Urban Pathways

DESIGN

THE STARTING POINT FOR A CIRCULAR BATTERY VALUE CHAIN

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Wuppertal Institut

UN HABITAT FOR A BETTER URBAN FUTURE

UN environment programme

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The Urban Pathways project helps delivering on the Paris Agreement and the NDCs in the context of the New Urban Agenda and the Sustainable Development Goals. It has established a facility in close cooperation with other organisations and networks active in this area to support national and local governments to develop action plans and concrete implementation measures to boost low-carbon urban development. This builds on UN-Habitat's role as "a focal point on sustainable urbanisation and human settlements including in the implementation and follow-up and review of the New Urban Agenda". The project develops national action plans and local implementation concepts in key emerging economies with a high mitigation potential. The local implementation concepts are being developed into bankable projects, focusing on the access to urban basic services to create a direct link between climate change mitigation and sustainable development goals.

Project concept

The project follows a structured approach to boost Low Carbon Plans for urban mobility, energy and waste management services that deliver on the Paris Agreement and the New Urban Agenda. The project works on concrete steps towards a maximum impact with regards to the contribution of urban basic services (mobility, energy and waste management) in cities to global climate change mitigation efforts and sustainable and inclusive urban development. This project makes an active contribution to achieve global climate change targets to a 1.5°C stabilisation pathway by unlocking the global emission reduction potential of urban energy, transport and resource sectors. The project will contribute to a direct emission reduction in the pilot and outreach countries, which will trigger a longer term emission reduction with the aim to replicate this regionally and globally to make a substantial contribution to the overall emission reduction potential.

Project aims

This project implements integrated urban services solutions as proposed in the New Urban Agenda providing access to jobs and public services in urban areas, contributing to equality and social coherence and deliver on the Paris Agreement and the Sustainable Development Goals.This is the first dedicated implementation action oriented project, led by UN-Habitat to deliver on inclusive, low-carbon urban services. Securing sustainability and multiplier effect, the project aims to leverage domestic and international funding for the implementation projects that will follow from this initiative

Urban
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Urban Pathways Project and Replication Cities

IN BRIEF

Road transport emissions account for 5.8 GtCO_2e per year – almost 75% of all transport GHG emissions and 11% of global GHG emissions. Within road transport, passenger road transport is the largest emitter with 4.0 GtCO_2e, followed by commercial road transport with 1.8 GtCO_2e. Electrification is the key decarbonization lever for road transport. In use, EVs currently emit 30-60% fewer emissions than combustion engines depending on the power mix (Global Battery Alliance, 2019). EVs also help to improve local air quality by avoiding other toxic emissions, for example, nitrogen oxide or particulate matter.

Battery electric vehicles will probably account for most of the car fleet in the long term. The lithium-ion battery market, the fastest-growing segment, is forecast to reach $100 billion by 2025 (World Economic Forum, 2019). The costs of batteries are dropping and demand is rising; between 2010 and 2018, battery demand grew by 30% annually and reached a volume of 180 GWh in 2018. In the base case, the market is expected to keep growing at an estimated 25% annual rate, to reach a volume of 2,600 GWh in 2030 (Figure 1), ushering in a green transport revolution. By 2025, the volume of lithium-ion batteries being sold each year will increase five-fold to nearly 5 million tonnes. Because of this expected rapid growth in the market shares of battery-powered and plug-in hybrid vehicles, the annual production of lithium-ion (traction) batteries is expected to increase considerably in the coming decade. This would multiply the annual demand for key battery materials – especially for cobalt, lithium, and nickel. It is therefore necessary to accelerate their market breakthrough and make them socially and environmentally acceptable. The challenge of closing materials loops and regenerating natural assets is an exponential function of product complexity and supply chain length.

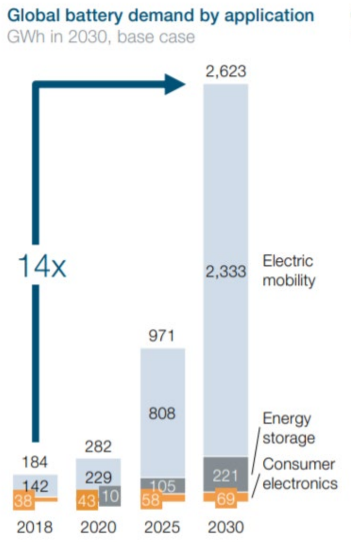


Figure 1. Global battery industry growth by application by 2030. Source: World Economic Forum, Global Battery Alliance; McKinsey analysis.

Over 11 million tonnes of used EV lithium-ion batteries are forecast to be discarded by 2030, representing a significant challenge, but also an opportunity given the dramatic rise in demand for materials such as lithium is and cobalt by 11 times. In electronics, device collection remains critical and, as with all components, will be important for the increased collection of batteries for recycling. When a battery has reached the end of its automotive life, it is first paramount to ensure that repurposing or refurbishing options have been considered, before recycling (see corresponding factsheets). After repurposing and refurbishing, it is essential to ensure those batteries are destined for best-in-class recyclers who have the technology to recover the key raw materials and ensuring batteries are not disposed of inappropriately.

Moving from a linear to a circular value chain can improve both the environmental and the economic footprint of batteries by getting more out of batteries in use, and by harvesting end-of-life value from batteries.

CIRCULAR ECONOMY – A SYSTEMIC VISION FOR A SUSTAINABLE BATTERY VALUE CHAIN

A circular economy is an industrial system that is restorative or regenerative by intention and design. It replaces the end-of-life concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals which impair reuse and return to the biosphere, and aims for the elimination of waste through the superior design of materials, products, systems and business models. Such an economy is based on a few simple principles: first, at its core, a circular economy aims to design out waste. Waste does not exist - products are designed and optimized for a cycle of disassembly and reuse. These tight components and product cycles define the circular economy and set it apart from disposal and even recycling, where large amounts of embedded energy and labour are lost. Second, circularity introduces a strict differentiation between consumable and durable components of a product. Unlike today, consumables in the circular economy are largely made of biological components that are at least non-toxic and possibly even beneficial, and can safely be returned to the biosphere, either directly or in a cascade of consecutive uses. Durables such as engines or computers, on the other hand, are made of technical components unsuitable for the biosphere, such as metals and most plastics. These are designed from the start for reuse, and products subject to rapid technological advancements are designed for an upgrade. Third, the energy required to fuel this cycle should be renewable by nature, again to decrease resource dependence and increase systems resilience.

There are important issues surrounding battery production's value chain, that must be knowledge and addressed, of which three will be detailed here. Firstly, over 60% of the global supply for cobalt (Co) comes from the Democratic Republic of Congo (DRC), about 90% of the cobalt produced in DRC, originates from large-scale and mechanized mining operations. However, 10% is estimated to originate from small-scale mining, often in dangerous working conditions. Secondly, the negative impacts associated with mining waste and tailing dams - it is becoming increasingly apparent that current methods of collecting and storing mining waste are not an ideal long-term solution. Rather, they are an economically unfeasible, environmental time bomb waiting to go off. Unfortunately, waste management issues are only going to increase as the need for commodities like rare earth escalates; a pressing issue that most industry players have identified. This is linked with the third issue, resources scarcity. From the 1850s to 2000, reusing materials was not a priority, as it was easier to obtain primary resources and cheap to dispose of them when they reached the end of their use. However, in a trend separate from the repeated financial and economic crises over the last decade and a half, commodity prices overall increased by nearly 150% from 2002 to 2010, erasing the entire last century's worth of real price declines. Price volatility levels for metals in the first decade of the 21st century was higher than in any single decade in the 20th century. Higher resource price volatility can dampen economic growth by increasing uncertainty, discouraging businesses from investing, and increasing the cost of hedging against resource-related risks. Professor James Clark from the University of York in the UK has analysed current recycling levels across several elements of the periodic table and suggests that the pressure on finite resources is likely to remain high as we are unable to keep up the high quality of the existing stock of materials in use due to recycling leakage (Figure 2).

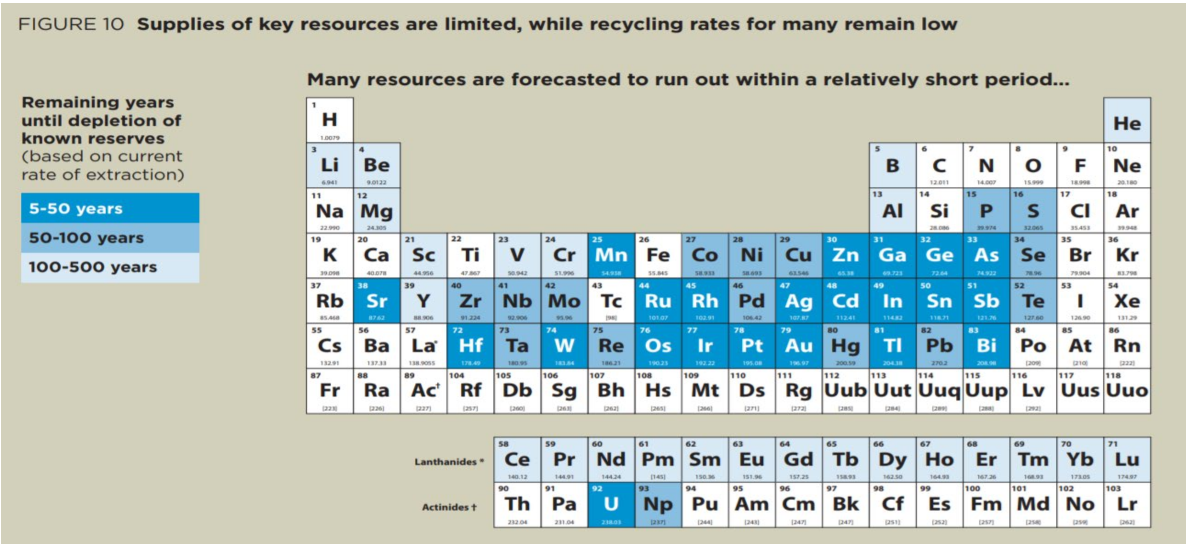


Figure 2. Supplies of key resources are limited while recycling rates for many remain low. Source: Professor James Clark, Green Chemistry, The University of York.

Systems thinking is one design approach, rather than starting from a specific user's needs, it often starts with the issue, and analyzes the root cause systematically and create a new system by decomposing and patterning changes, components, and dependencies.

The Figure 3 describes the 4-stage approach for systems thinking design.

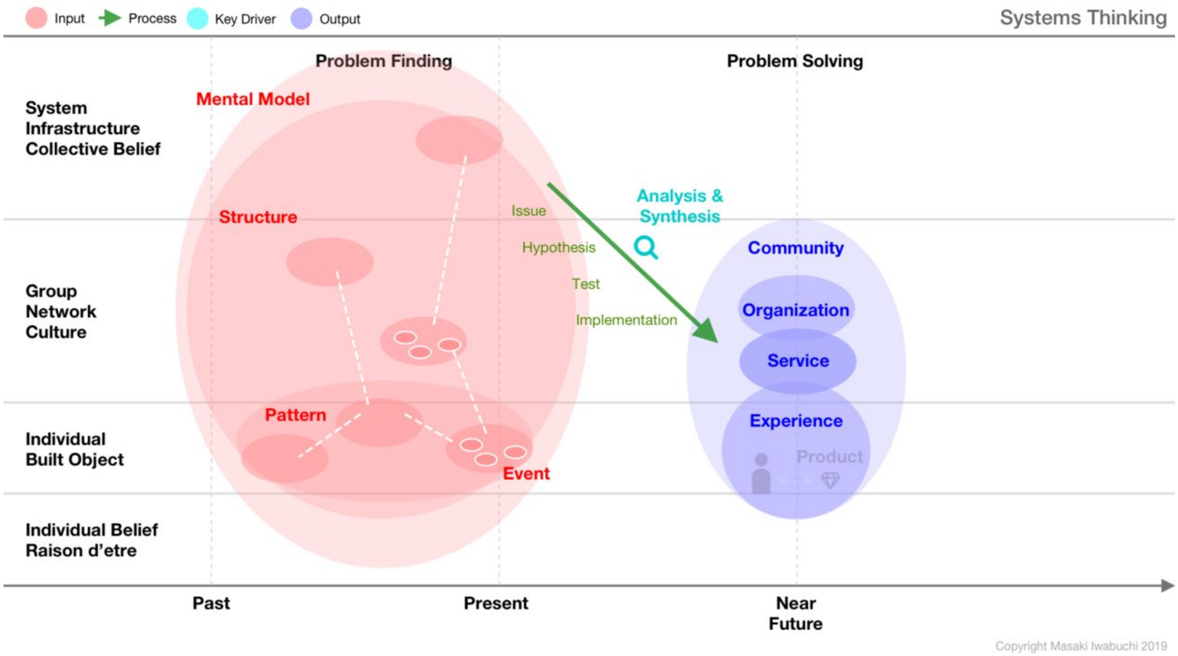


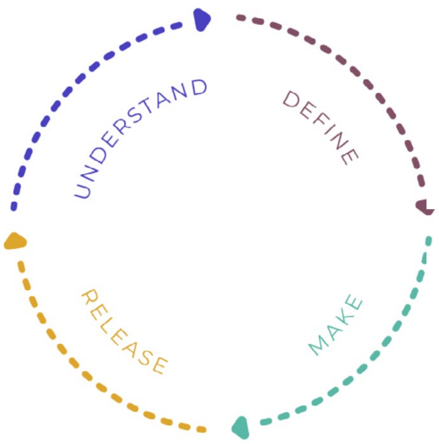
Figure 3: Systems Thinking Design Model. Source: Masaki Iwabuchi.

The linkages between the different levels of battery value chain have to be addressed through a circular and systemic approach across social, environmental and economic dimensions, to achieve sustainable practices and policies.

CIRCULAR DESIGN

The design sits prominently at the heart of the circular economy. Design is the way we create products, services and systems, and is the mechanism by which we shape the material environment around us to meet our needs and desires. Crucially, when something is designed important decisions are made that impact how it is manufactured, how it is used, and what happens when it is no longer needed or wanted. It is exceedingly difficult to go back and undo the effects of those decisions if they are later found to produce undesirable consequences.

The circular design process comprises four stages and is informed by approaches such as design thinking and human-centred design:

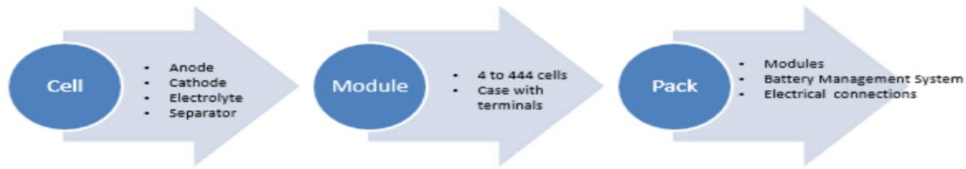


- Understand - Get to know the user and/or the system
- Define - Put into words the design challenge
- Make – Design and prototype
- Release - Launch your design and build your narrative.

Source: Ellen MacArthur Foundation

Understand

Lithium-ion batteries can be constructed and packed in two major formations, which are metal cans either in the shape of cylindrical or prismatic and laminate films (stacked cells) so-called lithium-ion polymer batteries. There are three stages of electric vehicle battery production (Figure 4):



Source: Compiled from industry representative, interview with USITC staff, Washington DC, November 14, 2018; industry representative, telephone interview with USITC staff, June 12, 2018.

Figure 4. Stages of an electric vehicle battery production. Source: compiled from industry representatives.

Several factors affect the health and lifespan of Li-ion batteries and to help maintain the battery life, manufacturers have typically added battery management systems (BMS) to mitigate this issue by not allowing the battery to be drained or charged beyond specific set points. It is also possible to improve on the design of the electrodes and increase the battery capacity reviewing the design and/or size of the materials used for the construction of the battery. The performance of existing lithium batteries is heavily dependent on material characteristics and thermal conditions.

Define

The goal is to design to close the loop, increasing the potential savings on the shares of material, labour, energy and capital still embedded in the product, and mitigating the associated externalities (such as greenhouse gas [GHG] emissions, water and toxicity). Also, to maximize the number of consecutive cycles (be it repair, reuse, or full remanufacturing) and/or the time in each cycle. Each prolonged cycle avoids the material, energy and labour of creating a new product or component.

According to Deutsche Bank, lithium-ion batteries for EVs accounted for 14 percent of lithium demand in 2015 (and demand has risen since then). The bank predicts that EVs will generate 38% of lithium demand by 2025. Some have predicted a shortfall of 100,000 metric tons for lithium by 2025. This scarcity could drive up the lithium's price and other important raw materials. In addition to lithium, lithium-ion batteries contain other materials such as aluminium, cobalt, graphite, manganese, and nickel, among others. Based on recent estimates, more than one-half of the cost of a finished lithium-ion battery pack is the cost of these materials (Platform for Accelerating the Circular Economy, 2019). Among the common materials, lithium, graphite, and cobalt face supply constraints, while the other metals do not face similar issues.

Aluminium, manganese, and nickel have larger end-user markets outside of lithium-ion batteries.

Today's materials complexity compounds the obstacles to scaling up the circular economy. While tools and methods exist to create complex product formulations, it is still extremely difficult after the fact—even for a manufacturer—to identify and separate materials, maintain quality and ensure purity (including non-toxicity). Without reliable classification, it is hard to collect materials at sufficient scale and robust supply rates to create arbitrage opportunities.

Make

Designing is an iterative process that never finishes. The ideas are constantly tested and refined as it is understood how the solution interact with the design, and how it fits within the wider system. At its core, a circular economy means that products no longer have a life cycle with a beginning, middle, and end, and therefore contributes less waste and can add value to their ecosystem. When materials stop getting used, they go back into a useful cycle, hence the circular economy.

In this stage, the objective is to get acquainted with the different ways of being circular, to go through each loop and define the most relevant or achievable for the design, considering the current position of batteries within the flows.

- **Design for reuse:** batteries intended to be repurposed in second-life applications will have to compete, at the end of their first life, with improved battery technologies that are likely produced at lower costs. This increases the risk of some potential use cases for second-life batteries.
- **Design for maintenance**: the circular economy largely replaces the concept of a consumer with that of a user. This calls for a new contract between businesses and their customers based on product performance. Unlike in today's buy-and-consume economy, durable products are leased, rented or shared wherever possible. Electric shared mobility concepts, such as car-sharing and vehicle fleet management, could have positive effects on both vehicle demand and life cycle design. They could help incentivize an increased focus on design for purpose and disassembly.

- **Design for refurbishment/design for remanufacturing:** extend the lifetime of batteries in use. Repair and refurbishment can extend the lifetime of EV batteries, reducing the demand for new capacity and improving costs over their lifetime. As for all circular economy levers affecting end-of-life batteries, recollection is the key gateway to allow further productive use. Thus, concerted action is needed to maximize battery collection rates – lifting them from an estimated average of 61% in the base case to 79% in 2030 assuming that battery design for disassembly and lifetime extension is a high priority for the industry, supporting repair and refurbishment (World Economic Forum, 2019).
- **Design for recycle:** recycling processes are currently costly. The need for high safety precautions due to the fire hazard of large lithium-ion batteries and the toxic properties of some materials creates substantial hurdles to economic recycling practices. The recovery of materials, other than the most valuable ones like cobalt, copper or nickel, is limited in most current processes, lowering the benefits of recycling. Improved recycling technologies will be key to recover more materials, and at a higher quality.

Release

Business Cases

1. NorthVolt

Northvolt was founded in 2016 with a mission to deliver the world's greenest lithium-ion battery with a minimal CO_2 footprint. In 2019 they announced the Europe's first home-grown gigafactory for lithium-ion battery cells, Northvolt Ett, in Sweden. The new gigafactory is currently under construction in Skellefteå in northern Sweden – a region home to a prominent raw material and mining cluster, which has a long history of process manufacturing and recycling. Northvolt Ett will serve as Northvolt's primary production site, hosting active material preparation, cell assembly, recycling and auxiliaries. Ramping up to full capacity, Northvolt Ett will produce 16 GWh of battery capacity per year in its initial phase, to be scaled up at a later stage to potentially 40 GWh.

2. Umicore

Umicore is a Belgian-based global materials technology and recycling which transforms metals into functional materials and recycle them to make new materials. In June of 2020, the European Investment Bank (EIB) has signed a €125 million loan with Umicore, to finance part of the greenfield production facility for cathode materials in Poland. The cathode materials will be supplied to battery manufacturers of high-tech lithium-ion batteries that are primarily used in electric vehicles. The greenfield facility will provide a reliable supply of advanced cathode materials, a key component for lithium-ion battery cell manufacturers in the region and worldwide.

CONCLUSIONS

Business models are needed that allow better access to products, components and materials during and within the post-usage loops. Business model innovation will be critical to mainstreaming the uptake of the circular economy principle in more B2B setups, and in B2C. If solutions are not available today, identify who else in the system can provide support in the short-, medium-, and long-term. This may include local, regional or national authorities, universities and research institutions, or industry associations. Mobilising multiple stakeholders is always a challenge. Actions need to rely on a commonly agreed fact base around which the business case is built, with the benefits shared among everyone involved. Capability building for all stakeholders involved would also be required to ensure that all parties are up to speed with the circular economy concepts and applications.

Automotive original equipment manufacturers (OEMs) are launching more than 300 electric vehicles models in the next five years. Cost-efficient and sustainable batteries, as well as a supporting ecosystem for battery-enabled dispatchable renewable energy deployment, and a dense charging infrastructure network are preconditions for broad customer acceptance and economically viable powertrain transition.

To accelerate deployment, more investment needs to be attracted along the entire value chain as well as into application infrastructure (e.g. charging infrastructure). Moreover, batteries need to become more affordable through lower production costs, higher utilization and improved business cases for end-users. To produce these batteries responsibly and sustainably means lowering emissions, eliminating human rights violations, ensuring safe working conditions across the value chain, and improving repurposing and recycling.

A circular battery value chain that is a major driver to achieve the transformation of the economy in the value chain, creating new jobs and additional value. An industry safeguarding human rights, supporting a just energy transition and fostering economic development, in line with the Sustainable Development Goals (SDGs).

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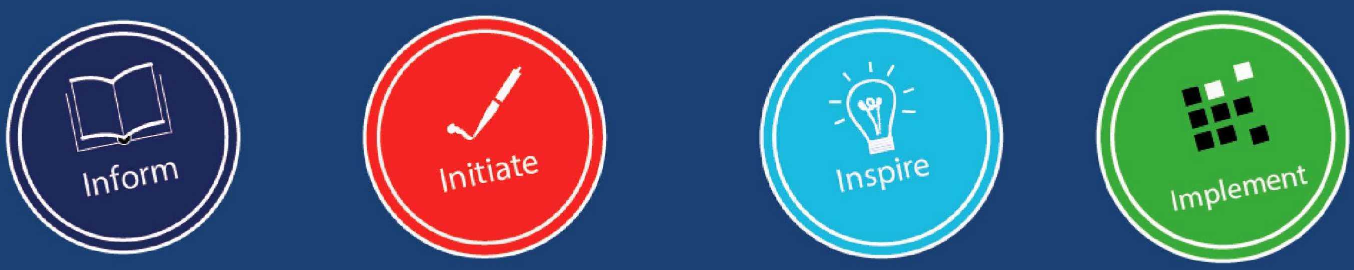

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