Circular economy in the clean technology industry and its role in reviving local manufacturing

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Introduction

The world's ever-growing population and rapidly changing climate has forced global society to rethink and reshape how energy is produced, transported and utilized. Traditionally, humans have used fossil fuels to produce energy, resulting in large volumes of carbon dioxide and other greenhouse gases to be released into the atmosphere. This, in turn, increased global temperatures, causing potentially irreversible environmental damage and posing a severe risk to the planet's biodiversity and broader planetary health.

The usage of renewable energy resources and cutting-edge technologies designed to harvest and convert renewables into usable energy has been proposed as a viable and sustainable solution to fossil fuel-based energy production. However, current renewable energy technologies are not free of challenges, nor are they entirely green or sustainable.

Most of the renewable energy technologies deployed today rely on rare earth metals which are mined using highly harmful practices, including the use of toxic chemicals. The manufacturing of these technologies is also greatly energy-intensive and, as of today, the majority of this energy is not yet green. Additionally, there are the manufacturing value chain encompasses other issues, such as the use of strong acids and toxic solvents in certain manufacturing steps. Certain manufacturing processes may also face socio-economic challenges including forced labour.

Among further issues associated with the clean technology value chain are the lack of not only recycling standards and practices but of safe disposal and monitoring of spent technologies. For example, when batteries reach the end of their lifetime, most end up in landfills where they slowly break down, toxifying the local soil and water. Today's renewable and clean technologies have not been designed with recycling standards in mind. In order to effectively talk about green or clean technologies, a holistic approach must be deployed that aims to clean up the entire value chain from raw materials supply through to the manufacturing, deployment, use, recycling and recovery.

A case for battery recycling

Traditionally, the recycling industry has largely not been profitable apart from minor exceptions. Generally, it has been cheaper and easier to mine and process raw materials in bulk in order to produce brand new products than it has been to establish new value chains focused on recycled and recovered materials. This, however, has now started to change due to the growing demand for battery systems, particularly lithium-ion batteries used in electric vehicles, as well as batteries used in large-scale grid applications. The growing interest in batteries and fear that the current supply of battery metals will be unable to meet global demand has driven the prices of three major minerals used in battery production, namely lithium, nickel, and cobalt, to an all-time high, thereby incentivising the recycling and reuse of materials.[1],[2] With lithium, nickel and cobalt, it is possible to extract them from spent batteries at a high profitability margin.

Technology companies and start-ups are now increasingly attempting to capitalise on this growing demand for batteries by developing new circular economy value chains.[3] For example, in February 2022, Nevada-based Redwood Materials disclosed its launch of the most comprehensive electric vehicle battery recycling program in the world. Initially deployed in California, the program will establish efficient, safe and effective recovery pathways that allow for the recycling of battery packs from both hybrid and electric vehicles. The program will be capable of processing both lithium-ion and nickel-metal hydride batteries.[4] That same month, Redwood announced their expansion plan into Europe in order to address the lack of end-of-life battery

[1] Zhou, L-F., Yang, D., Du, T., Gong, H. and Luo, W-B. (2020). The current process for the recycling of spent lithium ion batteries. Front. Chem. 8:578044. doi: 10.3389/fchem.2020.578044

[2] Pagliaro, M. and Meneguzzo, F. (2019). Lithium battery reusing and recycling: A circular economy insight. Heliyon, 5 (6), E01866, https://doi.org/10.1016/j.heliyon.2019.e01866

[3] Niese, N., Pieper, C., Arora, A. and Xie, A. (2020). The case for a circular economy in electric vehicle batteries. Boston Consulting Group, https://www.bcg.com/en-au/publications/2020/case-for-circular-economy-in-electric-vehicle-batteries

[4] (2022). Redwood Materials creates the first pathways for end-of-life electric vehicles; kicks off in California. Redwood Materials, https://www.redwoodmaterials.com/press/redwood-materials-creates-the-first-pathways-for-end-of-life-electric-vehicles-kicks-off-in-california

processing in European markets.[5] In March 2022, Canadian-based Li-Cycle reported that they were close to setting up operations at the Arizona Spoke, the first recycling plant to use the company's proprietary technology to not only process full battery packs but also to increase lithium-ion battery processing capacity up to 10,000 tonnes per year.[6] Recently, Northvolt, an emerging global battery producer with headquarters in Sweden, announced the successful production of the first battery using fully recycled materials.[7]

Today's batteries are not designed for recycling and often do not comply with global recycling standards.[8] A significant amount of work remains until battery-specific design and recycling standards are established. For example, most of today's batteries use polyvinylidene fluoride (PVDF) as an electrode binder. PVDF is often selected for its outstanding chemical and mechanical properties, including stability in harsh environments and excellent adhesive properties. However, these same properties make recycling challenging. PVDF also generally requires the use of N-Methyl-2-pyrrolidone (NMP), dimethyl sulfoxide (DMSO), dimethylformamide (DMF) or similar solvents, many of which are classified as toxic or highly toxic.

Despite all this, the global chemical industry has been increasingly engaging with alternatives in order to move away from toxic and highly polluting battery solutions. For instance, carboxymethyl cellulose (CMC) is now being widely deployed as a thickening agent and electrode binder in battery research – compared to PVDF, CMC is water-soluble, reducing its toxicity. The use of a water-soluble binder also opens up new opportunities in battery recycling where to the electrode structure can be fully or partially broken down for material extraction and processing.

Norway-based Circa Group has also been developing alternative greener and safer solvents for battery binders to address the toxicity of NMP. Dihydrolevoglucosenone, for instance, is marketed under the Cyrene™ brand.[9] Cyrene™ is a bio-based alternative to both DMF and NMP. Beyond battery electrode binders, DMF is used in the production of plastics and drug discovery while NMP finds applications in drug formulation, materials manufacturing and electronics. According to the Merck Group[5], the annual production of DMF and NMP reaches approximately 225,000 and 125,000 tons per year, respectively.

Moving beyond the battery industry

There is a growing want and need to apply lessons learned from the battery industry to other renewable energy sectors and technologies and to develop more sustainable and circular value chains. In particular, the solar and wind industries have experienced significant uptake of solar panels and wind turbines, both of which will reach the end of their lifetimes at some point. Currently, there is a lack of viable and industrially scalable processes to recycle this equipment. In addition, similarly to the battery industry, the solar and wind industries still lack clear and unified recycling standards and regulations and most of today's solar panels and wind turbines have not been designed to comply with recycling processes and practices.

Furthermore, the semiconducting industry faces a similar path to that of the battery industry. A lack of silicon wafers has driven up the cost of equipment has put significant constraints on global supply chains and equipment lead times.[10,11] Recycling solar panels and other e-waste constitutes one effective option to address this shortage.

A case for re-establishing local recycling and manufacturing capabilities

The 20th century has seen immense industrialization and shifts in manufacturing power, predominantly driven by continuously increasing labour costs and more stringent environmental regulations. A large portion of Western manufacturing has been transferred out to Asia and elsewhere due to competitive labour costs and a lack of environmental regulatory constraints. While this global shift has enabled Asian

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[5] (2022). Redwood Materials expands into Europe. Redwood Materials, https://www.redwoodmaterials.com/press/redwood-materials-expands-into-europe

[6] (2022). Li-Cycle reports first quarter 2022 financial results; significant milestone achieved for Rochester Hub Project. Business Wire, https://www.businesswire.com/news/home/20220317005400/en/Li-Cycle-Reports-First-Quarter-2022-Financial-Results-Significant-Milestone-Achieved-for-Rochester-Hub-Project

[7] (2021). Northvolt produces first fully recycled battery cell – looks towards establishing 125,000 ton/year giga recycling plant. Northvolt, https://northvolt.com/articles/recycled-battery/

[8] Thompson, D. L., Hartley, J. M., Lambert, S. M., Shiref, M., Harper, G. D. J., Kendrick, E., Anderson, P., Ryder, K. S., Gaines, L. and Abbott, A. P. (2020). The importance of design in lithium ion battery recycling – a critical review. Green Chem., 22, 7585-7603, https://doi.org/10.1039/D0GC02745F

[9] (2020). Can Cyrene offer a greener alternative to harmful solvents? Merck Grouphttps://www.merckgroup.com/en/research/science-space/envisioning-tomorrow/scarcity-of-resources/cyrene.html

[10] Adler, M., Murtaugh, D., and Chia, K. (2021). Solar power may be the next victim of china's coal shortage. Bloomberg, https://www.bloomberg.com/news/articles/2021-09-29/china-slashes-silicon-output-signaling-higher-solar-panel-costs

[11] Murtaugh, D. (2022) China's solar giants have a fix for their broken supply chain. Bloomberg Green, https://www.bloomberg.com/news/articles/2022-01-10/how-china-will-fix-its-snarled-solar-panel-supply-chain

economies to become manufacturing superpowers, a circular economy may enable yet another shift.

It is simply impractical from both an economic and environmental perspective to ship used products across the globe for recycling. The growing prices of raw materials are driven by resource scarcity, among other factors, and increasing fuel prices and a strong environmental push towards becoming a global net-zero economy may be able to re-introduce local recycling and re-manufacturing practices across the globe. Those manufacturing hubs will likely be more decentralized and of a smaller scale than factories in Asia but powered by renewable energy, experiencing continuous price decreases, as well as the opportunity to cut shipping costs to and from recycling and processing plants. With the help of regulatory measures and the support of green chemistry and sustainable processing technologies, environmental concerns can be minimized and reduced to more manageable levels.

Environmental taxation, including carbon taxation, Pays Principle-based mechanisms will reinforce the case for and incentivise recycling and local manufacturing, creating new jobs and economic growth across countries and regions.

A case for policies, regulations and economic incentives

While industry leaders are already addressing current and future challenges in the green economy, these issues will continue to become more prevalent as penetration of clean technologies increases. There is a noticeable gap in governmental support for these challenges and their early engagement. Industry leaders are awaiting clear guidance and directions. This can be easily addressed by implementing clear policies and recycling standards and putting more emphasis on recycling practices.

While the battery industry can today embrace the costs of the circular economy due to growing raw material prices, other clean technologies are not yet at this stage and, as a result, some sectors may require certain early economic incentives in the form of grants or tax rebates to make a case for circular economy and to encourage the establishment of early circular economy value chains.

Education and capacity building at all levels is also urgently needed to cultivate the future circular economy workforce and to institute a common sense around the benefits and need for a circular economy within broader society.

Enabling a circular economy in clean technology and other industries through policies, economic incentives and educational practices can return enormous social, economic and environmental benefits by re-establishing local manufacturing hubs, fostering economic growth, creating jobs and protecting the planet.