3D Printing in Environmental and Logistical Contexts

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3D Printing: Logistics and Sustainability

- Logistics includes manufacture, storage, shipping...
- Logistics is data intensive, risk-vulnerable and global
- Freight movement is growing rapidly (~double by 2030)
- Delivery components (small vehicles) at double that
- Environmental impacts : transport, production, waste..
- So what can Additive Manufacturing "3D printing" add?
  - Locally (e.g. household focused)
  - Regionally (e.g. relocalised manufacture/warehouses)
  - Globally (e.g. supply chain restructuring)
  - Out of this world (ISS, AMAZE, lunar construction)

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Start at home – today

***"What they found was a stark contrast between buying complete goods and making them at home: It would cost a consumer from $312 to $1944 to purchase the 20 items online compared to $18 to print them over the course of a weekend"* (Wittbrodt et al 2013)**

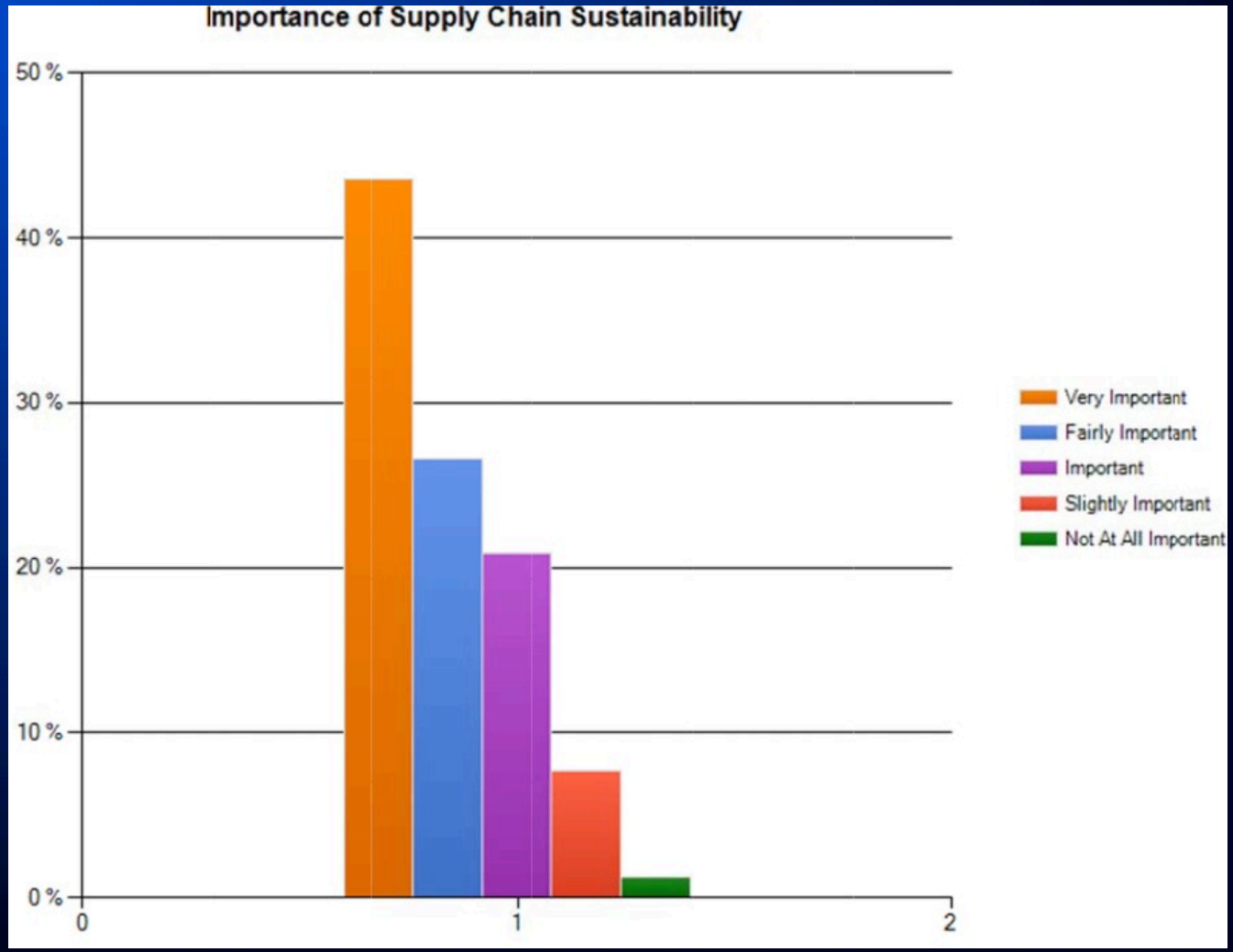
What is missing in this careful US study of *real home items V web sourcing* using a minimal home 3D printer?

All

of the travel, shipping costs, and environmental impacts

B.T. Wittbrodt[a], A.G. Glover[a], J. Laureto[a], G.C. Anzalone[b], D. Oppliger[c], J.L. Irwin[d], J.M. Pearce (2013) Life-cycle economic analysis of distributed manufacturing with open-source 3-D printers, Mechatronics Volume 23, Issue 6, September Pages 713–726

What does the Supply Chain Industry think?



eyefortransport.co.uk. *Global Chief Supply Chain Officer Strategy Report: A Brief Analysis of Eyefortransport's Recent Survey. 2013.*

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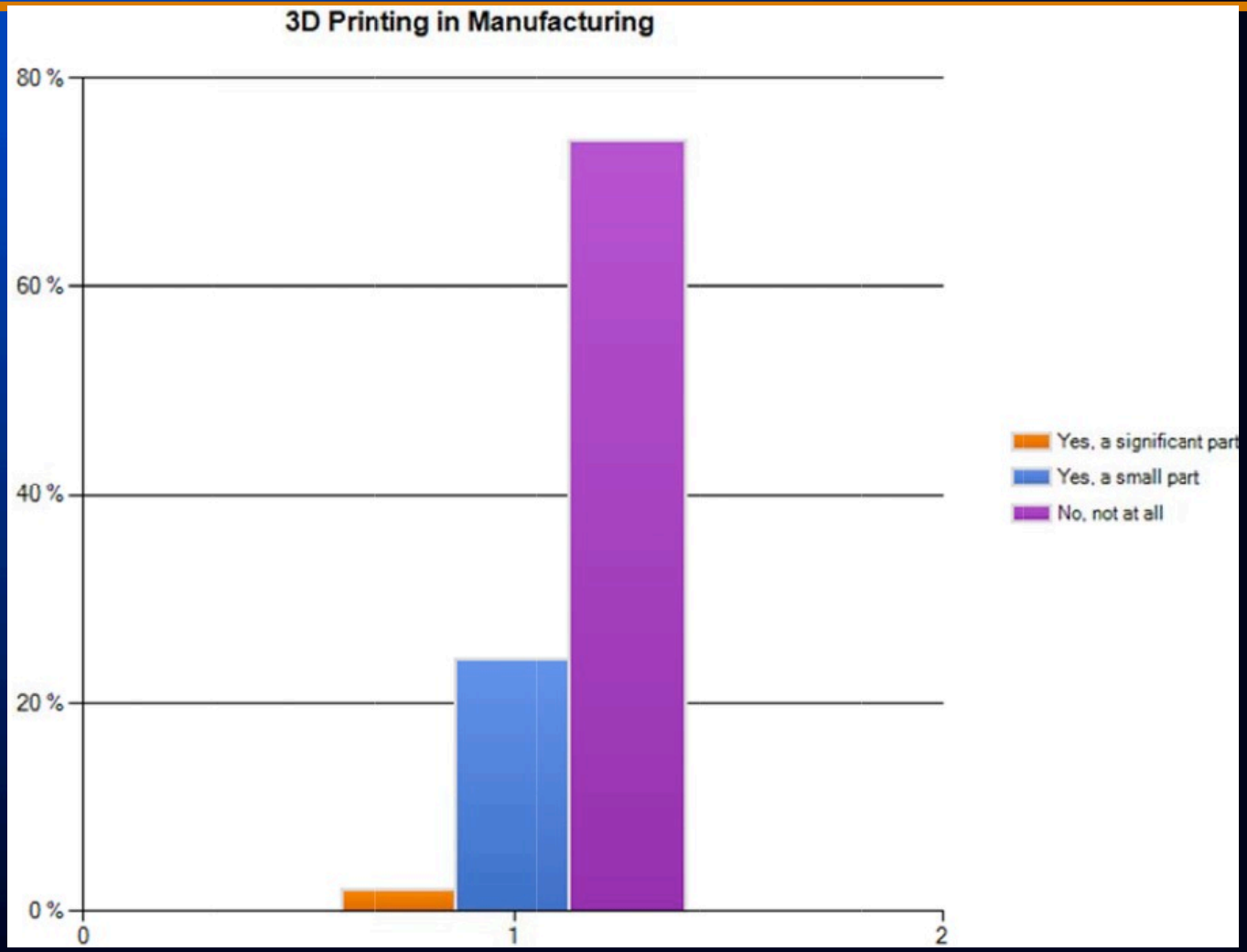
And about 3D printing contributions? (In 2011)



eyefortransport.co.uk. *Global Chief Supply Chain Officer Strategy Report: A Brief Analysis of Eyefortransport's Recent Survey. 2013.*

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A few relevant numbers

- **At the micro scale, 3D printing using plastics can show lifecycle energy costs reductions of 42-74%**

  (Krieger, M, and J.M Pearce. "Environmental Life Cycle Analysis of Distributed Three-Dimensional Printing and Conventional Manufacturing of Polymer Products." *ACS Sustainable Chem. Eng 1, no. 12 (2013): 1511-1519).*

- **At the macro scale, logistics (transport administration warehousing in the main) represents 6-10% of the GDP of western nations. So tiny gains will be large!**

  (Rantasila, K, and L Ojala. *Measurement of National-Level Logistics Costs and Performance. Paris: OECD: International Transport Forum, 2012. Discussion Paper 2012-4).*

- **Most industry views are that mass 3D printing "will take another 10-15 years to make major inroads".**

- **NB This does not really consider household level Open Source activities...**

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Lets not get ahead of ourselves

- While small scale 3D items are already economic for households (and will save much travel...)
- They are a tiny issue at present
- Just like 1980 MicroComputers and 1984 Laser printers were - but still economic against traditional printing then
- 3D printing will reduce travel, reduce waste and thereby contribute to sustainability even now
- But mass customisation and small scale manufacture is built in once metal becomes economic
- This will help spare parts, stock holding and other non obvious resource savings in the logistics chain
- But- 2020 before 30% of manufactures use a 3d element

What industries look vulnerable? Δ 2010->13

Table 1: Potential for 3D printing disruption in each manufacturing subsector

Subsector	SIC code	Total Gross Value Added, £billions (2010)	Potential for disruption from 3D printing
Food, drink and tobacco	10 - 12	25	Unlikely to move wholly to 3D printing, although some components (including packaging) may be 3D printed within supply chains.
Textiles, clothing and leather	13 – 15	4.5	Likely to be heavily disrupted by 3D printing, with design, logistics and retail processes potentially transformed.
Wood and paper	16 – 17	4.8	3D printing penetration will depend on ability to process different materials.
Printing and recording	18	7.1	Printing and recording have already been hugely disrupted by shift to digital content; this is likely to be far more significant than 3D printing, as digital media dominate physical media.
Refined fuels	19	2.2	Unlikely to be significantly affected by 3D printing.
Chemicals	20	11.7	Some parts of the industry may be affected by shift to 3D printing, but complexity of chemical technologies likely to make 3D printing slow to disrupt.
Pharmaceuticals	21	11.9	Significant potential for on-demand manufacture of drugs in hospitals, although much will depend on technology.

Our Comments

Logistics vulnerability in 2013

Printed foods already here

Yes- already visible

Both are already here

Yes, but the digital transmission IP remains an issue

Yes

Just starting

Just starting

Sissons, A, and S Thompson. *Three Dimensional Policy: Why Britain Needs a Policy Framework for 3d Printing. Big Innovation Centre (The Work Foundation and Lancaster University), 2012. (a 2010 analysis)*

Continued…

Rubber and plastics	22	5	High likelihood of disruption, especially for bespoke shaped plastics. Plastics are also likely to be the key material for 3D printing, which may prompt innovation in development of plastics.
Metals and building materials	23 – 25	22.9	Potential for significant disruption from 3D printing. However, 3D printing may not provide the scale of production required for some industrial and construction processes.
Computers, electronics and electrical equipment	26 – 27	13.8	Some potential for disruption from 3D printing, although issues of assembly and precision may limit uptake.
Machinery	28	10.4	3D printing is likely to play a major role in providing bespoke and on-demand machinery.
Cars and other vehicles	29	5.6	3D printing is unlikely to remove assembly lines or end mass production, but may play a role in manufacture of components.
Ships and aerospace	30.1 and 30.3	5.6	Large scale building projects make 3D printing unlikely, although may be involved in the supply chain.
Furniture	31	3.5	3D printing should play a major role in re-shaping furniture markets, with designs and logistics heavily disrupted.
Other manufacturing	32 and rest of 30	4.2	Other manufacturing includes a range of low-tech, bespoke manufactures such as toys; these are likely to be one of the earliest markets for 3D printing.

Source: GVA data from ONS Supply and Use Tables, 2010. Commentary based on authors' assessment.

2013: Home Production

Buildings now printing

Some beginnings

Parts yes..

Parts and bodies...

Off Planet under way

Slow to start

Well under way

Sissons, A, and S Thompson. *Three Dimensional Policy: Why Britain Needs a Policy Framework for 3d Printing. Big Innovation Centre (The Work Foundation and Lancaster University), 2012. (a 2010 analysis)*

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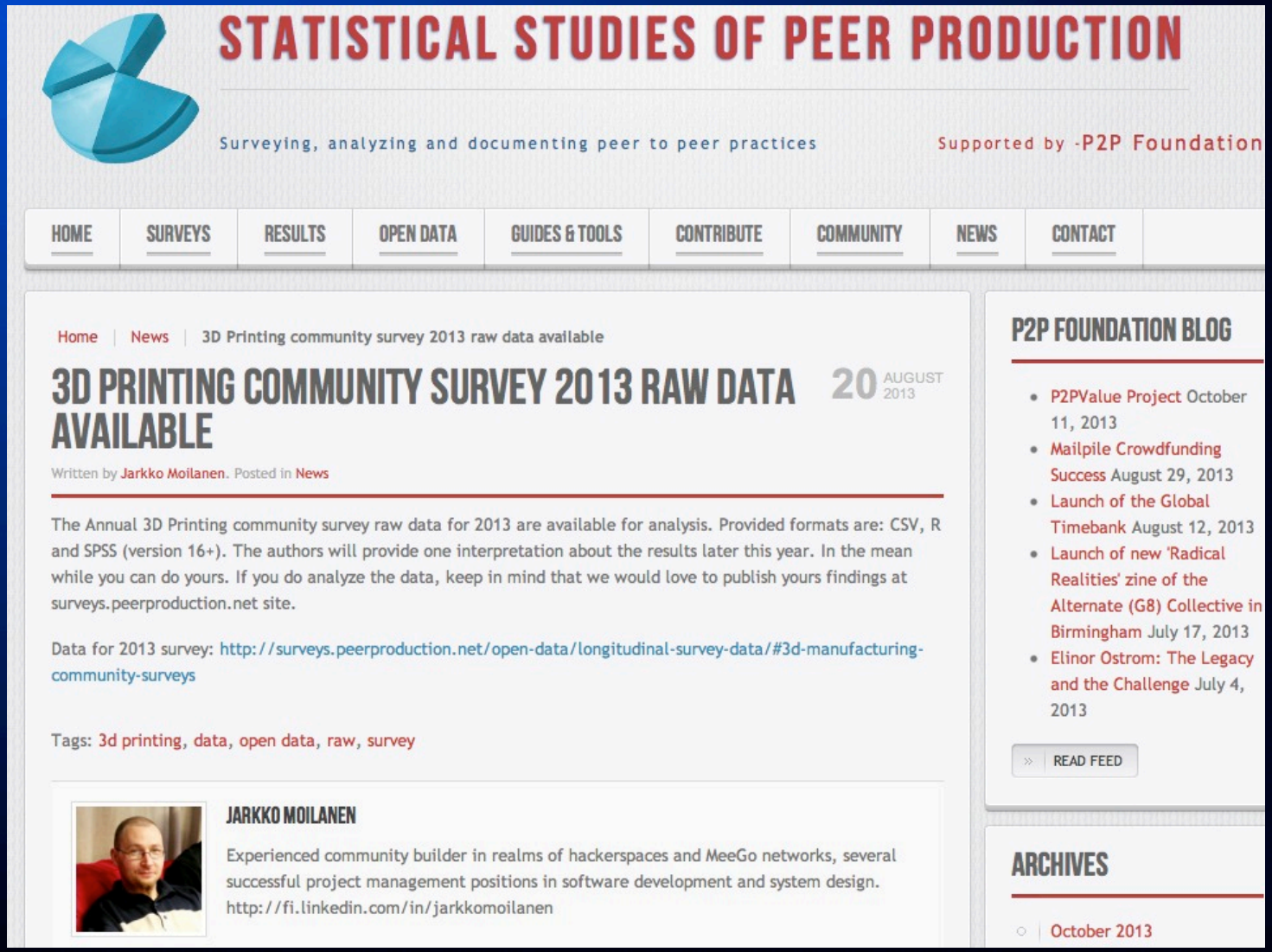
Explore peer developments yourselves: Open data



http://surveys.peerproduction.net/?s=longitudinal includes earlier data years

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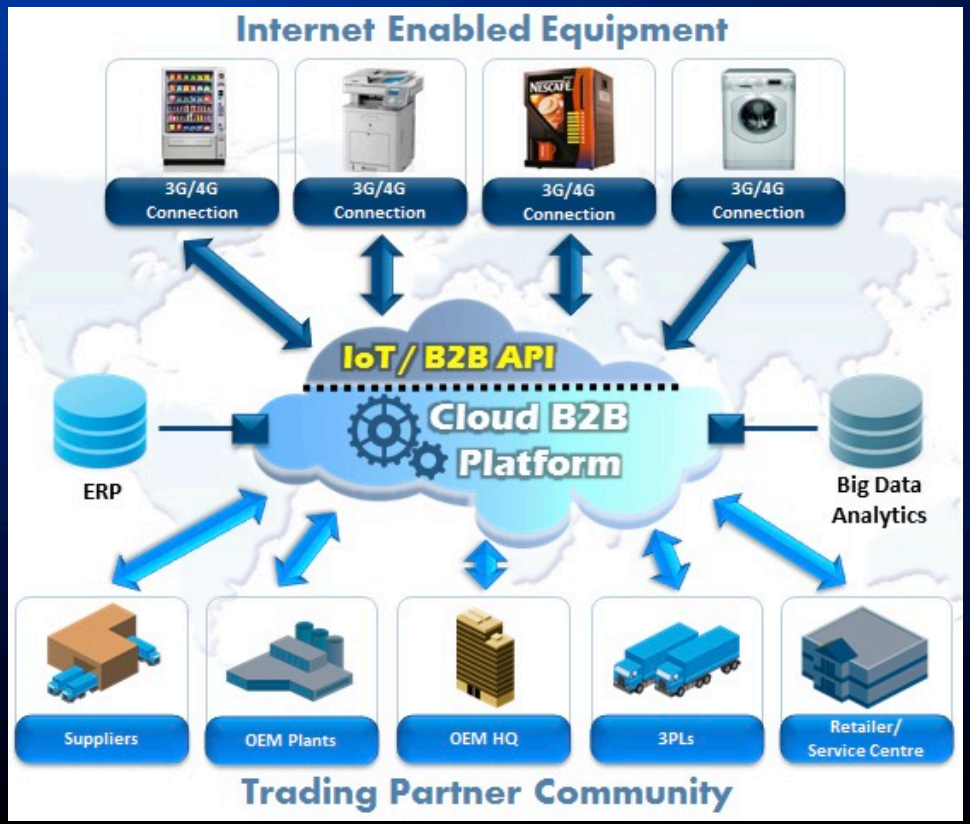
Logistics is integrated into manufacture... So..

- **Direct retail, distribution, Internet of Things (IoT) .. Is Zero steps away from 3D printing of parts for maintenance requirements etc. Missing in this very conventional IoT picture are direct links to 3D printing**



http://www.gxsblogs.com/morleym/2013/10/how-the-internet-of-things-will-impact-b2b-and-global-supply-chains.html

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Low Earth Orbit applications today: a Zero Length Supply Chain with minimal environmental impacts

Prototype 3D printer passes its microgravity field tests – and is well on its way for its ISS deployment in 2014

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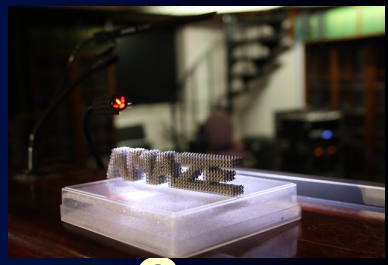
Taking 3d printing to the mass space market

- **AMAZE project – Additive Manufacturing Aiming Towards Zero Waste and Efficient Production of High-Tech Metal Products**
- **ESA is committed to complex printed parts made of metal that can withstand temperatures up to 3500C° – fit for space and the most demanding Earth applications**
- **AMAZE began in January 2013**



- **Factory sites are now being set up in France, Germany, Italy, Norway and the UK to develop a full industrial supply chain with production, metrology, QA.....**
- **Aimed at the first 3D metal printer for the ISS**

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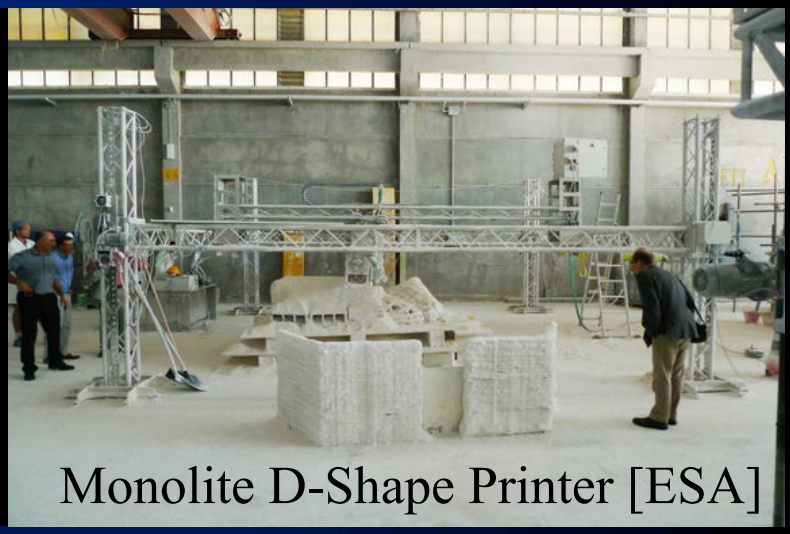
The largest environmental logistics overheads....

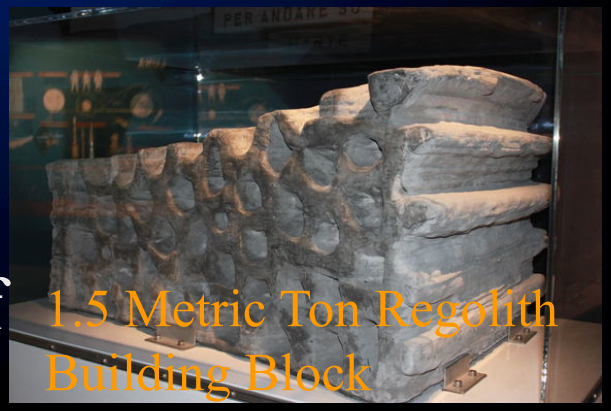
The South Pole of the Moon, where ESA studied robotic 3D printed buildings from lunar regolith now. Regolith emulation construction trials have worked well..

Mosaic of the Lunar South Pole



Monolite D-Shape Printer [ESA]

Space X estimates $3000USD/Kg to Low Earth Orbit, which is about $15000USD/Kg to the Lunar Surface/ Plus environmental costs of rocket fuel exhaust gases



1.5 Metric Ton Regolith Building Block

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And so?

- **Expect lower costs, wider access and easier use of simple 3D in the home**
- **Expect home production and personal sustainability gains very soon – some even now**
- **Expect and demand more mass customisation before seeing transformed supply chains**
- **Expect massive logistics sustainability gains in Space soon**
- **Hope for lower cost and easier access to spare parts of obsolete consumer items**
- **Pray for no new IP-vice to lock down access to the emerging innovations**