Circular economy of electric power smart meters

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Abstract

Activities aimed at achieving a more sustainable future take numerous forms across the globe and across many sectors. Energy and electronics businesses are also attempting to solve crucial issues such as energy usage, material recovery, e-waste, procurement, and supplier working conditions. The actions undertaken support this objective by constructing a framework with criteria describing socially responsible work practices, as well as researching, designing, and manufacturing a fair smart meter. The major goals are to solve the issues of materials, working environment, energy, and toxicity. For decades, businesses have made substantial efforts to fulfill the highest standards, environmental awareness, and commercial ethics, with a particular emphasis on how to manufacture smart energy technologies.

Smart meters provide considerable energy efficiency improvements as well as the integration of renewable resources from decentralized production into the energy grid. As a result, utilities and end users are able to drastically cut their carbon dioxide (CO_2) emissions.

Keywords: Electricity grid, carbon dioxide emissions, energy, smart meters, circular economy.

1. Introduction

The electricity sector has seen several changes in recent decades as a result of market liberalization. Nowadays, competitive energy markets offer sufficient electricity production, technological innovation, and lower pricing. The safe functioning of electrical systems in this environment necessitates continuous monitoring of their operating conditions. This is accomplished via control centers, which gather data from different measuring equipment in order to limit and regulate power losses and avert difficulties.

Electricity grids have progressively started to incorporate all of these technological developments as information and computer technologies have advanced, resulting in the birth of the smart grid [1]. The smart grid is an electrical grid that offers energy to clients from several places and distributes energy using novel applications on existing transmission and distribution networks.

The "construction" of the smart grid entails the use of information and communication technologies to make it more efficient and reliable. It can include unstable renewables and make them more dependable and controllable. The information produced by smart grid apps is used to optimize the flow of power. The combination of sensors, novel information-processing services, and digital communications makes the smart grid viewable, controlled, automated, and completely interconnected. There are two ways to smart grid development.

The European approach is based on the needs of electricity networks in order to be flexible in meeting customer needs, respond to future changes, and be accessible with connectivity to all network users, particularly for renewables and high-efficiency local production with zero or low carbon emissions. At the same time, it implies being dependable by assuring and increasing the safety and quality of the energy delivered, fulfilling the needs of the new age, and being resilient to risks and uncertainties. Finally, in order to successfully manage energy and enhance competition among suppliers, it must be economically feasible to deliver the best pricing via technical improvements [2, 3].

The American method is based on improved interactive communications and controls rather than on a cyber-infrastructure put on an existing network [4, 5].

Smart grids are energy systems that can monitor energy flows automatically and respond to changes in energy supply and demand. Smart grids reach consumers and suppliers by giving real-time usage statistics when paired with smart metering systems. Consumers may adapt their energy consumption to varying energy prices throughout the day using smart meters, enabling them to consume more at lower price times and save money on their energy bills.

The current study focuses on the potential of the cyclical electricity meter economy in terms of energy efficiency, renewable resource integration, and end-users' ability to dramatically cut carbon dioxide (CO_2) emissions.

2. Smart Meters

Because smart grids provide information on supply and demand, they are especially useful for integrating renewable energy sources such as solar and wind energy, which often rely on whether to provide sufficient efficiency. Furthermore, smart grids allow users who produce their own energy to meet rates while selling excess quantities to the grid.

When compared to a standard energy meter, a smart meter (Figure I) is an enhanced energy meter that detects a consumer's energy use and gives extra information to the utility provider. Smart meters can read real-time power consumption data, including voltage, phase angle, and frequency values, and securely send this information. The information gathered is a mix of factors such as a unique meter ID, data time stamping, and power consumption numbers.

The capacity of smart meters to communicate in two directions enables for the gathering of data on the energy returned to the mains from the customer's premises.

Fig. I. Three-phase smart meter.

The smart meter, communication infrastructure, and control devices are all part of a smart meter system. Smart meters can connect with one another and perform remote control commands as well as local directives. The smart meters can monitor and operate all household appliances as well as gadgets at the customer's location. They may also gather diagnostic data about the distribution network and residential appliances, as well as connect with other meters. They may monitor grid electricity use, support decentralized power sources and energy storage devices, and bill customers appropriately [6].

Smart meters may be designed to only charge for electricity used by the utility grid and not for power consumed by distributed generating sources or customer-owned storage devices. Smart meters have the ability to regulate maximum power use and to turn off or restore electricity to any distant consumer [6].

The EU wants to replace at least 80% of power meters with smart meters by 2020, if possible. This smart meter, together with the development of smart grids, has the potential to cut EU emissions by up to 9% and home yearly energy use by comparable amounts. EU nations performed cost-benefit analyses based on European Commission standards to assess cost-effectiveness. A comparable evaluation was carried out on smart gas meters.

Smart meters should enable customers to realize the advantages of the energy market's growing digitalization via a variety of activities. Customers should also be able to obtain dynamic power pricing contracts [1].

3. Circular Economy

A circular economy is defined as a collection of economic activities that concentrate on decreasing long-term waste of manufacturing process resources. The circular economy emphasizes the use of renewable resources, the recovery and reuse of goods, the generation of energy from waste manufacturing processes, the extension of product life, and the economic usage of items, with the ultimate objective of delivering services to numerous users. As a result, one may argue that the circular economy is a kind of recycling development [7].

The circular economy model is applicable to every modern society and especially attractive to researchers and young scientists. The changes that are now taking place, both in the economy and development, and particularly in the sector of waste management, contribute significantly to this field.

Over the last decade there are many chances in the Circular Economy, particularly among young people. The shortage of accessible cash for the acquisition of raw materials, the flexibility of small and medium-sized firms and social enterprises, as well as the necessity for employment for young scientists, and environmental regulation obligations, all drive recycling and reuse projects [8].

The circular economy has the potential to generate a qualitative leap in the economy, resulting in a growth revolution. It generates new employment, supports small and medium-sized businesses, the development of new professions, and the social economy.

The following are the basic components of public policy for the circular economy [8]:

- Financial instruments
- Create regulatory frameworks and rules, as well as reduce bureaucratic impediments.
- Connecting small and medium-sized enterprises (SMEs) and the social economy to technology innovation, as well as planning and implementing pilot / demonstration circular economy initiatives
- Improve governance and networking, as well as accelerate processes

4. Smart Meters Circular Economy

The manufacturing process and the product life cycle must be examined in order to achieve circular economy at the smart grid level, with a focus on smart power meters. Because there are many realizations and most smart meter manufacturers do not give extensive information on the material/component composition of their components, defining the usual structure and, as a result, the typical material/component composition of smart meters has proved problematic. A combined analytical and experimental analysis of data from diverse sources to improve data accuracy is conducted. Some data, for example, were acquired by disassembling devices and measuring the weight of constituent parts: In order to compute average values, these data were blended with data from different manufacturer requirements. We used five different types of smart meters to discover the average values corresponded extremely well to each specific component, namely, Landis+Gyr E650 (x1), Landis+Gyr E850 (x1), Actaris ACE5000 (x1), Actaris ACE 6000 (x1) and Edmi Mk10E ATLAS (x1). Table I presents the material/component composition of the above smart meters. The materials/components of smart meters can be divided to five major categories expressed in kg. The first two categories related with steel and copper. The rest of the components include plastic, LCD (Liquid-crystal display) and other components such as epoxies, ceramics etc. Note that the first two columns of the Table I express the type of smart meter and its corresponding weight as mentioned in vendors' data sheets.

Table I. Material/component composition of the five smart meters.

Smart Meter Type	Weight (kg)	Steel (kg)	Copper (kg)	Plastic (kg)	LCD (kg)	Other (kg)
E650	1.500	0.310	0.500	0.405	0.040	0.245
E850	1.600	0.345	0.532	0.428	0.031	0.264
ACE 5000	1.700	0.390	0.591	0.422	0.036	0.261
ACE 6000	1.900	0.401	0.664	0.531	0.026	0.278
Mk10E	2.000	0.417	0.666	0.559	0.038	0.320

Figure II depicts the average values of the above components expressed in kg, while it should be noticed that the average weight of the total amount of the smart meters is equal to 1.740kg.

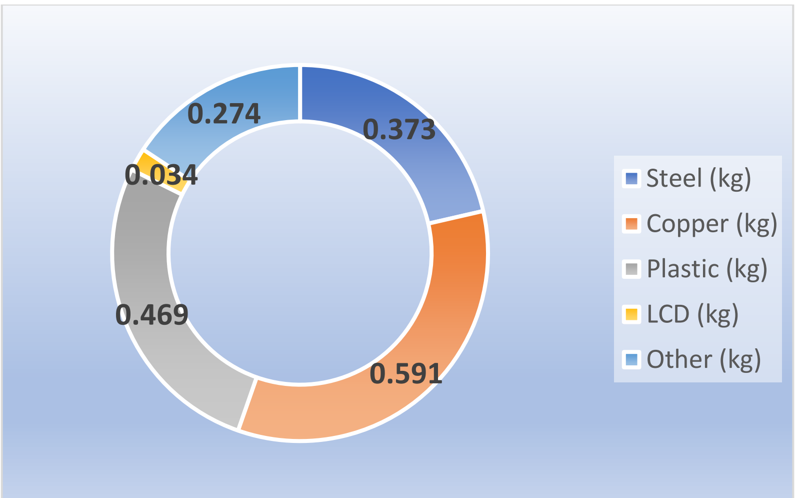

Fig. II. The five smart meters' material/component composition given in kg.

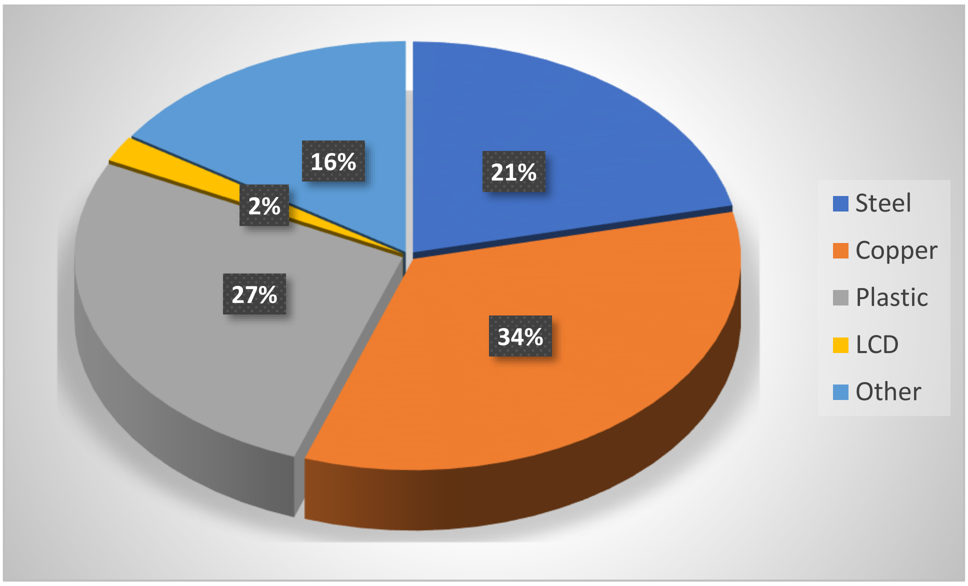

Fig. III. The five smart meters' material/component composition given in percent of the total smart meter weight.

Figure III presents the five smart meters' material/component composition given in percent of the total smart meter weight.

In order to quantify the average weight of each component in terms of materials' cost, we calculate the average cost of the components considering their corresponding market value as this provided by stock markets [9-11]. Table II presents the average cost of each material.

Table II. Average material cost of the five smart meters.

Material	Cost (US$/t)	Average material cost
Steel	1,647.50	0.61
Copper	10,255.00	6.06
Plastic	3,562.58	1.67
LCD	250.00	0.01
Other	300.00	0.08

The energy and electronics sectors are likewise working to address crucial issues such as energy usage, material use, e-waste, supplier sourcing, and labor conditions. Under these circumstances there is an aim to provide a framework with guidelines dealing with socially acceptable work practices, as well as researching, designing, and manufacturing of a fair smart meter [12].

A "fair" smart meter is characterized as one that:

- made with the use of circular materials and fair labor methods,
- operates with minimum energy consumption and
- contains no harmful compounds or minerals

The most essential obstacles that must be overcome while developing the "fair" smart meter are as follows:

- working circumstances,
- "conflicting minerals",
- mineral deficiency and
- the dumping of minerals

Working circumstances are defined as a work environment in which the employee has a managerial position and a permanent contract, his employment is fascinating, safe, well compensated, neither risky or stressful, and gives autonomy and high career possibilities [13]. By "conflicting minerals", we mean minerals such as copper, tantalum, tungsten, ores and their mineral derivatives, and gold derived from mining operations in conflict-affected countries that might result in worldwide production. provide [14]. As a result, it is desirable that these materials be derived via recycling. The scarcity of minerals is caused by the quantity of mining that becomes economical under present market circumstances [15], but the waste of minerals is caused by population increase and the repercussions that emerge from it. Table III summarizes the most fundamental and particular concerns to be studied for the implementation of the "fair" meter.

Table III. Basic and Special concerns that will be explored.

KEY ISSUES	SPECIAL ISSUES
Transparency in the supply chain	Neutrality of CO_2
Transparency in software and data	Circularity
Security	Colliding metals or raw materials
Privacy	Good working conditions Non-hazardous substances

Table IV summarizes the principles to be followed throughout the manufacturing process and the life cycle of the "fair" smart meter, with the ultimate objective of achieving a sustainable energy future.

Table IV. Guidelines for "Fair" Smart Meters.

Production process	Final product
• Reduced energy consumption and emissions throughout the supply chain	• Self-feeding for the purpose of operating the meter itself
• Avoid the use of minerals in conflict	• Use of environmentally friendly resources and raw materials
• Managing an ethical and responsible supply chain	• Software application and data processing for data protection and privacy
• Transparent product production processes	• Self-feeding for the purpose of operating the meter itself
	• Use of environmentally friendly resources and raw materials

The features of "fair" smart meter would be transferred to next-generation meters and their manufacturing, operation, and usage, as well as to the recycling procedures related with smart meters. The major goal, with a specific emphasis on circularity, was the usage of resources and raw materials throughout the lifespan of a smart meter. Circularity focuses on striving to circulate resources of both raw and used materials in order to decrease waste through reusing, refurbishing, remanufacturing, and recycling. As a result, the value that was developed from raw materials and resources is retained to the greatest extent possible. Figure IV presents the smart meters circular economy chain.

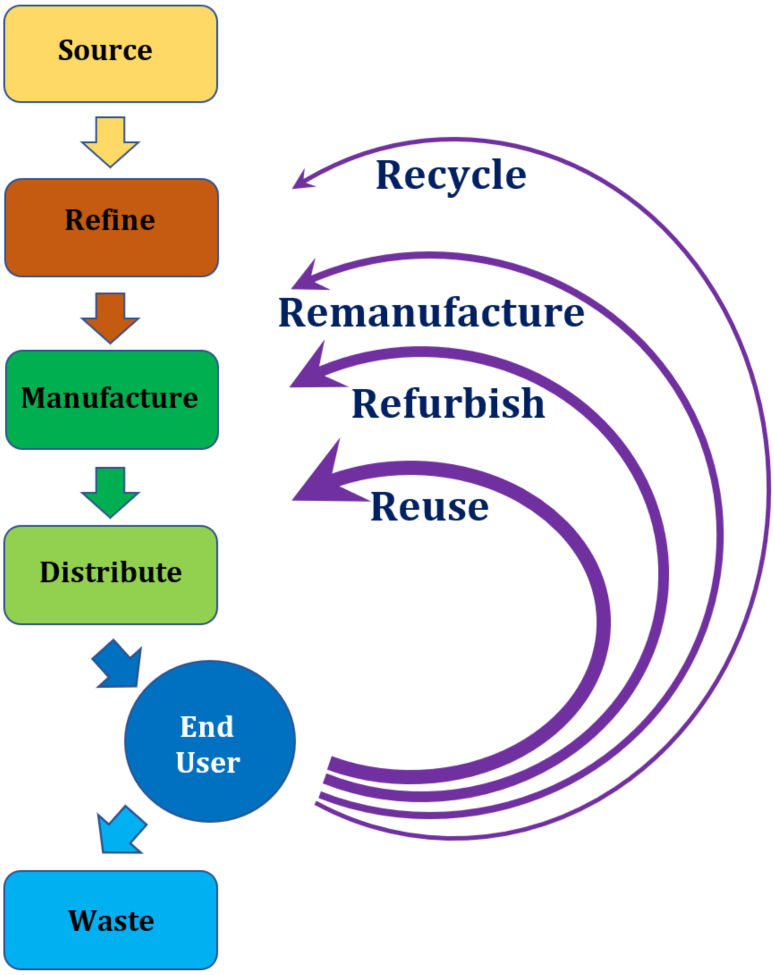

Fig. IV. Smart meters circular economy chain.

5. Conclusions

Smart meters are a critical measuring equipment for the development and seamless functioning of smart networks. Material must be reduced, avoided, or replaced whenever and wherever is feasible in order to build a new and better smart meter design in order to guarantee the green footprint in manufacturing and prolong the life of a smart meter within the circular economy bounds. Furthermore, the usage of impact, critical and rare materials, as well as materials with high built-in carbon values should be avoided. Of course, the material's attributes must fulfill the needed requirements as well as conform with EU regulations and guidelines.

Another goal should be to simplify the end-of-life treatment process by simplifying materials (cutting the amount of materials utilized) and product disassembly (avoiding additional screws, glue or other kinds of connections of different material). At the conclusion of its life cycle, the smart meter should be recycled using a specialized procedure that involves collecting, sorting, breaking, cleaning, and drying.

6. References

[1] EC. COMMISSION STAFF WORKING DOCUMENT. COM(2011) 202 FINAL. IOP Publishing EUR-Lex. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011SC0463&from=EN. Accessed 16 March 2022

[2] Ardito, L., Procaccianti, G., Menga, G., Morisio, M.: Smart Grid Technologies in Europe: An Overview. Energies. 6, 251-281 (2013)

[3] Gangale, F., Mengolini, A., Onyeji, I.: Consumer engagement: An insight from smart grid projects in Europe. Energy Policy. 60, 621-628 (2013)

[4] Krishnamurti, T., Schwartz, D., Davis, A., Fischhoff, B., Bruine de Bruin, W., Lave, L., Wang, J.: Preparing for smart grid technologies: A behavioral decision research approach to understanding consumer expectations about smart meters. Energy Policy. 41, 790-797 (2012)

[5] Metke, R.A., Ekl, L.R.: Smart Grid security technology. Innovative Smart Grid Technologies (ISGT), Gothenburg, Sweden (2010)

[6] Depuru, S.S.S.R., Wang, L., Devabhaktuni, V., Gudi, N.: Smart Meters for Power Grid – Challenges, Issues, Advantages and Status. IEEE/PES Power Systems Conference and Exposition, Phoenix, AZ, USA (2011)

[7] Abramov, A.P.: Balanced and Cyclical Growth in Models of Decentralized Economy. Springer International Publishing Switzerland. (2014)

[8] Van Veen, J.: Accelerating the transition to the circular economy – Improving access to finance for circular economy projects. IOP Publishing EC-Europa. https://ec.europa.eu/info/sites/default/files/research_and_innovation/knowledge_publications_tools_and_data/documents/accelerating_circular_economy_032019.pdf Accessed 16 March 2022

[9] https://www.lme.com/ Accessed 16 March 2022

[10] https://www.echemi.com/ Accessed 16 March 2022

[11] https://fred.stlouisfed.org/ Accessed 16 March 2022

[12] Andrews, J.: The Fair Meter Initiative Circularity Innovations in Smart Meters. IOP Publishing FairMeter. https://www.fairsmartmeter.com/wp-content/uploads/2018/04/Fair-Meter-Circularity_March-20181.pdf (2018). Accessed 16 March 2022

[13] Drobnič, S., Beham, B., Präg, P.: Good Job, Good Life? Working Conditions and Quality of Life in Europe. Springer Science+Business Media B.V. (2010)

[14] Young, S.B.: Responsible sourcing of metals: certification approaches for conflict minerals and conflict-free metals. Springer-Verlag Berlin Heidelberg (2015)

[15] Yellishetty, M., Ranjith, P.G., Tharumarajah, A., Bhosale, S.: Life cycle assessment in the minerals and metals sector: a critical review of selected issues and challenges. The International Journal of Life Cycle Assessment (2009)