even ban motor transport from certain parts of the city.

Consider:

- **How could cities be improved if the amount of land space dedicated to vehicles (currently 50%) was significantly reduced?**
- **Does the information in Figure 1 present a strong enough case to stop using cars?**

Electric vehicles

The vast majority of cars today have a petrol engine. Petrol is, of course, derived from oil: a finite substance with a volatile price. The environmental cost of petrol-based engines is well-understood, which is why there have been ongoing calls for alternative methods of powering motor vehicles. Some countries such as Scotland, France, and India have already pledged to ban the sale of petrol and diesel engines in the next two decades.

In 2016, we saw a global increase of 2 million electric vehicles (EV) on the roads which doubled on recorded numbers for 2015. But for EVs to become the most popular mode of transport, the **system conditions** will need to change in their favour. For example, the necessary infrastructure will have to be put in place such as a network of electric charging points in convenient locations. In addition, a national government can make these vehicles more attractive by offering financial incentives to users, such as reduced vehicle taxes. Incentives introduced by the Norwegian Government[13] helped the EV market get off the ground. In the first three months of 2016, almost 25% of all new vehicles registered were EVs: the highest figure in the world.

However, going electric is not without its inevitable complications and pitfalls. The batteries used to power these vehicles rely on lithium, a finite natural resource that has to be mined and therefore comes with an environmental toll. Lithium expert Joe Lowry expects demand to nearly triple by 2025[14], which is likely to inflate the price and result in increased competition between countries and manufacturers looking to secure the precious metal.

Future trends

The car fleet could change significantly in the next 10-20 years. Car sharing schemes (like **Zipcar**), electric vehicles, and interconnected mobility options (enabling people to catch a bus just as they get off a train, for example) are already on the rise. Advances in materials technology and production methods are also likely to make vehicles lighter and improve energy efficiency. Using new, lightweight materials like carbon fibre might lower the cost of using cars significantly[15]. However, when the cost of a service falls, demand often increases. If more users switch from public transport to lower cost vehicles, then this could increase congestion and traffic-related accidents.

WATCH: Rasmus Lindholm from Ertico-ITS Europe and Paul Godsmark from CAVCOE discuss the idea of mobility as a service in this short video (video: Mobility as a service)

14. **Barnato, K., This country has hit a major milestone for electric cars—here's how, CNBC (2016)**
15. **The White Gold Rush: A Battle for Supremacy in the Lithium Triangle, The Economist (2017)**
16. 25-40 percent by 2030: **Ellen MacArthur Foundation, SUN and McKinsey Center for Business and Environment, Growth Within: a circular economy vision for a competitive Europe (2015)**

Photo 1: Volkswagen's I.D. Buzz - the iconic camper van goes electric
Photo credit: harry_nl on Visualhunt / CC BY-NC-SA

An **autonomous car** is a vehicle that is capable of sensing its environment and navigating without any need for human input. The car uses a number of sensors to detect its position on the road, the other vehicles and objects around it, its speed and direction, then makes decisions based on this continuous data input. The human passengers do not need to operate the vehicle in any way. Several car manufacturers have been experimenting with autonomous vehicles for some time now. Google's autonomous cars have driven over 1.5 million miles already[17].

A **report** produced by Rethink X on the disruptions to the transportation industry, predict that by 2030, "95% of U.S. passenger miles traveled will be served by on-demand autonomous electric vehicles owned by fleets, not individuals." They refer to this new business model as "transport-as-a-service" (TaaS). The report states:

> "The TaaS disruption will have enormous implications across the transportation and oil industries, decimating entire portions of their value chains, causing oil demand and prices to plummet, and destroying trillions of dollars in investor value — but also creating trillions of dollars in new business opportunities, consumer surplus and GDP growth."

WATCH: Paul Godsmark from CAVCOE share his vision for autonomous vehicles in this short video (video: Growth in autonomous vehicles)

WATCH: Robin Chase, co-founder and former CEO of Zipcar talking about The Future of Autonomous Vehicles

17. Lambert, F., Google's Self Driving Car Vs Tesla Autopilot, Electrek (2016)

at risk: why would a haulage company or a taxi company[18] employ a person to drive when a computer can do it instead? After all, the computer doesn't need a holiday, won't take time off sick, can work 24 hours a day, and shouldn't make errors in handling the vehicle.

Consider:

- **Clearly, many jobs will be lost due to vehicle automation but what types of jobs could emerge from these trends?**
- **What are the potential risks associated with autonomous vehicles? How could these be addressed?**

Connectivity

Because of the low cost of sensors and the pervasiveness of the mobile internet, we are now able to track vehicles in real time. These sensors have been used to help customers access shared car schemes, and by taxi companies. Uber is perhaps the most famous example of a taxi company that has successfully utilised this technology. A customer downloads the Uber app, then books their ride with one press of a button. The Uber driver knows exactly where the customer is because of the GPS service on the customer's phone. Using the same technology, the customer can track the location of the Uber car as it makes its way towards them.

Shared car schemes are those where customers pay to have access to a fleet of vehicles, but don't actually have to own the car. The customer will pay a usage fee, which is usually based on the number of miles driven, or the number of minutes the car was used for. This is yet another example of mobility as a service. Shared cars can be booked using an app on a mobile phone, or by using a computer. Studies show that shared car schemes reduce the total number of vehicles on the road[19].

Consider:

- **What are some of the potential benefits to citizens of having access to vehicles (as a service) rather than owning the vehicle?**
- **Are there any downsides to mobility as a service?**

18. **Harris, M., Self-driving Taxis Roll Out in Singapore - Beating Uber to it, The Guardian (2016)**
19. **Alison, M., US Car Sharing Service Kept 28,000 Private Cars off the Road in 3 Years, The Guardian (2016)**

Multi-modal mobility

In most cities there are numerous transport options for users - shared cars, buses, trams, trains, and shared bikes, for example. The promise of **multi-modal mobility** is to see these services work together and offer an all-in-one solution for the user. This would likely take the form of an app that the user could operate to identify the best mode of transport for them. The app would also arrange payment for the service - providing a one-stop shop for all mobility needs. A highly effective multi-modal mobility system could reduce the demand for and thereby number of private cars on the road. In turn, this could ease traffic congestion, reduce air pollution, and provide an affordable and convenient service for the user. These services are already in operation in some cities[20], and with increased connectivity, it is likely we will see more of them in the future.

Circular vehicles

Regardless of how the vehicles are powered, or who or what drives them, we need to consider how the car is designed so that we can make much better use of the vehicle's materials after it is no longer usable. The materials of a car that has been designed for disassembly (meaning it can be easily taken apart) could be reused at high quality in the next car, or in another product. A lot of energy is used to create car parts, and that energy is not wasted if the parts - or materials - are able to be used again. Car manufacturer Renault has made considerable progress in this area. The company set up an innovative recycling scheme in which a variety of materials including copper, steel, textiles and plastics are taken from end-of-life (ELV) vehicles and put into new vehicles with the same level of performance as virgin materials. Currently, 36% of the total mass of a newly produced Renault vehicle in Europe is made from recycled materials, and 85% of an ELV is recyclable. This approach of considering the next life of materials is a crucial part of a **circular economy**. Read the full **Renault case study here**.

If we were to combine all of the future trend ideas, we would create a **circular mobility system**. This system would offer more choices and be shared, electrified, autonomous, multi-modal, and looped. Individualised mobility would be provided as a service. Better system integration would make most trips multi-modal. Combined, these changes would mean fewer, better-utilised cars, with such positive side effects as less congestion, less land and investment committed to parking and roads, and reduced or eliminated air pollution. In this system, cost per average passenger-km could drop by as much as 80 percent by 2050[21]. See Figure 2, below, for more details.

20. **Peters, A., This New "Mobility Service" App Will Help Helsinki Ditch Car Ownership, Fastcompany (2016)**
21. **Ellen MacArthur Foundation, SUN and McKinsey Center for Business and Environment, Growth Within: a circular economy vision for a competitive Europe (2015)**

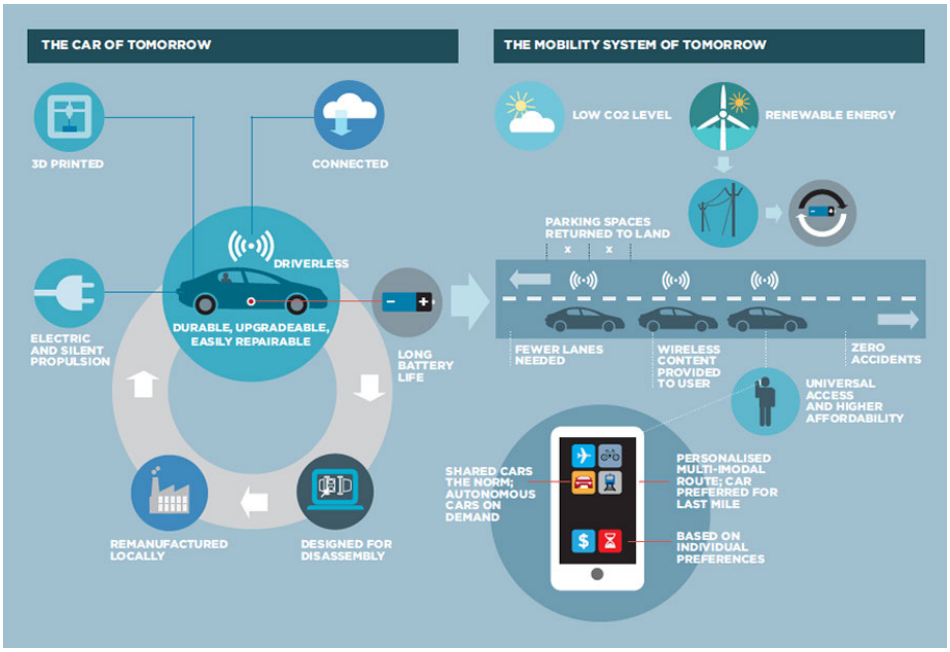


Figure 2 - A circular mobility system
Credit: Ellen MacArthur Foundation

WATCH: Jeffrey Greenblatt from Lawrence Berkeley National Laboratory describe the new trends in mobility will impact energy use in this short video (video: Energy saving in the future of mobility)

Consider:

- **Why might national governments be increasingly interested in creating incentives for electric vehicle use?**
- **What advantages are there for the users of autonomous vehicles?**
- **Imagine the autonomous vehicle system was 'hacked'. What might be the consequences?**

Action:

- **After you have read the article and watched the accompanying videos, show on the city map how your city would change if it adopted some of the ideas and technologies referred to here.**

Further Reading:

Chase, R., What Uber's Next CEO Needs to Say, Wired (2017)

Chase, R., Self-driving Cars will Improve our Cities. If they Don't Ruin Them., Wired (2016)

Global EV Outlook 2017: Two Million and Counting - report by International Energy Agency

Rethinking Transportation 2020-2030 - report by Rethink X

SECTION 5: FOOD AND WASTEWATER

A circular economy is characterised by two material cycles: the technical cycle, featuring products, materials and components made of plastics, metals and alloys that can be recovered and reused, preferably at high quality. The other cycle - the biological cycle (or bio-cycle) - is the focus of this section. In the bio-cycle, products and materials can be safely returned to regenerate the biosphere and aid future production. As the saying goes, 'waste becomes food'. In some cases the products may go through multiple stages of processing, which can include being eaten, composted and anaerobically digested.

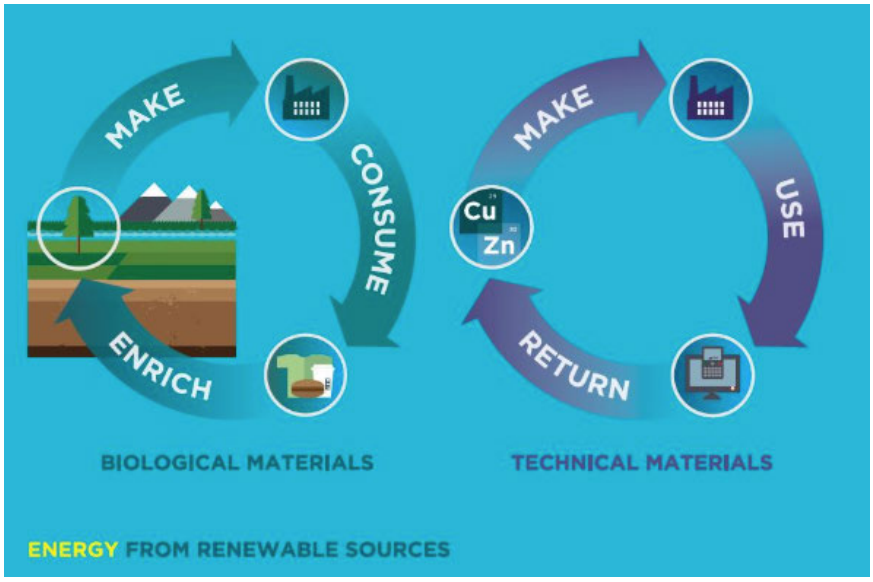


Figure 1: The two cycles in a circular economy
Credit: Ellen MacArthur Foundation

This section deals with two key questions:

1. What should cities do with bio-cycle nutrients once they've been used, or deemed unsuitable for use: throw them away or find a valuable route for them to return into a healthy system?
2. Does it make economic, environmental, and social sense to grow food inside of our cities?

This section contains two videos (approximately 12 mins viewing time total) and one slideshow (approx 10 mins reading time total) and one article including question prompts and action points (allow approximately 1 hr or 1hr 30 mins to include the 'One step further' task). **Suggested total time for this section is between 1 hr 15 mins - 1hr 45 mins**.

Vertical farms, featuring Dickson Despommier (7:07)

Food waste in Amsterdam, featuring Shyaam Ramkumar from Circle Economy (5:13)

It's all about soil, a slideshow about agriculture

Mapping biological assets

The city of Amsterdam asked Circle Economy, a Dutch social enterprise, to conduct a 'Circle City Scan' in order to evaluate the potential of utilising the circular economy throughout the city. When looking at the bio-cycle, the first thing Circle Economy did was analyse all of the biological flows into and through the city. In doing so, they identified a number of ways to increase revenue, create jobs and reduce material waste and CO2 emissions.

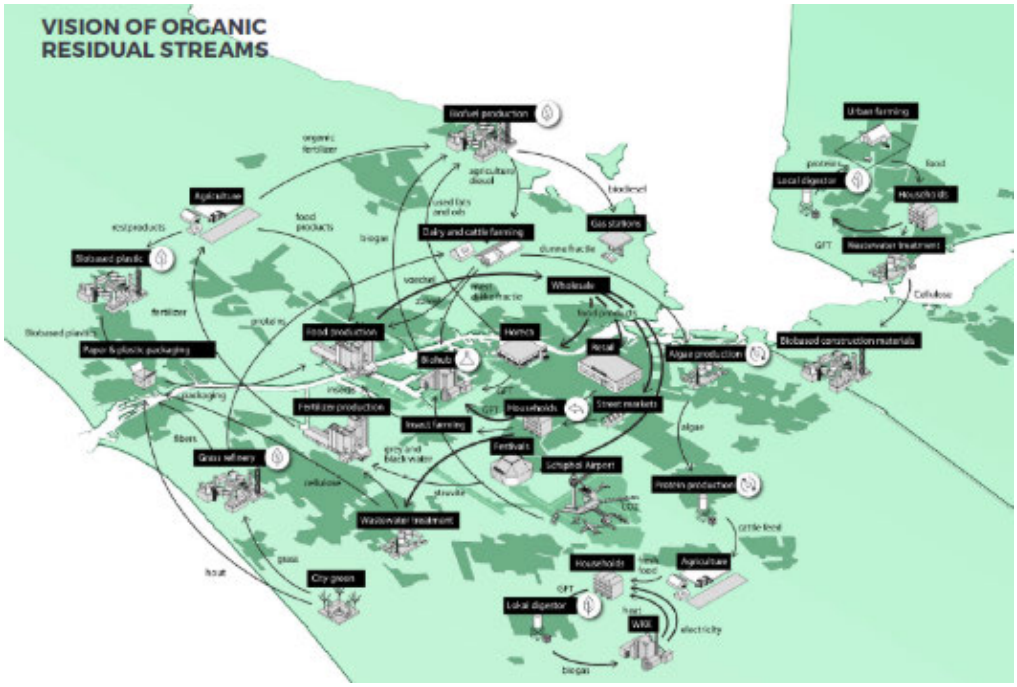


Figure 2: Mapping circular flows. Image for illustrative purposes only; visit the report to view the entire image in high-res. Credit: Circular Amsterdam, Circle Economy

Once the gaps in the system have been identified, they recommended the city gathers together relevant entrepreneurs, civil society and local government to work together to innovate and realise the value of the bio-cycle across the city. You can watch Circle Economy explain the process of mapping biological flows and identifying the opportunities in the video connected to this piece, **Food waste in Amsterdam**.

As a result of their work in Amsterdam, they concluded that, if the city seized all of the opportunities identified, the combined value would be worth:

- EU 140 billion in revenue
- 1200 new jobs
- 900 ktons of material savings
- 600 ktons of CO_2 savings

You can read the details of their work **here**.

WATCH: Circle Economy describe some of their work in Amsterdam in this short video (video: Food waste in Amsterdam)

There is value in food waste

Cities are importers of food that is, typically, grown elsewhere. The food comes into cities and then food waste works its way into landfill or sewage systems. In a circular system, rather than losing those precious nutrients, they would be recovered and then returned, either to the countryside or for use in urban agriculture as fertilisers for the soils. This makes economic and environmental sense because, in theory at least, nitrogen, phosphorus and potassium nutrients recovered from food, animal and human waste streams on a global scale could contribute nearly 2.7 times the nutrients contained within the volumes of chemical fertiliser currently used, with none of the negative side-effects[22].

In Europe, 31% of all food grown is lost or wasted at some point between production and consumption[23]. The smartest way to preserve resources is to minimise wastage. That includes waste created through overproduction and elsewhere along the supply chain (such as during transportation) before the food even reaches a retailer.

One approach we could take to reduce food waste is to use smartphone technology to connect those who have with those who want. Software and apps such as Spoiler Alert[24] enable restaurants or stores with excess food to find a buyer, often charities and discount buyers.

Other approaches include encouraging stores to sell 'ugly' fruit and vegetables[25] or sell items by weight instead of per piece (think of apples in a store - why is there only ever one size of apple when apples come in many sizes? What happens to the misfits?). In France, it is illegal for large shops to throw away food that's approaching it's sell-by date[26]. Stores must either compost the food or give it away to charity. Public information campaigns can help reduce wastage, too.

Applying the waste = food idea in a very literal sense, London-based company **Rubies in the Rubble** started taking surplus fruit and veg (destined for landfill) from the city's markets and turning it into chutneys, jams and preserves. This business now employs a small team of people and sells a range of award-winning condiments to retailers throughout the UK.

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22. **Ellen MacArthur Foundation, Towards the Circular Economy 2 (2013)**
23. **Ellen MacArthur Foundation, SUN and McKinsey Center for Business and Environment, Growth Within: a circular economy vision for a competitive Europe (2015)**
24. Spoiler Alert: **https://www.spoileralert.com/**
25. **Bhatia, J.,Ugly Fruits and Vegetables: Why you Have to Learn to Love Them (2016)**
26. It's Now Illegal For Supermarkets to Waste Food in France, Huffington Post, **https://www.huffingtonpost.com/entry/france-supermarkets-food-waste_us_56b4ba4de4b04f9b57d93f53**

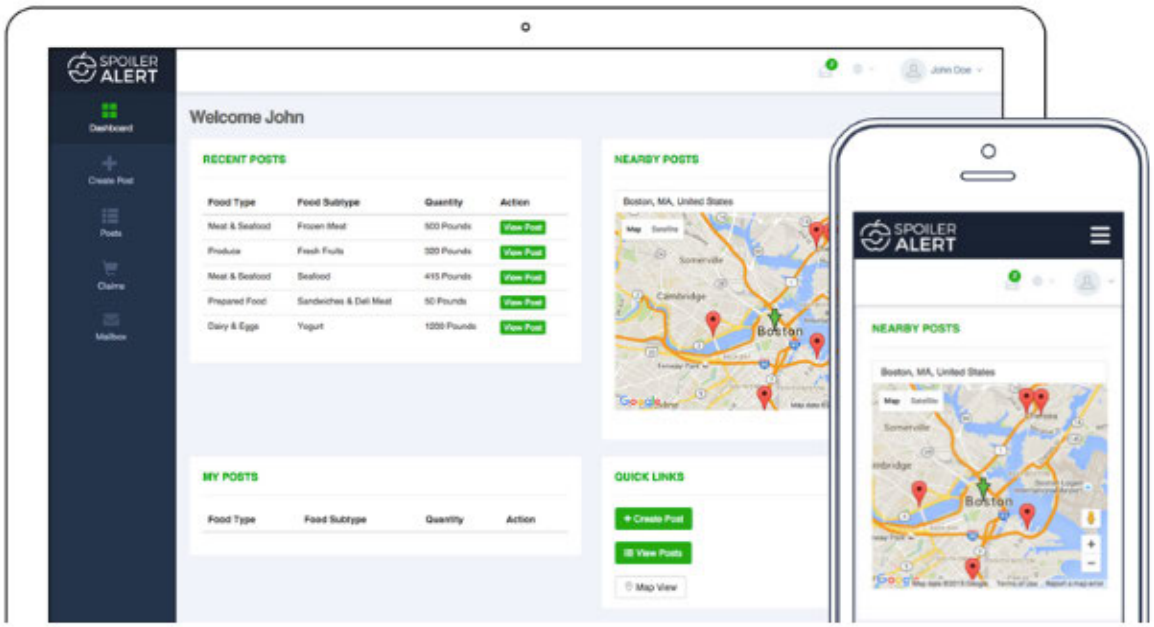

Figure 3: Spoiler Alert is an app that connects excess food with those who need it. Credit: Spoiler Alert.

However, no system is perfect, so completely eradicating food waste will prove impossible. This means that cities need to consider how they can extract nutrients from household waste and sewage systems. Some cities have begun the processes of collecting food waste from the public. For example, Milan has high rates of recovery which it uses to generate revenue by producing energy and compost, with the decayed organic material used as a fertiliser. The nation of Taiwan collects food waste from citizens and uses it to feed its 5.5 million pigs, saving money for farmers and reducing the land space required to grow crops for animal feed[27].

There are also economic opportunities in rethinking how we manage sewage (also known as wastewater). Typical wastewater processes tend to lose most nutrients and use a lot of clean water and energy in the process. However, the technologies that allow compost, energy, and clean water to be derived from wastewater are well-established. One US study found that wastewater treatment plants, taken collectively, could meet 10% of the nation's demand for electricity[28]. In the city of Odense in Denmark, a wastewater treatment plant harvests enough energy from wastewater to run the treatment process, and has an extra 10% left over that it sells back to the electricity grid. When Mads Leth, the Director of Operations and Maintenance for the wastewater plant was asked what the most important factor was in making it energy positive, his reply was:

> "A change in mindset is critical. The technology exists, but it must go hand in hand with a mindset that says not only do we want to produce clean water, but we want to do it in a way that leads to carbon neutrality which goes hand in hand with energy optimisation."[29]

27. Jennings, R., In Taiwan, Leftover Food Scraps Help Farmers Sustain Porky Appetites (2016)
28. Scott, L., Capturing Energy in Wastewater Treatment Plants
29. Jeffries, N., Organic Matters (2017)

Clearly, there is an opportunity to capture value from food waste and wastewater systems. But there are barriers before this value is realised. These include regulatory barriers - such as inconsistent and ill-fitting definitions of waste, and economic barriers, including the absence of accurate **externality** pricing. These barriers give bias to existing 'linear' systems and make it less likely that the true potential of biological waste will be unlocked.

The message with both food waste and wastewater is straightforward: there is value in 'waste'. We need to overcome the barriers and invent the systems to help us connect outputs to inputs and reap the economic, environmental, and societal benefits.

READ: This slideshow story looks at many of the benefits of growing food and capturing nutrients in our cities (link: **It's All About Soil** [30])

Consider:

- **What are the practical steps a city would have to take to facilitate the widespread collection of food waste?**
- **Which factors would a city have to consider if switching to wastewater treatment facilities that recovered nutrients and biogas?**

Growing food in the city

There are numerous advantages to growing food in the city: delivery costs are minimised by growing the food close to the consumers, there are health and psychological advantages to creating green spaces in cities, they make the city a more attractive environment and entrepreneurial and employment opportunities are created, too. Of course, many cities already have a thriving allotment culture, but allotments tend to be small-scale production units. There are other ways and locations to grow food in a city. For example, rooftops, underground tunnels, shipping containers, and abandoned buildings have all been successfully utilised. Let's look at them in turn.

Rooftops

Flat roofs are perfect locations for rooftop gardens. Whether a collection of pots or something more substantial - such as that built by Ford at their truck plant in Michigan (see Photo 1 below) - rooftop farming (or 'green roofs' or 'living roofs', as some call them) can bring substantial benefits to a city.

30. It's All About Soil. **https://www.slideshare.net/ColinWebster2/its-all-about-soil**

Photo 1: Ford's living roof in Dearborn, Michigan, is the largest in North America. Credit: Flickr user Scott Monty.

Cities tend to have higher average temperatures than surrounding suburban or rural areas, a phenomenon known as the 'urban heat island effect'. Vegetation helps reflect heat, meaning a building with a green roof will be a cooler place to live and work, reducing demand for energy-intensive air conditioning. As well as this, rooftop farming helps insulate buildings, absorb rainfall and mitigate against a city's carbon emissions. And, of course, they can be used to grow food, too.

Finally, there are many studies about the psychological benefits of gardening[31/32]. Contact with nature can help people cope with mental fatigue, recover from stress and illness, and improve productivity. By increasing gardening opportunities through green roofs, more people in a city can benefit.

Underground

Growing above the city is one thing, but what about growing food underneath the city? That's what **Growing Underground** are doing 33 metres below the streets of London. Utilising disused air raid shelters from World War II, Growing Underground have a unique climate- and pest-controlled environment where they grow a range of micro herbs. Stacked in trays from floor to ceiling, the herbs are stimulated to grow thanks to the use of LED lighting. This **hydroponic** system uses 70% less water than traditional growing, needs no pesticide, and isn't affected by the weather.

31. Psychological and mental benefits of gardening, Huffington Post. Available from: **http://www.huffingtonpost.com/jill-l-ferguson/physical-and-mental-benefits-of-gardening_b_9750328.html**

32. Maller, Cecily., Townsend, Mardie., Pryor, Anita., Brown, Peter., St. Leger, Lawrence. (2005). Healthy nature healthy people: 'contact with nature' as an upstream health promotion intervention for populations. Health Promotion International

Hydroponics and Aquaponics

Of course, hydroponic systems can flourish anywhere, not just underground. A hydroponic system is simply one in which plants are grown without soil. Instead, the plants grow in a nutrient-rich solution. In an aquaponics system, aquatic life such as fish, snails or prawns are added to the mix. The waste from these creatures help support the growing of the plants. One particularly circular example of an operation like this at work can be found at **The Plant** in Chicago.

Hydroponics and Aquaponics are the system at the heart of many **vertical farms**, which are essentially multi-story greenhouses. Dickson Despommier, a leading voice in the vertical farm movement, claims that, because of height advantages, one indoor hectare can produce as much food as ten hectares of outdoor farmland. See the video associated with this section to hear more from Despommier.

Photo 2. 'Strawberry season is here'. Strawberries grown using hydroponics. Source: Flickr user Lars Ploughman

Other growing facilities

Some entrepreneurs have seen the opportunity in hydroponics and underutilised city space to create farms inside of shipping containers. Two of the more famous examples, **Freight Farms** and **Cropbox**, offer the opportunity for people to purchase shipping containers kitted out with all the high-tech equipment required for a farm that will never be affected by the outside climate.

Cities can also make use of underutilised space by building large greenhouses or urban polytunnels: in essence, spaces that extend the growing season of various crops and allowing more diverse crops to be grown. Despite these possibilities, it is worth noting that not all crops can be grown inside of such facilities - for example, many root vegetables need deep soil and these systems cannot provide that.

The market garden used to be a feature of urban spaces but many have disappeared with the advent of agricultural intensification. Now that the opportunities and outcomes of growing food in urban spaces are better known, cities might once more become major growers of food. However, do not be left with the opinion that these methods should replace typical field-based agriculture. Rather, they should complement it, and in the context of the circular economy, be used to facilitate the return flow of nutrients back into productive agricultural use.

WATCH: Watch Dickson Despommier tell us of some examples of vertical farms around the world (video: vertical farms)

Consider:

- **What are the benefits of growing food inside cities?**
- **What might be the effect on rural locations if more of our food is grown in cities?**
- **Which factors limit the potential success of urban agriculture?**
- **What is missing from the opportunities listed above?**

Action:

- **After you have read the article and watched the accompanying videos, show on your city map where you might grow food in the city.**

One step further:

- **Have a go at drawing a rough map of what the current food system flowing into and through a city looks like. Can you find and map the opportunities for making it less wasteful and more circular? For example, how could consumer waste be returned to agricultural land to be used as fertiliser? (You could use this online systems mapping tool or just draw some ideas on paper.)**

Further Reading:

Urban Biocycles - report by Ellen MacArthur Foundation

Freight Farms Allows Crops to be Grown Inside Shipping Containers - article by Calum Lindsay

Developing a Roadmap for the First Circular City: Amsterdam - report by Circle Economy

High Yields, High Above the City - article by Nick Jeffries

The Recipe for Urban Circular Food Systems - article by Jack Barrie

How can we design a better food system for tomorrow? - by IDEO

SECTION 6: THE IMPACT ON PEOPLE

If cities begin to apply the circular economy framework to the areas referred to in this course, then what might that mean for people's experiences of life in the city? This article looks at a few ideas about how society might benefit.

This section contains two videos (approximately 8 mins viewing time total) and one article including question prompts and action points (allow approximately 1 hr). **Suggested total time for this section is approximately 1 hr 15**.

Smart cities social impact, featuring Rick Robinson formerly of IBM (4:06)

The social, environmental & economic benefits of repair, featuring Kyle Wiens from iFixit (4:11)

Health and wellbeing

It is not possible to precisely quantify the health benefits of a circular economy, but it is possible to make informed guesses. For starters, if there are fewer cars powered by petrol engines, more city-based vegetation and healthier materials inside and outside of buildings, the air will be cleaner. One estimate by the Ellen MacArthur Foundation predicts a halving of the EU's CO_2 emissions by 2030 if a circular approach is taken in mobility, food and the built environment[33]. The basic rule is cleaner air = healthier people.

On top of that, if we reduce road congestion - and there are signs a circular economy approach can support that[34] - then we waste less time inside vehicles and simultaneously reduce stress levels. The benefits of cleaner air and a less stressed population go beyond health: in theory, fewer people would be late to work or off sick, meaning reduced pressure on the health service and more productivity at work or school/university.

Another potential health and wellbeing benefit could come from creating cities that are more walking and cycling friendly. Take for example, New York's 'The Highline', a public park built on a historic freight rail line, elevated above the Manhattan streets. By cleverly repurposing this disused infrastructure, the city has created a much-loved walkway with stunning views of the iconic skyline. This encourages social gatherings, exercise, and generates a considerable amount of economic value due to its popularity as a tourist destination.

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33. **Ellen MacArthur Foundation, SUN and McKinsey Center for Business and Environment, Growth Within: a circular economy vision for a competitive Europe (2015)**

34. **Ellen MacArthur Foundation, Intelligent Assets: Unlocking the Circular Economy Potential (2016)**

Photo 1: Manhattan's Highline walkway.
Credit: avianto on VisualHunt.com/CC BY-NC-SA

Products

How will we access goods and services in a circular city? Some ideas have been explored elsewhere in this course, but what about everyday products? Think about some of the promises a circular economy offers for everyday goods - they could be designed for durability, for easier upgradability, for repairability, to be more customisable and even produced locally. Finally, they could be offered as services to be used and then given back.

Of course, not all products will have all of these features, but each feature brings a measure of additional usefulness. In these circumstances we can derive greater use from products, access the best technology at lower cost and declutter the unused objects from our homes. For example, there would be no initial outlay or repair charges for a boiler if we simply pay to access hot water, and any upgrades required would be part of the service.

Linking back to health and wellbeing, products and packaging designed to fit with a circular economy would take into account the core principle of designing out waste and pollution. This can be done by using non-toxic materials, keeping products in use for longer through easy to reuse and repair designs, phasing out single use items, applying new business models, and improving the recyclability of products at end of use. Such a shift would lead to healthier societies, economies and ecosystems - each of which is ultimately reliant on the others for its long-term prosperity.

Income

In a study comparing the current development path in Europe to one that adopts a circular economy, it was concluded that the circular path could produce improved welfare, economic and employment outcomes[35]. The analysis suggests that the disposable income of European households could be 11% higher in the circular scenario[36]. Furthermore, a review of 65 academic studies of the circular economy indicates that for a number of sectors there are positive employment effects if a circular economy is adopted[37]. For example, new jobs could become available as the need for repair and remanufacturing increases and as more service-based models for products arise. Not all sectors would benefit from increased employment: it might be the case that fewer jobs are required in, for example, sales and waste disposal.

WATCH: Watch as Rick Robinson describes a number of ways in which technology and 'smart cities' can create job opportunities, safer streets, smarter energy systems and reduce food waste. (video: Smart cities social impact)

Consider:

- **What might be the positive psychological and social benefits of having products that can be easily upgraded, repaired and/or replaced?**
- **If people have more disposable income due to lower access costs to goods and services, how might this be a boost to the economy?**
- **What potential risks might there be with leasing products rather than actually owning them?**
- **Rick Robinson points out some examples of how greater connectivity can lead to positive outcomes. However, can you think of some examples of how new technology has led to negative outcomes for citizens?**

Maker movement and repair cafes

The falling cost of 3D Printers, fabric printers and associated equipment has gone hand-in-hand with the rise of the maker movement. This informal, peer-led, decentralised and networked movement has found a home in many cities across the world, making entrepreneurs of some people, and learners and designers of others. By putting sophisticated production (and/or repair) equipment into the hands of the general public, the maker movement helps to democratise production and enables communities to meet local demand by using local resources, in small batches.

Imagine scaling up the idea and connecting facilities across a city: now you have the basic concept of a Fab City. Those behind the Fab Cities network believe that cities will produce everything they consume by the year 2054, using locally sourced materials and open source designs.

35. Ellen MacArthur Foundation, SUN and McKinsey Center for Business and Environment, Growth Within: a circular economy vision for a competitive Europe (2015)
36. Ellen MacArthur Foundation, Intelligent Assets: Unlocking the Circular Economy Potential (2016)
37. Horbach, J. et al., Circular Economy and Employment (2015)

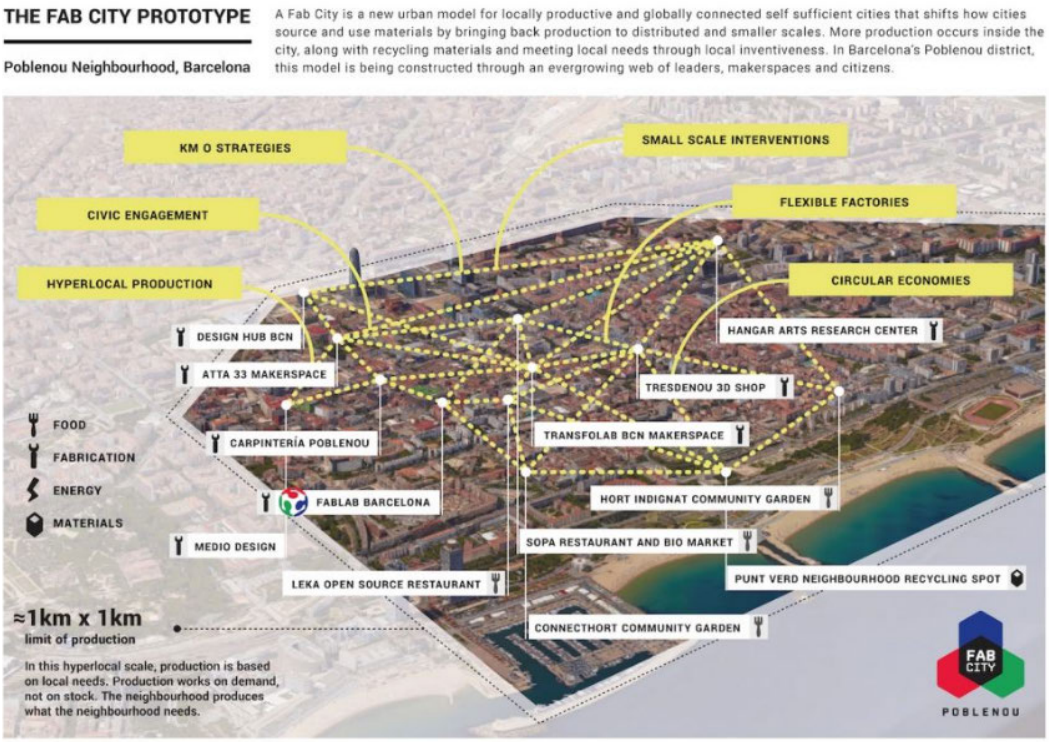

Figure 1: The Fab City Prototype

Tomas Diez, instigator of the Fab City concept, sees the connection between the maker movement and the circular economy:

> *"I can design something in Barcelona, and without using fossil fuel, create the identical product in Cape Town, Wellington or Tokyo. Our approach is closely linked to the notion of circular economy, in the sense that we aim to shorten and localise production loops. With the right infrastructure and knowledge we could reduce the amount of material that a city imports and rescale globalisation. It also allows companies to create social value and not only profit[38]."*

Of course, it will never be the case that everyone in a community will participate in anything resembling a Fab City, even if it were on their doorstep. However, for those who do, it could be argued that the community benefit goes beyond locally produced goods. Supporters of the idea of 'social capital'[39] would say that facilities like these will help people develop positive relationships within the community, which could potentially achieve positive outcomes on social and health issues.

WATCH: Kyle Wiens of iFixit explains the social, environmental and economic benefits related to repairing mobile phones (video: The social, environmental and economic benefits of repair)

38. http://circulatenews.org/2017/02/future-of-cities-explore-the-fab-city/
39. https://www.wikiwand.com/en/Social_capital

Consider:

- **What are the limitations of the maker movement?**
- **Kyle Wiens explains that there are 'legal challenges' related to repairing mobile phones. Some manufacturers do not like their repair manuals to be publicly accessible. Why do you think this is? What is your argument against it?**

Action:

- **After you have read the article and watched the accompanying videos, what could you change about your city map?**

Further reading:

Five Ways the Maker Movement can Catalyze a Manufacturing Renaissance - article by Mark Muro & Peter Hirshberg

Discover more about Fab Cities

Future of Cities: Explore the Fab City - article by Benjamin Tincq

How a Decentralized Economy Helps Society - article by AJ Agrawal

The Social Power of the Circular Economy - article by Femke Groothuis

SECTION 7: THE BIG PICTURE

This section contains one article including question prompts and action points.
Suggested total time for this section is 30 mins.

As we have seen in this course, cities are aggregators of people, ideas, raw materials, nutrients, data, energy and more. It is the interaction between all of these elements that shapes how the city operates, and how people experience it. Just as a slight change at the cellular level in a human body can have a significant impact on overall health, change one element in a city - a sudden population increase, for example - and its effects can be felt across many different areas. All of a sudden there are more cars on the roads, higher property prices, a greater strain on the sewage system, and so it goes on - some outcomes can be foreseen, but many remain unforeseen and simply emerge as different elements interact. These 'emergent' properties are typical of all complex systems not just of cities; therefore, it is important that we are able to think, act, and adapt in response to these changes.

Hopefully, this course has highlighted the importance of systems thinking. **Systems thinking** involves looking at the bigger picture to understand the parts of a system in relation to the whole. This can often bring to light hidden costs and consequences as well as possible ways to improve the system's overall effectiveness. By contrast, a linear approach to a challenge is one that does not take a broad enough perspective and will often lead to 'solutions' that address symptoms rather than causes.

Systems thinking, as well as insights taken from **Complexity Science** about how systems work can help in the transition towards a circular economy as they provide a lens through which to observe, understand, and replicate real-world systems. This ability to mimic the highly efficient and effective cycles found in the natural environment is a fundamental aspect of the circular economy, reflected in its three core principles:

1. **Design out waste and pollution**
2. **Keep products and materials in use**
3. **Regenerate natural systems**

The question is: what patterns and behaviours do we want to see emerging from all of these interacting elements? There is still a long way to go, but once we understand that these elements are connected, we can design every aspect of the city to work as part of an integrated 'ecosystem'. This is an entirely new way of thinking which requires new levels of collaboration, and plenty of creativity. However, we now have many tools that can help us implement a circular approach, which, as we have discussed throughout this course, has the potential to create better outcomes for the economy, society, and environment.

Consider:

- **In the opening of this section, a city is compared to a human body. To what extent is this an effective metaphor? What other metaphors might you use to describe a city?**
- **Many of today's challenges are becoming increasingly complex. Often referred to as 'wicked' problems because they cannot be tackled in a straightforward way. Examples include global poverty and ocean plastic waste. Can you think of any other 'wicked' problems that we are currently facing which would benefit from a broader systems thinking perspective?**

The Sustainable Development Goals (SDGs)

The United Nations SDGs are a 'universal call to action to end poverty, protect the planet and ensure that all people enjoy peace and prosperity.' The **seventeen Global Goals** came into effect in 2016 with the aim of guiding the world towards a sustainable development path by 2030.

We believe the circular economy has the potential to help us achieve many of these goals and sets out a clear framework for doing so. When it comes to approaching the goals - as we have seen with cities - a systems perspective that recognises interconnections is crucial. For example, ending poverty (goal 1) would mean simultaneously addressing good health and well-being (goal 3), providing access to quality education (goal 4) as well as having the kind of work and economy (goal 8) that would create the necessary conditions and so on...

in fact, when you start to look at where the connections are, it is hard to find where they are not. As John Muir said:

> *"When we try to pick out anything by itself, we find it hitched to everything else in the universe."*

So where and how does the circular economy concept intersect with the SDGs? Now it's over to you to think it through and develop your systems thinking skills.

TIP:

- **Take a step back and observe the whole (reflect on your experience of taking this course).**
- **Look for connections and relationships (can you articulate them?)**
- **Ask yourself how_____ impacts _____which leads to_____ (and so on.....)**

Action:

- **Add your final thoughts and comments to your city map. We then suggest sticking it to a much larger piece of paper (e.g. flipchart paper) and then printing the SDG icons from this page. Working in a small group cut up the goals and start mapping them onto your city map. Draw the connecting arrows, note down how they connect, how many different icons can you use? This will help you to assess the positive impact your circular city could have. (Don't worry, it's going to look messy/complex!)**

Final Action:

- **Refer to the 'How to use' section of this course to explore a range of ideas for extension activities.**

Further Reading & Resources:

Habits of a Systems Thinker - a useful set of 14 habits that help you to think in systems

Compass Education - Tools for systems thinking

Complexity Module - A Case by Case Introduction to Complexity for students

Donella Meadows Project - Site Dedicated to the Work of Renowned Systems Thinker, Donella Meadows

Complexity Labs - Explore a Range of Resources Related to Complexity

World's Largest Lesson - Find a range of teaching resources relating to each of the SDGs

WHAT NEXT?

EXPLORE

Other courses, podcasts and circular economy resources on our **itunes U page** and on our Schools and Colleges **Teaching and Learning resource page**.

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Please email **info@ellenmacarthurfoundation.org** and let us know how we could improve our resources or fill in a short **questionnaire**

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