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European Renewable Energy. Applying Circular Economy Thinking to Policy-Making

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Abstract.

This article addresses European energy policy through conventional and transformative sustainability approaches. The reader is guided towards an understanding of different renewable energy options that are available on the policy making table and how the policy choices have been shaped. In arguing that so far, European energy policy has been guided by conventional sustainability framework that focuses on eco-efficiency and 'energy mix', this article proposes greater reliance on circular economy (CE) and Cradle to Cradle (C2C) frameworks. Exploring the current European reliance on biofuels as a source of renewable energy, this article will provide recommendations for transition to transformative energy choices.

Key words. climate change · Circular Economy (CE) · Cradle to Cradle (C2C) · European Union · renewable energy · solar energy · wind energy

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***Perspective**: Theoretical and research visions*

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Introduction

The use of renewable energy is seen as one of the crucial components of sustainability strategy developed by the European Union (EU) over the past decade. In 2016, the European Commission aimed at designing the European Energy policies for the next decade[1]. These policies are aimed to devote a major effort to establishing new sustainability criteria for biomass and biofuels within the larger framework of sustainability largely in terms of increasing eco-efficiency and increasing the use of renewable energy.

According to the International Energy Agency,[2] "renewable energy is derived from natural processes that are replenished at a higher rate than they are consumed". Solar, wind, geothermal, hydropower, bio-energy from biomass, power of ocean or sea, and more contentiously, nuclear generation are associated with renewable energy [3]. Today, wind power, solar power, tidal waves, and geothermal power stations and the like produced about 1.3% between them[4].

Basically, some types of renewable energy, like hydropower, are considered clean, safe, and widely available from local sources[5]. However, the same hydropower may have unintended negative side-effects, such as dams that can cause disruption of natural systems, affecting river environments, fisheries and land[6],[7]. Other renewable energy sources have been even more controversial. For example, after the Fukushima nuclear accident in 2011, Germany has permanently shut down eight of its 17 reactors.[8] Presently, there is no broad scientific consensus about how safe nuclear energy is, and the debates are still raging in both scientific, as well as political, public and vested interests arenas.

While some sustainability experts, including those involved in formulating European energy policy, propose eco-efficiency (*reducing* energy use per unit of output) or a mix of strategies (*combining* both fossil fuels and renewable energy); others are in favour of more strict and transformative measures[9]. Generally, eco-efficiency as a term associated with sustainability is widely accepted in European policy documents as well as public discourse. Those advocated more transformative measures will be discussed further in this article.

This article will focus on specific types of renewable energy, biofuels on the one hand and wind and solar energy on the other hand, and examine these through the use of Cradle to Cradle (C2C) and Circular Economy (CE) frameworks. The CE[10] and C2C[11] are specifically highlighted as they provide measures that seek to reach beyond conventional approaches that are based on the assumption that pragmatic approach to renewable is more feasible and economically desirable[12]. Concretely, pragmatism in this case implies that the 'energy mix' includes whatever sources of energy are balanced in accordance to economic imperatives, social needs and partially ecological requirements.

By contrast to conventional eco-efficiency, CE and C2C postulate that rather than environment being merely one of the three

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[1] http://europa.eu/rapid/press-release_IP-16-4009_en.htm Accessed 13 May 2017.

[2] IEA (International Energy Agency). FAQ: renewable energy. http://www.iea.org/aboutus/faqs/renewable energy/ (2015). Accessed 13 December 2016.

[3] Stigka et al 2014

[4] The Economist 2015b

[5] https://www.energy.gov/eere/water/benefits-hydropower

[6] http://www.conserve-energy-future.com/Disadvantages_HydroPower.php

[7] International Rivers http://www.internationalrivers.org/environmental-impacts-of-dams 'Environmental Impact of Dams' Accessed 13 June 2015.

[8] Breidthardt 2011.

[9] Ellen MacArthur Foundation 2014

[10] EC http://ec.europa.eu/environment/circular-economy/index_en.htm 'Circular economy strategy' Accessed 13 June 2017.

[11] McDonough and Braungart 2002; EC http://ec.europa.eu/environment/ecoap/about-eco-innovation/good-practices/eu/575_en.htm 'Eco-innovation' Accessed 13 June 2017.

[12] Duflou et al 2012.

commonly accepted pillars of sustainability (the terms coined by John Elkington 'people, planet, profit'), it is foundational as economic and social systems are contingent upon functioning of healthy ecosystems. Ideally, at least, circular economy is 'restorative and regenerative by design, and aims to keep products, components, and materials at their highest utility and value at all times'.[13] Consequently, these transformative frameworks advocate renewable energy, outlining the danger of compromise in which economic imperatives take the front seat. According to C2C, eco-efficiency allows energy sources that are harmful to 'be less bad' rather than eliminating them altogether[14]. One example of 'less bad' energy source is biofuel derived from wood.

The Economist[15] journal termed the use of wood as a renewable energy source 'Environmental lunacy in Europe'. The article reflects that while biofuels are supposed to be 'carbon neutral', biomass plantations are harvested at the rate faster than they grow back. Also, these plantations displace ecologically diverse ecosystems that could have absorbed carbon more efficiently. They also compete with land that could have been used for food production. A poverty-combatting charity *Action Aid* has issued this statement: "If biofuels targets set by the U.S. and Europe are met the amount of land used to create fuel rather than food will increase dramatically. The result? Food prices could rise by up to 76% by 2020, pushing 600 million people into hunger[16].

This article will focus on the energy policy in the European Union in the larger context of sustainability, considering both conventional and alternative approaches. The sections below will place the issue of energy in Europe in the larger context of climate change, and then turn to the discussion of renewable energy. It will be argued that while EU claims to lead ecological modernization,[17] as well addressing global concerns about climate change[18] – yet its leadership role for a transition to renewable energy leaves some room for interpretation[19], especially in European embrace of biofuels.[20] We shall discuss the problematic role of biofuels in the European 'energy mix' in the sections below by first introducing the concept of C2C and CE, and then discussing how renewable energy is currently conceived in Europe. The question explored in this article is how the C2C and CE can be applied to evaluate the energy policy in Europe. The reason why these specific frameworks are especially relevant to the task of transition to sustainable energy is that they reach beyond the currently acceptable 'energy mix' solutions which still allow non-renewable or partially renewable sources of energy to be used. In being more categorically opposed to any sources of non-renewable energy, C2C and CE promise to address the root causes as well as offer realistic solutions to climate change, one of the key issues of concern identified in European environmental policy.

Climate Change

Increased consumption of fossil fuels results in emissions of greenhouse gases (GHG) and particularly carbon dioxide (CO_2) that most scientists agree cause climate change and air pollution.[21] The International Panel for Climate Change (IPCC)[22] has established that it is necessary to limit GHG to avoid the 2 degrees Celsius warming threshold. However, at present, the use of fossil fuels has not subsided and the global GHG emissions have actually risen to about 40% after the signing of Kyoto

[13] Ellen MacArthur Foundation https://www.ellenmacarthurfoundation.org/circular-economy

[14] McDonough and Braungart 2002; MacArthur Foundation 2014

[15] The Economist 2013.

[16] https://www.actionaid.org.uk/sites/default/files/publications/biofuels_fuelling_hunger.pdf

[17] Schelly 2015, pp 55-69.

[18] Lewis 2015.

[19] EC http://ec.europa.eu/clima/policies/international/negotiations/future/index_en.htm 'Paris agreement' Accessed May 17, 2016

[20] Van Renssen 2016.

[21] Kopnina and Blewitt 2014.

[22] IPCC 2011.

Protocol.[23] The Kyoto Protocol[24] signed in 1987 was followed by initiatives developed in the consequent climate change conferences, including the Paris agreement (2015) that is currently threatened by the American presidency of Donald Trump[25]. A great threat to climate change is the immense complexity of the challenge, in social, economic and even cultural terms. Climate change is intimately intertwined with energy, transportation and tax policies, with the very fabric of 'modern' living dependent on fossil fuel economy[26]. As a result of difficulties of addressing climate change, at the turn of the millennium, the five-year mean of global surface air temperature has increased by 0.5 degrees Celsius.[27]

Despite present American withdrawal from climate mitigation commitments the curbing of emissions is seen as an issue of primary importance within international sustainability politics. The climate and energy package developed by the EU is a set of binding legislation, which aims to ensure the targets for 2020. Known as the "20-20-20" targets for 2020, the targets include a 20% reduction in EU emissions from 1990 levels; raising the share of EU's renewable energy consumption to 20%; and a 20% improvement in the EU's energy efficiency[28]. There is large variation in the level of target fulfilment with France, the Netherlands and UK lagging behind, and Sweden, Denmark, Finland and Belgium over-fulfilling their target[29]. Remarkably, many laggard countries rely on biofuels as primary sources of renewable energy[30].

Circular economy (CE) and Cradle to Cradle (C2C) frameworks

The authors of the Cradle to Cradle concept, McDonough and Braungart[31], criticize the dominant method of industrial production as a "cradle to grave" process in which a product is made and then wasted. Recycling is in reality 'down-cycling' – an energy-costly process that invariably involves transportation, energy and water, and results in a product of less value. In fact, McDonough and Braungart argue, most products are not made from the start to be recycled, or even better, re-used infinitely: most of ubiquitous materials such as paper and plastic diminish in quality if recycled.

Another problem with conventional sustainability thinking is reliance on eco-efficiency – a strategy that tends to 'save' at least part of the product, such as electricity, by using it more efficiently. As McDonough and Braungart argue, however, a bad thing (such as fossil fuel converted to electricity) should not be 'efficient'. Efficiency helps to retain unsustainable products, instead of eliminating them altogether. In fact, most products, from cars to phones, are based on the 'built-in-obsolescence' or 'planned obsolescence' principle[32]. This means that products are intentionally not made to last, stimulating consumers to buy newer models.

C2C formulates three key design principles for production, which are also crucial for understanding sustainable energy generation principles: (a) waste equals food; (b) use current solar income, and (c) celebrate diversity. More concretely:

Waste equals food. Unproductive waste does not exist in nature because the processes of

[23] IPCC 2014.
[24] IPCC 2014.
[25]http://www.independent.co.uk/news/world/americas/us-elections/president-donald-trump-disaster-paris-climate-change-agreement-cop-22-un-climate-summit-a7406366.html
[26] Kopnina and 2014
[27] IPCC 2011.
[28]EC http://ec.europa.eu/clima/policies/international/paris_protocol/energy/index_en.htm 'A Global Deal for Climate'. Accessed 13 June 2015.
[29] https://ens.dk/sites/ens.dk/files/Globalcooperation/eu_energy_and_climate_policy_overview.pdf
[30]http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Biofuels%20Annual_The%20Hague_EU-28_7-15-2015.pdf
[31] McDonough and Braungart 2002
[32] Bulow 1986

each organism contribute to the health of the whole ecosystem. Typically, for example, a cherry tree's 'waste' is productive and even nutritional for other species – if not eaten, the berries and the leaves decompose into food for other living things providing nutrients flow indefinitely. Besides biological metabolism, the technical metabolism is designed to mirror natural cycles in a closed-loop system in which valuable, high-tech synthetics circulate in cycles of production, use, recovery and remanufacture.

Use current solar income. Noting that plants literally convert sunlight into useful substances used by other 'users' that are dependent on oxygen and vegetable food, sunlight is a logical source of endless renewable energy. Broadly, in C2C systems, any other types of endlessly available energy can be used, including wind and kinetic (power generated by movement) energy.

Celebrate diversity. Diversity in this case refers to healthy and various ecosystems that include highly complex communities of living things with a unique adaptation system to their surroundings that works in concert with other elements of this ecosystem. In recognising this natural diversity, C2C uses the idea of highly diversified and locally adapted natural systems as a prototype for making products[33].

In C2C planning, life cycle assessment helps to make informed choices at various stages in the product's life[34]. Life cycle assessments[35], which are also very useful as cradle-to-cradle analyses, are a way to look at all the inputs (raw materials, energy, etc.) and all the outputs created from the production, use, and disposal of the product (the product itself, pollution, waste by-products, etc.). In this way, business leaders or indeed energy companies can use life cycle assessments to select the types of energy sources or materials that are really safer and cleaner and without unforeseen negative side effects. Based on C2C, a circular economy framework proposes 'closed-loop' systems in which it is – at least ideally – possible to decouple[36] economic growth from impact. In the section below, we shall discuss how the case of renewable energy can be viewed through C2C and CE frameworks.

Renewable energy

Biomass is typically constituted from organic material such as plants, or algae and agricultural and urban organic (biodegradable) rest-products, with these materials used for generation of heat, electricity, fuel, and chemicals (ECg[37]). Another way to produce energy from biomass is garbage incineration, a technology otherwise known as "waste-to-energy technologies" or "energy recovery", which is a widely used energy source notably in The Netherlands[38]. However, some sustainability experts have pointed out that there are severe side effects of most of such renewable energy sources.[39] The monocultures of 'fuel forests' compete with productive agricultural land[40] and wild habitats. Biofuels generate CO2 when burned, but also the process that involves planting crops for generation of biofuel, fertilizing, harvesting, processing, and distribution emits significant amounts of CO2.[41] Biofuels also require continuous supply of timber, some of which takes tens of years to regenerate.[42]

Solar and wind were singled out as the most promising sources of renewable energy and were calculated to be able to supply between

[33] Kopnina and Blewitt 2014.

[34]http://eplca.jrc.ec.europa.eu/uploads/LCT-Making-sustainable-consumption-and-production-a-reality-A-guide-for-business-and-policy-makers-to-Life-Cycle-Thinking-and-Assessment.pdf

[35] https://www.gdrc.org/uem/lca/lca-define.html

[36] Kopnina and Blewitt 2014.

[37] http://ec.europa.eu/energy/en/topics/renewable-energy/biomass 'Biomass' Accessed 13 June 2017.

[38] http://www.suez-environnement.fr/wp-content/uploads/2015/03/Reenergy_EN.pdf

[39] Steer and Hanson 2015.

[40] Walsh 2014.

[41] Steer and Hanson 2015.

[42] The Economist 2013.

10 and 31% of electricity worldwide by 2050.[43] Complementary to wind and solar energy, geothermal energy, the energy of the ocean's waves, which are driven by both the tides and the wind[44] look promising. Geothermal energy, using hot water or steam reservoirs deep in the earth, taps the Earth's internal heat for electricity and heat production[45]. Tidal stream systems utilize the kinetic energy from water currents to turn turbines[46]. Indeed, according to C2C and CE frameworks, such systems are the only truly renewable sources of energy. Below we will focus on solar and wind energy and relate them to European energy policy.

Wind power

Wind power is known for hundreds of years for its use in windmills, and wind turbines today.[47] The Dutch windmills, for example, were present before the fourteenth century, with wind power applied to a wide range of industrial production[48].

At present, wind power can be stored either as electricity in batteries, heat in such media as molten salt, or as hydrogen, compressed air, or pumped storage, so that power is available on demand.[49] Battery storage has recently helped to improve capacity to store intermittent wind energy.[50],[51] The enlargement of the grid system, linking geographically dispersed wind turbines has facilitated power transfer.[52]

The challenge of integrating wind power into established electric power grids is described in the report *Technology Roadmap: Wind Energy,* by the International Energy Agency[53]. The *Roadmap* estimates that wind energy could account for up to 18% of the world's electricity by 2050, compared with 2.6% today. Yet, continuous obstacles hamper the successful spread of wind energy. One of the central arguments against wind energy is its cost.[54] An important factor in this respect is when established power companies buy excess power from disseminated wind power sources at a good price.[55] In the UK, the Government's Department for Energy and Climate Change (DECC) introduced the feed-in-tariffs or FITs in 2010,[56] providing opportunity for consumers to get money from their energy supplier if they installed a wind electricity-generating technology[57], enabling private users to save money on self-generated electricity, exporting surplus electricity to the grid.[58] According to the European Wind Energy Association (EWEA), onshore wind is cheaper than most other sources of energy when the costs of 'external' factors like pollution; toxicity and GHGs are taken into account.

Direct support mechanisms, such as government subsidies, as well as indirect ones, such as tax exemptions, price controls, trade restrictions, and limits to market access in regard to renewable energy need to be examined[59]. Indeed, if government regulators were to levy a significant carbon tax, they would drive the most polluting energy generators off the market, instead of relying on

[43] Barthelmie and Pryor 2014, pp 684-688; Diesendorf 2014.

[44] Renewable Energy World http://www.renewableenergyworld.com 'Renewable Energy News & Information'. Accessed 13 June 2017.

[45] NREL http://www.nrel.gov/learning/re_geothermal.html 'Geothermal energy basics' Accessed 13 June 2017.

[46] Tidal energy EUa http://www.tidalenergy.eu/tidal_stream_systems.html 'Tidal energy stream systems' Accessed 13 June 2017.

[47] Manwell et al. 2010.

[48] Kaldellis and Zafirakis 2011, pp 1887-1901.

[49] Armand and Tarascon 2008, pp 52-657.

[50] Divya and Østergaard 2009, pp 511-520.

[51] Teleke et al 2010, pp 787-794

[52] Sathyajith 2006

[53] https://www.iea.org/publications/freepublications/publication/Wind_2013_Road map.pdf Accessed 13 June 2017.

[54] Breton and Moe 2009, pp 646-654.

[55] Mendonça 2009.

[56] Seyfang et al. 2013, pp 977-989.

[57] Walker 2012, pp 383-388. (2012).

[58] Energy Saving Trust 2015, UK. scheme http://www.energysavingtrust.org.uk/domestic/content/feed-tariff-scheme. Accessed 1 May 2016.

[59] Rhodes 2016, pp 97-104.

the European Emissions Trading system which at present has a very low carbon price[60].

One significant barrier is industrial lobbies unwilling to undertake costly transition from fossil to renewable energy,[61] as well as protectionist national laws.[62] Fossil fuel lobbies often mediate public support of[63] or protest against[64] renewables[65]. Clever political and media manipulation by established power hegemonies[66] often places renewable energy production at a disadvantage in comparison to more 'traditional' industries that supposedly provide jobs and economic prosperity.[67] Such manipulation obscures the multiple benefits offered by wind power, including job creation and indeed, long-term prosperity.[68] The so-called 'green jobs' within wind industry are professions including engineers, iron and steel workers, millwrights, sheet metal workers, construction equipment operators, industrial truck drivers, and industrial production managers.[69] Thus, wind power provides hope for a possibility of generation of environmentally benign generation on the global scale.[70]

Solar power

In 1905, Albert Einstein published a paper explaining the photoelectric effect on a quantum basis.[71] Since then, technologies have been developing quickly. Generating solar power involves the conversion of sunlight into electrical charge, either directly or through concentrated solar power (CSP)[72], [73]. CSP can generate electricity without direct sunshine[74], rather requiring clear-sky solar radiation.[75]

As in the case of wind energy, research and development helped to bring down the price of solar power technologies, with the battery capacity to store solar energy improving so rapidly[76],[77]. It was calculated that, solar technology could potentially generate enough clean, renewable energy to provide a global supply of energy, provided land, sunlight, and legal permits[78],[79]. More recent discoveries and technological advancements have even enabled the first around-the-world solar flight[80]. Moreover, jobs in the sectors such as engineering, industrial machinery mechanics, welding, metal fabrication, electrical equipment assemblies, construction equipment operating, and construction management have actually resulted from development of solar technologies.[81] It becomes also evident that the plummeting prices for solar panels can also be beneficial to both the solar power developers and consumers. The energy generated by the sun and wind can be potentially appealing as aside from harnessing, storage and transfer technology, it is cost-free[82] as the production becomes more advanced and cost competitive.[83] Once a wind turbine or solar farm is set up, the marginal cost of it power output is almost zero[84]. It has been argued by the proponents that sunlight and wind are

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[60] The Economist 2015c

[61] Washington 2015.

[62] Braun 2012, p 14.

[63] Firestone & Kempton 2007, pp 1584-1598; Firestone et al. 2009, pp 183-202.

[64] Van Klaveren 2016.

[65] Van Klaveren 2016.

[66] Michaelowa 2000, pp 277-292.

[67] Levy and Egan 2003, pp 803-829.

[68] Bell et al. 2005, pp 460-477.

[69] Blanco and Rodrigues 2009, pp 2847-2857; Cleary and Kopicki 2009.

[70] Ibid.

[71] Pais 1982.

[72] Blair et al 2008.

[73] http://cordis.europa.eu/news/rcn/132388_en.html Accessed 1 May 2016.

[74] Pfenninger et al. 2014, pp 689-692.

[75] Boyde 2014.

[76] Divya and Østergaard 2009, pp 511-520; Teleke et al. 2010, pp 787-794.

[77] Nemet 2006, pp 3218-3232.

[78] Diesendorf 2014.

[79] London 2012.

[80] http://www.solar-flight.com 'Solar Flight' Accessed 13 June2017.

[81] Cleary and Kopicki 2009.

[82] Kopnina and Blewitt 2014.

[83] Kopnina and Blewitt 2014; Kopnina and Shoreman-Ouimet 2015.

[84] The Economist 2015c.

waste-free[85] as they avoid depletion of resources[86] and safe[87], as their use does not include potentially hazardous by-products, as nuclear energy does.[88] Thus, proponents of long-term sustainability have argued against compromises in energy mix and for strict reliance on wind and solar energy.[89]
However, there are still some considerable obstacles to the global use of solar energy. First of all, the demand did not keep pace with increasing supply, partially due to competition from other type of energy sources.[90] There are also significant political and ideological barriers to the use of solar power[91], with fossil fuel lobbies cleverly placing public and media attacks against measures that would restrict their operations.[92]

The business of subversion

Prior to the EU Treaty of Lisbon[93] in 2007, EU energy legislation was based on the EU's authority in the area of the common market and environment. The Treaty of Lisbon involved member countries' solidarity in matters of energy supply and changes to the energy policy. In practice, individual European countries still decide on their energy mix.[94] In Britain, Luxembourg, Malta and the Netherlands got less than 5 percent from green sources.[95] Solar energy now satisfies about 2% of the demand in the EU[96], while supply has grown many-fold in the last few years due to Chinese and American production[97]. Biomass appears to be a source favoured by environmental and energy ministries in Europe[98], with some of supply coming from American and Canadian forests that are cut to create wood pellets.[99]
Cultivation of biofuels often moves to natural land such as forests or grasslands[100]. Yet, the effects of this include the loss of biodiversity[101], deforestation and the actual net increase of emissions[102] in Europe and beyond. Applying the C2C and CE frameworks, it is clear that the burning of biomass is a 'cradle to grave' process, with energy generation similar to down-cycling, in which valuable materials are 'reworked' for a less valuable (and in this case, briefly lasting) product.
Non-renewables are limited in terms of their permanent availability and ability to 'earn back' technology investment harnessing and storing their power[103]. By strict definition, the only truly renewable sources of energy are sun, water (tidal waves), geo-thermal and wind.
Yet, closed-loop frameworks can be subverted to the business-as-usual practices. The Ellen MacArthur Foundation website[104] that places some businesses on the 'best case study' list of circular economy is replete with companies that focus on conventional business-as-usual sustainability[105]. The companies report their efforts at minimising damage, recycling (thus downcycling) and eco-efficiency in parts of

[85] McDonough and Braungart 2002.
[86] Washington 2015.
[87] Delucchi and Jacobson 2011, pp 1154-1169.
[88] Barthelmie and Pryor 2014, pp 684-688; Diesendorf 2014.
[89] Daly 1991; Washington 2015.
[90] Wang 2012.
[91] Geels 2014
[92] Adger et al. 2009, 93:335-354.
[93] Ibid.
[94] Ibid.
[95] Lewis 2015.
[96] EPIA 2016 http://www.epia.org/news/publications/global-market-outlook-for-photovoltaics-until-2016 'Global market outlook photovoltaics' Accessed 13 June 2017.
[97] Vaughan 2017.
[98] EC http://ec.europa.eu/energy/en/topics/renewable-energy/ biomass 'Biomass' 17 May 2016.
[99] The Economist 2013.
[100] EC http://ec.europa.eu/energy/en/topics/renewable-energy/biofuels 'Biofuels' Accessed 17 May 2017.
[101] https://www.nature.com/nature/journal/v405/n6783/full/405234a0.html
[102] Walsh 2014; Steer and Hanson 2015.
[103] WEF 2013
[104] https://www.ellenmacarthurfoundation.org/
[105] https://www.ellenmacarthurfoundation.org/ce100/directory/the-coca-cola-company

their operations, without revising the entire business models and supply chains. Circular economy is still advertised as a 'new engine of growth', rather than promoting fundamental change. Thus, optimistic 'simple and easy' approaches or compromises such as energy mix need to be treated with caution.

The Roadmap to Circular Economy formulated by the European Commission seems to be narrowly focused on economic growth, sustainable development[106] and 'sustainable and inclusive economic growth'[107]. The recent European energy strategy referred to in the Introduction of this article is replete with 'economic growth' objectives[108]. Often, the terms used in the so-called 'best case' examples placed on MacArthur Foundation's website include the terms describing practices of the good old efficiency and recycling (and not infinite reuse)[109], suggesting, regrettably, green-washing.

Another risk of subversion comes from over-reliance on monumental technological projects to solve climate change, and in the process abandoning the common-sense solutions offered by infinitely reusable energy of wind and sun. An example of this subversion is the Economist's article[110] in the Special issue titled 'Clear thinking on climate change'. The editorial states:

> *Paying for yet more wind turbines and solar panels is less wise than paying for research into the technologies that will replace them. Mankind will also have to think much more boldly... It will have to adapt, in part by growing crops that can tolerate heat and extreme weather, in part by abandoning the worst-affected places. Animals and plants will need help, including transporting them across national and even continental boundaries. More research is required on deliberately engineering the Earth's atmosphere in order to cool the planet.*

It is not entirely clear how humanity is going to engage in such planetary ambitious project, undertaking the Noah's monumental effort to move all species into safety (and what region will be safe?). C2C and CE do not require such apocalyptic (and very possibly dangerous) scenarios. While C2C and CE production systems still has a long way to go in practice, these systems can potentially reach beyond business-as-usual. This can imply that producers and consumers need to draw examples from pre-industrial design. Alternatively, and perhaps more appealingly to those averse to 'retrogressive' products, such production system can be innovative. In fact, a combination of 'ancient' natural materials, such as sun, water and wind, and modern technologies such as photovoltaic panels or wind turbines, illustrate how energy supply can be made sustainable.

In the case of biofuel, the material input (e.g. vegetable matter or garbage) and outputs created from the production process all present reasons for concern. Presently, considering different renewable energy options that are available on the European policy making table[111], the policy choices do not seem to be guided by understanding of transformative sustainability frameworks. Citing the case of biofuels, the authors of C2C describe that the 'typical response to industrial destruction has been to find a less bad approach'[112], particularly as regards those

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[106] EC http://ec.europa.eu/smart-regulation/impact/planned_ia/docs/2015_env_065_env+_032_circular_economy_en.pdf 'Circular economy' Accessed 17 May 2017.

[107] EC http://ec.europa.eu/environment/ecoap/about-eco-innovation/good-practices/eu/575_en.htm 'Eco-innovation at the heart of European policies' Accessed 17 May 2017.

[108] http://europa.eu/rapid/press-release_IP-16-4009_en.htm Accessed 13 June 2017.

[109] EC http://ec.europa.eu/environment/circular-economy/index_en.htm 'Circular economy' Accessed 17 May 2017.

[110] The Economist 2015b, p. 5.

[111] https://ec.europa.eu/energy/sites/ener/files/documents/1_en_act_part1_v7_1.pdf Accessed 17 May 2017.

[112] McDonough and Braungart 2002: 45

produced by burning trees or garbage[113]. The authors of the Cradle to Cradle book and model have asserted that while the garbage incineration may seem 'green', it is only one step removed from the so-called cradle–to-grave model in which the "Waste to Energy" paradigm fails to consider the high nutrient value of waste.[114] Most significantly, burning mixed garbage that contains valuable biological and technological materials literally makes valuable resources go up in smoke for a short spurt of energy:

> *Through incineration, we are throwing away exhaustible raw materials, along with the energy needed to mine natural resources and manufacture them into consumable products. With this approach, not only do we lose valuable nutrients, we also create an aggressive disincentive for materials' reuse*.[115]

Moreover, incinerators must keep being fed garbage for many years to be economical, removing incentives to reuse or recycle materials, or to terminate production of waste substances and toxic materials in the first place[116]. Through the creation of an 'eco-efficient' material, the destructive production process or material is only being slowed down, not halted completely.

Conclusions

If the EU is to revisit the *Limits to Growth*,[117] transformation based on C2C/CE principles needs to be considered, with political leaders taking decisive action on environmental problems associated with energy use[118]. The American inventor Thomas A. Edison[119] asserted many years ago: "I'd put my money on the sun and solar energy. What a source of power! I hope we don't have to wait until oil and coal run out before we tackle that". Will the EU follow this advice? Future projections support this hope as it is predicted that the price of solar power will continue to fall[120], until it becomes one of the cheapest form of energy. Increasing technical advances lead to the better affordability of wind[121] and solar power[122], [123].

An appropriate decarbonisation of the energy system must involve the three main sectors of heat, electricity and transport. Different renewable sources are differently suitable for each of the sectors, which sometimes overlap, and are sometimes distinct. Renewable electricity resources are often supported by solar and wind, with sources for renewable heat often relying on biomass, and renewable energy use in transport (biofuels). A technological as well as social and economic transition is needed for the transition to Cradle to Cradle and circular economy in energy.

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