II.

Reconsidering "Circular Economy" in Terms of Irreversible Evolution of Economic Activity and Interplay between Technosphere and Biosphere

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Abstract

The notion of circular economy has attracted increased attention in recent years. A set of common denominators of circular economy is identified. Then, four questions are raised to show that the ideas of a circular economy cannot be untenable: (i) is there any fundamental difference between the framework of circular economy and the neoclassical standard economics?; (ii) the efficiency improvement of energy and material use is achievable within the framework of circular economy proposal?; (iii) can the harmonious interplay between Technosphere and Biosphere be maintained?; and (iv) is there any serious consideration of "water fund" management within the framework of circular economy?

Keywords: Circular Economy, Jevons Paradox, Biosphere, Technosphere, Water Fund
JEL Classification: A1, P1, Q3

1. The Essence of "Circular Economy" Proposals

The notion of circular economy has attracted increased attention in recent years. While there are various "definitions" on circular economy (Kirchher *et al.*, 2017), we can identify a set of common denominators of circular economy if we carefully distill the essence of the ideas of circular economy.

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Fortunately, there is an influenctial institution that has been devoted to promote the idea of circular economy, The Ellen MacArthur Foundation, that was launched in 2010 to accelerate the transition to circular economy. In the foundation's site, they state that "since creation the charity has emerged as a global thought leader, establishing the circular economy on the agenda of decision makers across business, government and academia, with the support of its Core Philanthropic Partner SUN, MAVA and People's Postcode Lottery and Knowledge Partners Arup, IDEO, McKinsey & Company and SYSTEMIQ". Therefore, we believe that it would not cause any serious distortion of the holistic picture that characterizes the essence of circular economy if we examine the fundamental ideas of circular economy adopted by The Ellen MacArthur Foundation (2015), *Towards a Circular Economy: Business Rationale for an Accelerated Transition*. In the document they mention the history of circular economy: "Major schools of thought related to the circular economy emerged in the 1970s but gained prominence in the 1990s. Examples include the functional service economy (performance economy) of Walter Stahel; the "cradle to cradle" design philosophy of William McDonough and Michael Braungart; biomimicry as articulated by Janine Benyus; the industrial ecology of Reid Lifset and Thomas Graedel; natural capitalism by Amory and Hunter Lovins and Paul Hawken; and the blue economy systems approach described by Gunter Pauli".

The Ellen MacArthur Foundation summarizes the ideas behind circular economy: "A circular economy is one that is restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles. This new economic model seeks to ultimately decouple global economic development from finite resource consumption. A circular economy addresses mounting resource-related challenges for business and economies, and could generate growth, create jobs, and reduce environmental impacts, including carbon emissions. As the call for a new economic model based on systems-thinking grows louder, an unprecedented favorable alignment of technological and social factors today can enable the transition to a circular economy". Furthermore the foundation states that "the circular model of growth, decoupled from the consumption of finite resources and capable of delivering resilient economic systems, is increasingly looked upon as the next wave of development". "The circular economy, by moving much more biological material through the anaerobic digestion or composting process and back into the soil, will reduce the need for replenishment with additional nutrients. Systematic use of available organic waste could help regenerate land and replace chemical fertilizers 2.7 times over".

"The Ellen MacArthur Foundation, SUN, and McKinsey have identified that by adopting circular economy principles, Europe can take advantage of the impending technology revolution to create a net benefit of €1.8 trillion by 2030, or €0.9 trillion more than in the current linear development path. The circular economy could create tremendous opportunities for industrial renewal, regeneration, and innovation".

Perusing the 2015 above-mentioned document prepared by The Ellen MacArthur Foundation, we raise four questions of crucial importance to judge whether or not the ideas of circular economy given by the foundation can be taken at face value that they claim. Here it must be remembered that those questions that follow are distilled from many proposals we encountered during our investigation on the content and the meaning of circular economy, so that the four questions must be raised equally to other similar circular economy proposals including bioeconomy: (i) is there any fundamental difference between the framework of circular economy and the neoclassical standard economics?; (ii) decoupling - the efficiency improvement of energy and material use weaken the link between energy and material use and the intensity of economic activity - is achievable within the framework of circular economy proposal?; (iii) can the harmonious interplay between Technosphere and Biosphere be maintained? For simplicity's sake, we call the physical environment including the socioeconomic systems affected through building or modification by humans as Technosphere and the land and water area on the Earth occupied by living species, and the total biomass of life on the planet as Biosphere; and (iv) is there any serious consideration of "water fund" management within the framework of circular economy?

The rest of the paper is concerned with the four questions followed by a brief conclusion.

2. The Framework of Circular Economy and Neoclassical Economics

The Ellen MacArthur Foundation (2015) presents a schematic representation of circular economy where they treat the circularity between technical and biological cycles in relation to production and consumption processes. Technical cycles part describes collection, recycle, reuse, refurbishment and maintenance. Surprisingly, they treat these cycles as if these cycles were maintained without any input from and any waste into the environment including Biosphere that will be changed irreversibly. On the other hand, the part that they call biological cycles, consists of the processes such as farming (including hunting and fishing), extraction and regeneration of biochemical feedstocks. But they do not mention at all how these processes can be related to Biosphere. In reality, what they describe as technical and biological cycles belong only to Technosphere that could be viewed as a "super-connector" in order to transfer and transform all types of resources and industrial wastes which could be ultimately used under strong human control. Those technical and biological cycles have nothing to do with Biosphere. So, Biosphere, the ultimate source of all vital resources for human survival and the final sink of all waste energy and materials, does not really exist in their representation of circular economy, except only for that described as "biosphere" within the biological cycles examined above.

In fact, their representation is in essence exactly the same with the representation of the economic process adopted by the standard economics (see Samuelson and Nordhaus, 2010). To equate the economic process with a *mechanical analogue* implies, therefore, the myth that the economic process is a circular merry-go-round with complete reversibility which cannot possibly affect the environment of matter and energy in any way within Biosphere. The only feedbacks in the standard theory are those responsible for maintaining equilibrium, not for irreversible changes. The obvious conclusion is that there is no need for bringing the environment, including Biosphere, into the standard representation of the reversible economic process. The whole economic process is represented by a sort of perpetual motion described by Pigou in his *The Economics of Stationary States* (1935): "In a stationary state factors of production are stocks, unchanging in amount, out of which emerges a continuous flow, also unchanging in amount, of real income". At this moment to be fair to the standard economics, it is indicated by Georgescu-Roegen that the same idea, of a constant flow that can be obtained from an unchanging structure, lies at the basis of Marx's simple reproduction scheme that also ignores the problem of how to obtain the primary input flows (Georgescu-Roegen, 1975)

At this connection it is better to touch on B. Commoner's view who was seriously concerned with the ecological salvation and wrote *The Closing Circle* (1974). Commoner proposed four ecological laws, the fourth of which is "there is no such thing as a free lunch": you cannot get something for nothing. But this law unfortunately belongs to the first law of thermodynamics domain, in a sense that nothing can be obtained out of nothing. So, Commoner's law still belongs to the same mechanical perspective envisioned by the standard economics as well as the proponents of circular economy. Perhaps they do not correctly understand the irreversible nature of the ecological and economic process within both Technosphere and Biosphere.

In this respect, Georgescu-Roegen properly grasps the irreversible nature of economic production process: "production represents *a deficit in entropy terms*: it increases total entropy by a greater amount than that which would result in the absence of any productive activity" (1971, emphasis added). So, Commoner's law must be replaced by the statement by Georgescu-Roegen: "you cannot get anything but at a far greater cost in low entropy". Soddy (1961) also states the essence of the matter: "This [energy] flow always occurs in one natural direction, and it can only be reversed in direction by making more energy flow downstream, so to speak, than flows up". This new orientation towards the recognition of the entropic nature of the economic process must be a new maxim for the proponents of circular economy.

The following statement by the foundation completely misses the entropic nature of the production process in the economic system: "Waste is "designed out". In a circular economy, waste does not exist, and is designed out by intention". In 1945, Schrödinger added a note to Chapter VI, concluding "that we give off heat [thermal entropy] is not accidental, but essential. For this is precisely the manner in which we dispose of the surplus [thermal] entropy we continually produce in our physical life process" (Schrödinger 1967: 80). Schrödinger's deep insight shows that disposal of surplus thermal entropy is necessary for living things to continue life (Mayumi, 2001). So, the statement by the foundation is really misleading. This visualization clearly shows that in this narrative of circular economy there is no place for studying the role of the environment including Biosphere in the stabilization of the recycling materials. It must be concluded that "the current interpretation of the concept of circular economy implies that a perpetual motion machine is possible" (Cullen, 2017).

3. Efficiency Improvement and Decoupling through Technical Innovation? Jevons Paradox Revisited

The foundation states that "Working towards efficiency as a solution – a reduction of resources and fossil energy consumed per unit of economic output – will not alter the finite nature of material stocks but can only delay the inevitable". Furthermore, it states "This new economic model [circular economy] seeks to ultimately decouple global economic development from finite resource consumption".

Because decoupling means that the growing efficiency improvement at every aspect of economic activities can weaken the link between energy and material consumption and the scale of economic activity, these two statements are not compatible with each other. In fact, while emphasis is shifted from efficiency improvement to decoupling within the framework of circular economy, how is it possible to do ultimate decoupling? We cannot see any possibility of "decoupling" between energy efficiency improvement and decoupling phenomenon.

However, it is instructive to discuss briefly Jevons Paradox in relation to efficiency improvement and decoupling in the historical perspectives. Jevons paradox was first investigated by Jevons in *The Coal Question* (1865): an increase in output/input ratio ("efficiency" in using a resource) eventually leads to an increased use of that resource rather than to a reduction. Jevons was discussing possible trends of future consumption of coal and reacting to scenarios. As a matter of fact, like what is happening in our time, the contemporary of Jevons proposed to dramatically increase the "efficiency" of steam engines in order to reduce coal consumption. However, Jevons correctly grasped the essence of the matter: more efficient engines would have ultimately expanded the possible uses of coal for economic activities.

Jevons paradox proved to be true not only with regard to demand for coal and other fossil energy resources but also with regard to demand for resources in general. Doubling the efficiency of food production per hectare over the last 60 years through the Green Revolution did not solve the hunger problem. It unfortunately made that problem worse, because it increased population that requires more food and the malnourished (Giampietro, 1994). In a similar manner, increasing road area did not solve traffic problem, because increased road area allows people to use personal vehicles more often (Newman, 1991). As more energy efficient automobiles were introduced due to rising oil prices, those automobiles were intensively used for leisure driving (Cherfas, 1991). More efficient refrigerators have increased the size of those refrigerators, resulting in more electricity consumption (Khazzoom, 1987). A promotion of energy efficiency at the micro level of economic agents is scaled up, thus tending to increase energy consumption at the macro level of the whole society (Herring, 1999). In economic terms, we can describe Jevons Paradox as increasing supply capacity boosting long-term demand, much more robust than the Say's Law (Polimeni *et al*., 2007).

Under these explicit evidences of Jevons Paradox described above, the proponents of circular economy based on decoupling through efficiency improvement must show how the process of decoupling is to be achieved. The following claim made by the foundation is yet to be proved: "circular economy development path could result in a reduction of primary material consumption (measured by car and construction materials, real estate land, synthetic fertilizers, pesticides, agricultural water use, fuels, and non-renewable electricity) by 32% by 2030 and 53% by 2050, compared with today".

4. Harmonious Interplay between Technosphere and Biosphere

As already shown in Section 2, the technical and biological cycles proposed by circular economy have nothing to do with the real interplay between Technosphere and Biosphere. In this section we try to deal with this interplay in more theoretical and practical terms that might be useful for the proponent of circular economy towards understanding the nature of crucial interplay between the two spheres.

The school of non-equilibrium thermodynamics (Prigogine,1961; Glansdorff and Prigogine, 1971; Nicolis and Prigogine, 1977) postulate that the property of self-organization is unique to open dissipative systems - they have to gather inputs from their environment and dispose wastes into it. A dissipative system is expressing an organized pattern of interaction constrained by the activity of two components: (i) a dissipative structure - generating a positive entropy flux to express its structures and functions; (ii) an environment - providing a flux of low entropy energy and materials and discarding high entropy energy and materials, utilizing favorable gradients. Within the original formulation by Carnot (1824 included in Mendoza, ed. 1960), the favorable gradient corresponds to the temperature difference that guarantees the cyclic movement of Carnot engine. It must be emphasized here that even if there is only one heat source, it is *theoretically* possible to absorb heat and transform *completely* into mechanical work using isothermal expansion phase. However, in reality, the length of the piston must be finite, because this isothermal expansion phase is not cyclic! So, a sort of cyclic operation is a key to the survival of a dissipative system in an admissible environment. This property carries with it an existential predicament for all self-organizing systems including dissipative ones: in order to survive they must irreversibly stress the admissible environment in which they operate. This predicament of favorable gradients can become fatal for complex metabolic systems, such as human societies, that can grow both in size and in pace of activity per unit of size (*e.g.*, economic growth). For these complex metabolic systems to survive they must learn and adapt to changes in their boundary conditions of the environment that are always changing.

A socio-ecological system can be defined as the complex web of functional and structural components operating within a prescribed boundary, that is controlled in an integrated way by the activities expressed by a given set of ecosystems within Biosphere and a given set of social actors and institutions in Technosphere. In a social-ecological system the process of maintenance and reproduction of the components of Technosphere should not interfere too much with the process of maintenance and reproduction of the components of Biosphere.

A biophysical representation based on the rationale of metabolic systems describes "production factors" as fund elements or agent of production, that are treated as if they were intact during the process. This implies that the issue of sustainability, the compatibility between Technosphere and Biosphere, requires addressing the compatibility between: (i) the size and the metabolic speed of the funds operating in Technosphere; and (ii) the size and the metabolic speed of the funds operating in Biosphere. In reality, production agents both in Technosphere and Biosphere have to be produced, maintained and reproduced. Moreover, the identity of the fund elements entails a constraint on the output flow rates or assimilation flow rates: a cow cannot produce 300 liters of milk per day; a person cannot eat 200,000 kcal of food a day; and a healthy soil cannot absorb a ton of nitrogen per hectare per year.

While the theoretical analysis presented above is occasionally suitable for the general discussion of the metabolic systems, we must be careful to distinguish flows of various energy and materials. In fact, flows of water, energy and food metabolized by society take various forms in relation to how to use them. For this purpose, we must create a taxonomy of energy, food and water forms associated with different categories of accounting in metabolic systems (Giampietro *et al.*, 2012). To achieve this result we have to distinguish several category of flows considering the existence of two interfaces:

1. Primary flows are entering into Technosphere from Biosphere and getting out of Technosphere into Biosphere: (i) "primary sources" – *e.g.* aquifer, coal, arable land; and (ii) "primary sinks" – *e.g.* atmosphere, the water table, dumping sites;

2. Secondary inputs/outputs are produced and consumed in Technosphere. End uses entail both the expression of a final task such as production of secondary inputs and the generation of waste matters and emission ultimately dumped into Biosphere. In this case the secondary inputs can be termed as "carriers" consisting of certain forms of water, energy and food - *e.g.* irrigation water, electricity, potatoes. The two types of outputs are: (i) "end uses" - functions associated with useful task for the society - *e.g.* evapotranspiration of water for biomass production, consumption of electricity for expressing a task, eating of the potatoes; and (ii) "wastes" to be discharged outside that become primary flows into Biosphere – *e.g.* water vapor, heat and emissions for electricity, feces for food.

When analyzing the metabolism in this way we can realize that inside Technosphere there is not enough recycling result of primary flows of water, energy, food and minerals.

Sustainability requires the existence of a robust life support system for the activities of the economy capable of closing the loops of primary inputs and primary outputs. Coming to the economic view, there is a clear difference in the speed and density of the flows of water, energy, food transformed inside Technosphere – *i.e.* the processing of secondary inputs in the economic process - and in the speed and density of the flows transformed in Biosphere – *i.e.* the supply provided by primary sources and the absorbing capacity of primary sinks. In Technosphere, the speed and density of economically relevant flows (products and materials) are determined by processes under human control, whereas in Biosphere the expected densities and paces of primary flows are determined by ecological processes within Biosphere (Loma and Giampietro, 2017) that is beyond human control. According to the first law of thermodynamics energy cannot be produced and according to the second principle of thermodynamics irreversible processes do affect the characteristics of energy and material flows. This entails that recycling can be partially achieved if there are resources for doing it and at increasing costs. The amount of wastes can be reduced, but the production of wastes is not avoidable, as Georgescu-Roegen's description of deficit in entropy terms.

For example, biogas from manure or electricity produced burning solid urban waste are secondary inputs. They are welcome contributions to an effective use of resources, but their existence depends on the previous availability of primary energy sources required to produce feed for animal or the discarded products ended up in solid wastes! Internal recycling is important, but when analyzing the factors determining the sustainability of the metabolic pattern of social-ecological systems, what really matters is the relation between the scale and speed of the primary flows required by Technosphere and the scale and speed of the primary sources and primary sinks made available by Biosphere.

The coexistence of two views of metabolic flows must be noticed. We must have the processes taking place in the primary sectors of the economy (Agriculture, Energy and Mining) – what we call the catabolic part of the metabolic process. In the catabolic part primary sources (favorable gradients provided by Biosphere) are degraded to produce secondary inputs (commodities, goods and services) that are used inside Technosphere. These secondary inputs are used to generate other secondary inputs (products and material) that is again used to build and maintain the activity of functional and structural elements. Therefore, in the anabolic part the secondary inputs are both produced and consumed in the economic process. This means that the secondary outputs of a given sector – *e.g.* the supply of electricity or food or mineral and products – becomes secondary inputs to another sector – *e.g.* the consumers of electricity or food or mineral and products.

5. Where is "Water Fund" Management Issue within the Framework of Circular Economy?

The amount of water required to produce biomass is enormous. When dealing with terrestrial ecosystems in average 570 tons of water must be evaporated-perspired per ton of net primary productivity of global terrestrial ecosystems (Xia *et al.,* 2015). Even more demanding is the requirement of water for the production of crops. The water footprint benchmarks for crop production (Mekonnen and Hoekstra, 2014) are in the range of 600-1,700 tons of water per ton of biomass. This fact implies that when considering the issue of scale human technology is totally irrelevant when coming to the control of the water cycle.

Just to provide an idea of the crucial dependency of the human food supply on the stability of existing biogeochemical cycles on this planet, it is helpful to use a few numbers. The total amount of exosomatic energy controlled by humankind in 1999, for all its activities (agriculture, industry, transportation, military activities, services and residential), is around 11 TW (1 TW = 10^{12} J/sec), which is about 350 x 10^{18} J/year. For keeping just the water cycle, the natural processes of Earth are using 44,000 TW of solar energy (about 1,400,000 x 1018 J/year), 4,000 times the energy under human control" (Giampietro, 2003).

Coming to biodiversity, the identity of ecosystems establishes a link between the requirement of water for biomass, food production and the required external sources of energy to power all these processes (Lomas and Giampietro, 2017). As discussed earlier the processes generating food and energy carriers in Technosphere and the processes recycling water and preserving biodiversity in Biosphere represent an inextricable entanglement between ecological processes and technical processes – what is called the NEXUS. They cannot be studied or tinkered independently of each other.

A paper by Haas *et al.* (2015), entitled "how circular is the global economy" shows that neither the global economy nor the economies of developed countries are circular. Their analysis of the material throughput divides the total of 6.7 GT/year of material input consumed by the European Union (EU) in 2005 into three major typologies of flows: (i) more than half - 52% (3.5 GT/year) - is composed of either food or energy inputs, which are *by default* degraded in an irreversible way into wastes and therefore cannot be recycled; (ii) a small quantity of material flow – 3% (0.7 GT/year) - associated with consumable and durable products. Recycling rates differ substantially among materials and countries (Smil, 2013), but the level of recirculation of the materials in consumable and durable products is generally low – the average well below 50% (Cullen, 2017); (iii) the remaining material input getting into the economy is composed of construction materials that become part of the structural components of society. These materials are integrated into fund elements, such as buildings and infrastructures, for an extended period of time. Due to the turnover of buildings and infrastructures a part of this material flow is recycled, but at different scales and paces. This fact makes it difficult to assess in an uncontested way the recycling rate of this fraction. When considering the overall rate of recycling Haas *et al.* propose a value of 13% over the whole input of 6.7 GT/year, when including the recycling of construction material.

However, in the conclusion of the paper, when providing the overall level of recirculation in the EU economy, Haas *et al.* 2015 provide an estimate of around 39% which seems to be in plain contrast with their original accounting: 13% can be recycled. The authors explain this inconsistency by arguing that *the flow of biomass* should be included among the "recycled" flows. We believe this is a misleading argument for three reasons. First, what is actually recycled in the production of biomass are the nutrients (*i.e.*, nitrogen, carbon, phosphorous) and the water contained in the biomass and not the biomass itself. Second, this important part of recycling does not take place within Technosphere, but in Biosphere, and therefore this recycling part is completely dependent on natural processes outside of human control: the speed and density of natural process cannot be altered at a large scale. Third, the biomass produced in modern agriculture can hardly be considered a renewable resource, because its production is highly dependent upon the use of technical inputs such as fertilizers, pesticides, machinery, irrigations that are produced with fossil energy.

But there is another important observation to be made: Haas *et al*. do *not* consider water flows in their assessment. As observed earlier, water plays a key role in stabilizing the functioning of social-ecological systems by making possible the renewable production of biomass and supporting the operation of the energy sector and therefore it is an essential component of the metabolism of social-ecological systems (Lomas and Giampietro, 2017).

For this reason we present a preliminary assessment of the order of magnitude of the material throughput associated with the operation of EU economy in 2005 including water in the material throughput starting from the assessment provided by Haas *et al.* The assessment of water consumption is based on the consideration of two types of biomass produced and consumed by society: (i) crops; and (ii) other biomass not used as food. Combining the two assessments discussed earlier of the requirement of tons of water per ton of biomass used by society adopting a conservative value of 600 tons of water perspired per ton of biomass consumed (for crops and generic biomass) we arrive at the conclusion that 1,380 Gt/year of evaporated-perspired water is required for producing 2.3 GT/year of biomass..

Water also plays the vital role in discarding the entropy production happening on the Earth. This important phenomenon is almost forgotten among people. Perhaps the first person who noticed the important role of water for the purpose of discarding high entropy is Soddy (1961, originally published in 1926). Soddy states that "A minute fraction of the energy that falls upon the ocean escapes total degradation into useless heat and evaporates the water. By a natural process - very similar, however, to that which is made artificially to occur in the steam engine — the water vapor ascends and suffers "adiabatic cooling and expansion." It so performs useful work upon itself in climbing against gravity. It chills as it ascends, until it is condensed again as rain, collects in rivers, which drive water-wheels and turbines on their course to the ocean". Soddy' idea was further extended by Tsuchida (1982). He explains convincingly how the earth disposes of thermal entropy generated within its system and the essential role played by land within Biosphere in thermal entropy disposal. Air convection and the water cycle constitute an atmospheric heat engine, which guarantees the existence of life on earth by continually discarding entropy into outer space. Within this heat engine, water and air circulate between the surface area of the earth (15℃ on average) and the air at high altitudes (-18℃). The low temperature of the upper atmosphere (-18℃), created by the adiabatic expansion of the air indicated by Soddy, is also important. It is possible to dispose of more the thermal entropy of radiation of the same quantity of heat at a lower temperature than at a higher temperature. In addition, at about –18℃, the vapor pressure is sufficiently low, and the air is so dry, that sunlight can pass easily through atmosphere. Water cycles emerge due to the asymmetry of the atmosphere. This asymmetry is created by the fact that the molecular weight of water vapor is 18, while the average molecular weight of air is 29. This difference in molecular weight creates an air pump, as it were, to lift water vapor to the upper atmosphere against gravity. If the earth's primitive atmosphere had consisted mainly of methane CH_4 (molecular weight is 16) instead of carbon dioxide, neither asymmetry nor life would have been possible. Through the operation of water cycles created by the earth's primitive atmosphere, living things on the earth can dispose of heat entropy. Thus water is really important for the health of Biosphere.

Regrettably, the water cycle idea envisioned by Soddy and Tsuchida is no longer ours. Georgescu-Roegen noticed that we must not ignore the substantial dissipation of matter caused not by purely natural phenomena but by some activities of living creatures, of humans, above all. It is the dissipation of some vital elements by man's consumption of food and timber in places far away from the farm and the forest that produced those items" (1979, 1040). Since the long-distance transportation of food and forest materials are ubiquitous with the modern economy, the amount of virtual water associated with the transportation must be tremendous. The land from which food and forest materials are exported will ultimately loses the virtual water fund, so that the local climate will be dramatically disturbed. In this respect water is vital element to keep the healthy condition for Biosphere.

6. Conclusion

The discussion given associated with the four questions in the previous sections must be seriously taken by the proponent of circular economy. Nobody knows what type of scheme of economic proposal will be useful to establish more sustainable and equitable society in the future. However, we sincerely hope that the four questions we raised will become a set of indispensable ingredients that reorient research and policy proposals toward such a direction.

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