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The effect of additive manufacturing on global energy demand: An assessment using a bottom-up approach

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ABSTRACT

The effect of disruptive technologies unrelated to the energy sector, such as additive manufacturing (AM), tends to be overlooked in energy scenarios. The present research assessed the potential effect of AM on the global energy demand in four energy scenarios for 2050 with extended versus limited globalisation and limited versus extensive adoption of AM. These scenarios were developed and applied for two cases, namely the aerospace sector and the construction sector, analysing the effect of AM on each phase in the value chain. In the aerospace sector, energy savings of 5–25% can be made, with the largest effect in the use phase because of weight reduction. In the construction sector, energy savings of 4–21% are achievable, with the largest effects in the feedstock, transport and use phases. Extrapolated to the global energy demand in 2050, a reduction of 26–138 EJ/yr, equivalent to 5–27% of global demand is achievable. It is recommended that energy policymakers should consider integrating AM and other disruptive technologies, such as robotics and the Internet of Things, into their long-term energy planning, policies and programmes, including Nationally Determined Contributions under the Paris Agreement on climate change.

1. Introduction

1.1. Disruptive technologies and future energy demand

The future of energy is widely studied and discussed in business, academia and politics, and scenario building is often used in these studies and discussions. However, the effect of emerging technologies – such as additive manufacturing (AM), big data, robotics, the Internet of Things and autonomous driving – on the future energy consumption is often overlooked. Even long-term energy scenarios and normative visions are usually based on familiar technologies, directly related to the energy industry. This gap may result in energy policymakers stimulating only traditional sectors rather than also looking at adjacent areas of innovation that can be extremely effective in reducing energy demand while matching important co-benefits (Nagji and Tuff, 2012).

In an effort to close this gap, this article presents a bottom-up assessment of the potential effect of one such disruptive technology, namely AM, on the global energy demand in 2050. AM was chosen because it is disruptive and paradigm changing for manufacturing, logistics, product design, intellectual property, local production and mass customisation.

1.2. Additive manufacturing

Additive manufacturing, popularly known as 3D printing, is the process of building objects bottom-up, one layer at a time. AM is an umbrella term for a group of technologies (Cotteleer, 2014). Table 1 and Fig. 1 present overviews of AM processes along with the related technologies and the materials used. As can be seen, the range of techniques and materials is extensive. Traditional subtractive manufacturing techniques build objects by cutting or machining raw materials into the desired shape, after which several objects are assembled to form the final product. Other mass production techniques, such as injection moulding and metal stamping, produce less waste but require large production volumes.

3D printing involves three essential phases (Campbell et al., 2011). First, a digital 3D model is designed and converted into a standard AM format file. Second, this file is sent to the 3D printer, where it is

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Table 1
Overview of additive manufacturing processes, the materials used and the technologies involved (Manyika et al., 2013; DOE, 2015).

AM process type	Brief description	Materials used	Technologies
Powder bed fusion	Thermal energy selectively fuses regions of a powder bed	Metals, polymers	Electron beam melting (EBM), selective laser sintering (SLS), selective heat sintering (SHS), direct metal laser sintering (DMLS)
Directed energy deposition	Focused thermal energy is used to fuse materials by melting as the material is being deposited	Metals	Laser metal deposition (LMD)
Material extrusion	Material is selectively dispensed through a nozzle or orifice	Polymers	Fused deposition modelling (FDM)
Vat photo polymerisation	Liquid photopolymer in a vat is selectively cured by light-activated polymerisation	Photopolymers	Stereolithography, digital light processing (DLP)
Binder jetting	A liquid bonding agent is selectively deposited to join powder materials	Polymers, foundry sand, metals	Powder bed and inkjet head (PBIH), plaster-based 3D printing (PP)
Material jetting	Droplets of build material are selectively deposited	Polymers, waxes	Multi-jet modelling (MJM)
Sheet lamination	Sheets of material are bonded to form an object	Paper, metals	Laminated object manufacturing (LOM), ultrasonic consolidation (UC)
Inkjet-bioprinting	A nozzle deposits tiny dots of a combination of scaffolding material (e.g. hydrogel) and living cells	Biomaterials, human cells	Inkjet-bioprinting

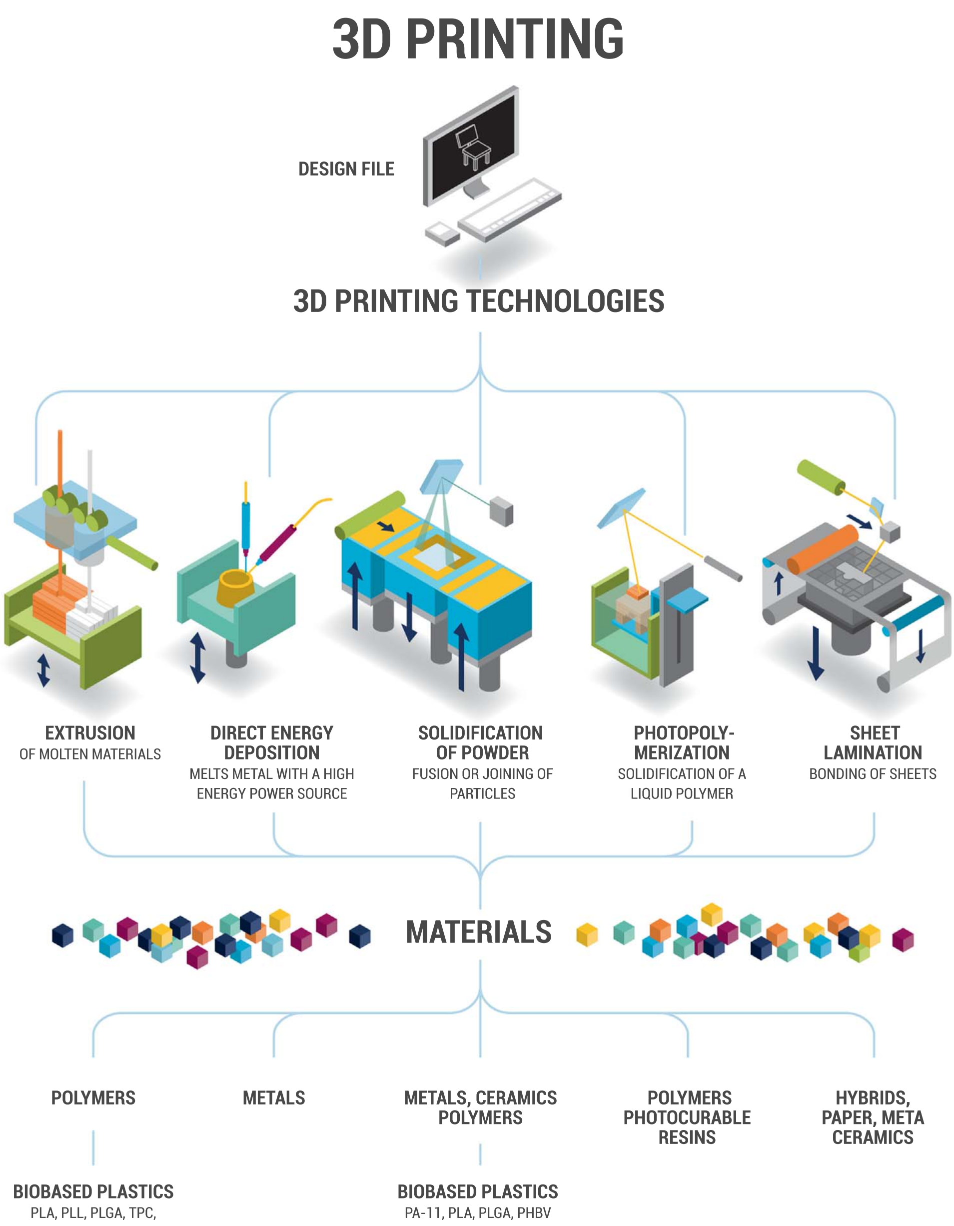

Fig. 1. Overview of additive manufacturing (*3D Printing*) technologies and the materials used, displaying the wide range of techniques and materials.