



# THE FUTURE OF THE BIOECONOMY

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LET'S START WITH SOME CAUTION

# Lots of promise...

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*“I truly believe that through synthetic biology **all petroleum-based products** can be produced from sugar-based microbes resulting in cleaner processes and slowing global warming.”*

**December 2013:** Jay Keasling the recipient of the 2013 George Washington Carver Award for innovation in industrial biotechnology





...but hardly any commercialisation

- 1,3-PDO, 1,4-BDO, 5-amino valerate, artemisinin



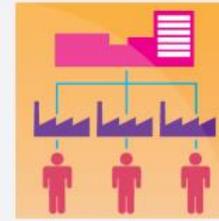
**Sep 30, 2016:** Inauguration of Mater-Biotech's plant in Bottrighe di Adria  
30,000 tonnes per year of 1,4-BDO



# SYNTHETIC BIOLOGY AND DISTRIBUTED MANUFACTURING



- Small-scale factories in many locations
- Replace as much of the material supply chain as possible with digital information
- More responsive supply chains
- Make locally, consume locally



## Distributed manufacturing

The factory of the future is online – and on your doorstep.

### 2020 vision

Potential to be mainstream in 5 years

5

### Disruptive force

Manufacturing

9

### Commercial clout

8

### Save the world?

Growth and jobs

3

### Risk factor\*

Employment, IP

5

Want to know more? Visit [wef.ch/futuretech](http://wef.ch/futuretech)



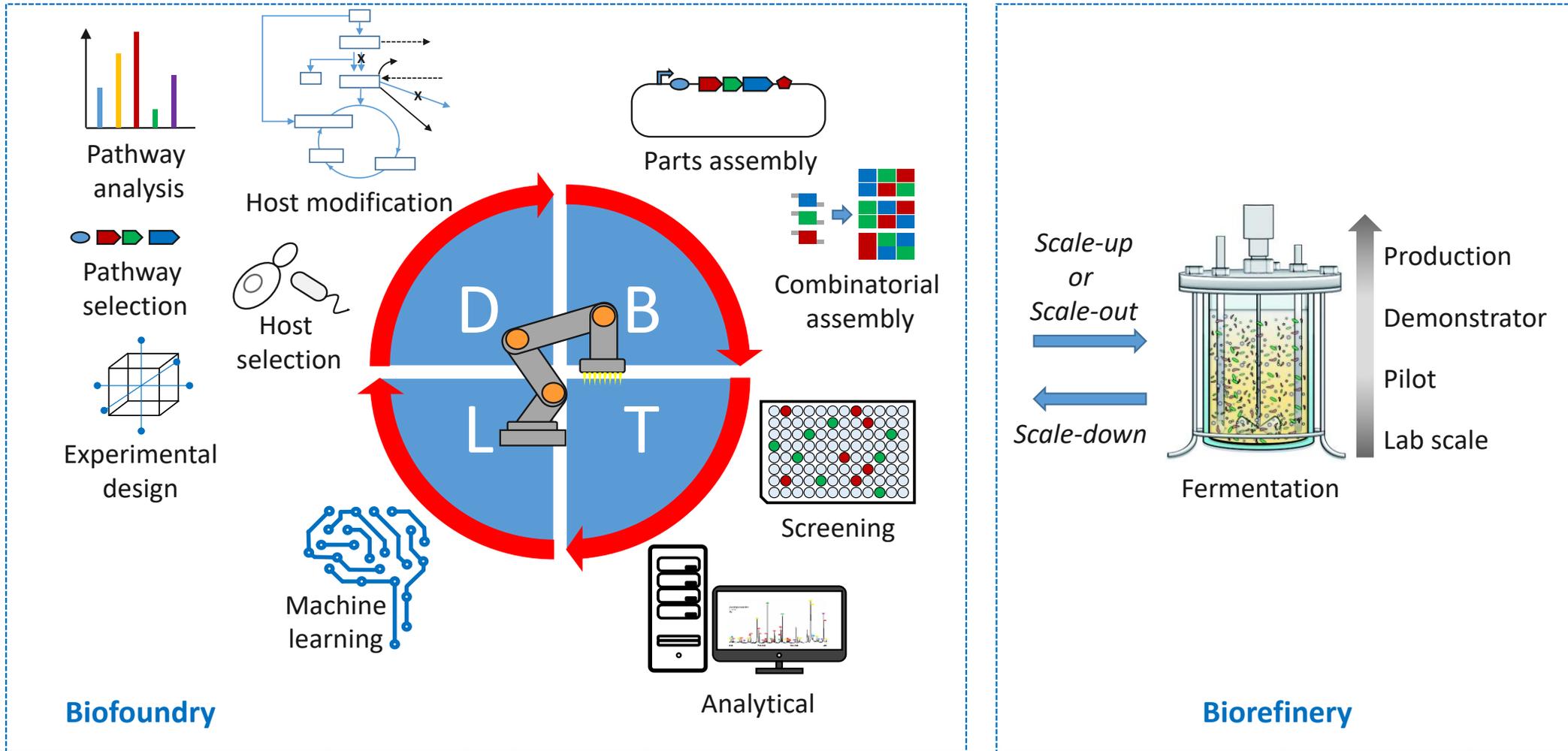
# HERE'S THE BIG BUT: Ludwigshafen integrated chemicals complex, Germany

- Employees: 39,000
- Buildings: 2000
- Production plants: 200
- How can small-scale production **compete on price** without policy intervention?





# Is the (public) biofoundry the missing link?





# Public biofoundries are concentrated in a small number of (elite) facilities

## Canada

- Concordia University

## United States

- Agile Biofoundry, CA
- DAMP Lab, MA
- (iBioFAB), IL
- MIT-Broad Foundry, MA

## Denmark

- Novo Nordisk Foundation Center for Biosustainability, Lyngby

## Germany

- CompuGene, Darmstadt

## France

- INRA, Toulouse

## Netherlands

- Delft University of Technology, Delft

## United Kingdom

- Earlham DNA Foundry, Norwich
- Edinburgh Genome Foundry, Edinburgh
- GeneMill, Liverpool
- London DNA Foundry, London
- SYNBIOCHEM, Manchester

## China

- BioFoundry, Tianjin
- TIB, Tianjin
- *Beijing Genome Institute, Beijing*
- *Shenzhen Core Facility for Synthetic Biology, Shenzhen*

## Japan

- Kobe University

## South Korea

- KAIST

## Singapore

- Synthetic Biology Foundry

## Australia

- *Australian Genome Foundry, Macquarie*
- *University of Queensland*



# CONVERGENCE WITH GREEN CHEMISTRY



# Wood-framed high-rise buildings

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*“We’re in an area where we have the resources, we have the forests, but we don’t fully have the solutions on how to transform this wood”*

Stéphane Sermadiras, Economic Development at *Bordeaux Euratlantique*



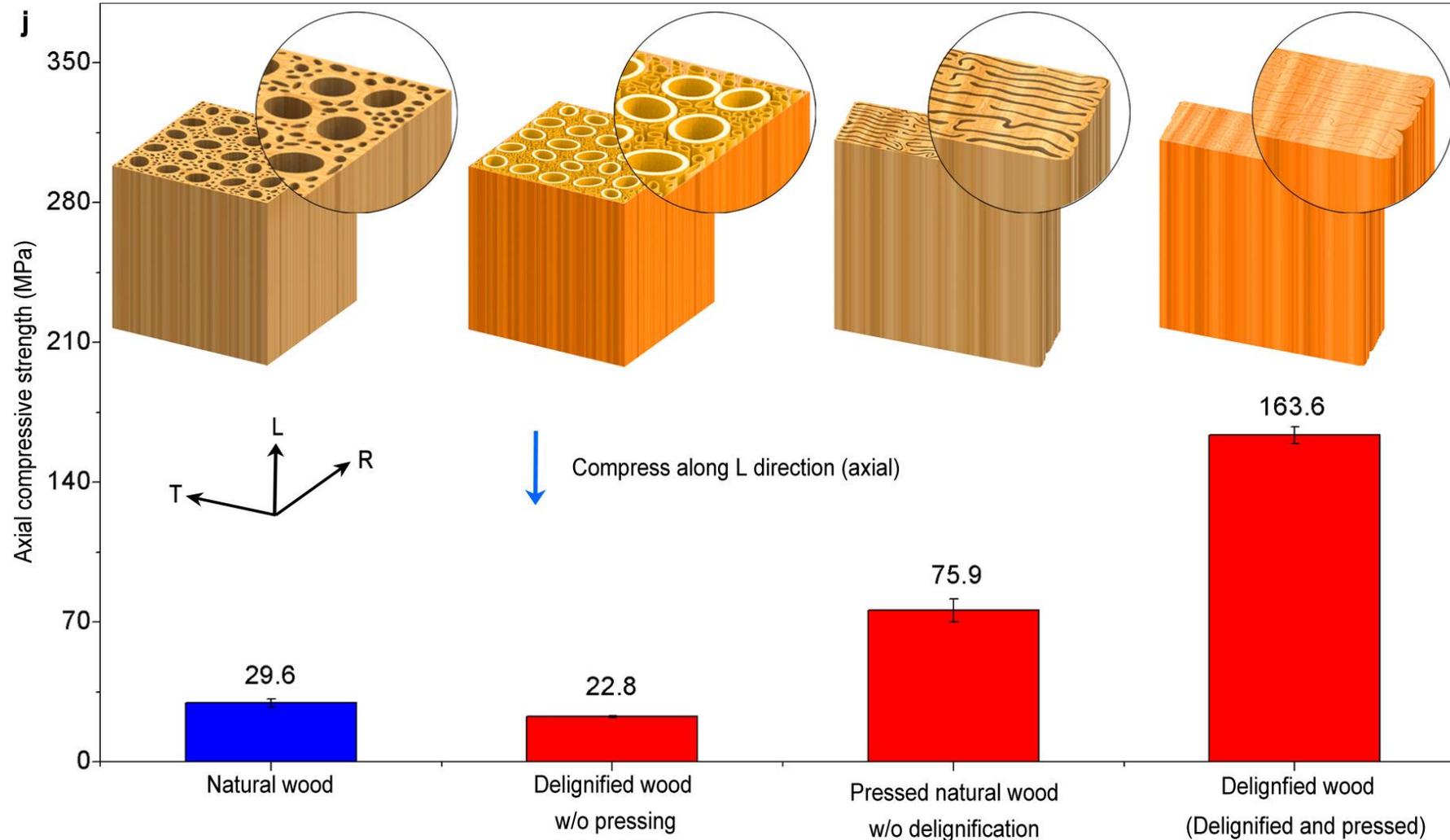
Tour Hypérion, Bordeaux, Jean-Paul Viguier et Associés

Why Timber Towers are on the Rise in France

<https://www.citylab.com/design/2017/10/why-timber-towers-are-on-the-rise-in-france/544098/>



# Processing bulk natural wood into a high-performance structural material





# Engineering biology and green chemistry

## Tiny membrane makes Sydney Harbour 'drinkable'

February 15, 2018 by Chris Still, [CSIRO](#)



Soybean oil to graphene

Seo et al. (2017). **Single-step** ambient-air synthesis of graphene from **renewable precursors** as electrochemical genosensor. *Nature Communications* 8:14217

September 12, 2018

## AMSILK ANNOUNCES PARTNERSHIP WITH AIRBUS TO DEVELOP THE NEXT GENERATION OF COMPOSITE FIBERS FOR LIGHTWEIGHT, HIGH-PERFORMANCE PLANES



*“We haven’t even begun to scratch the surface here. Ultimately, this material could enable us to approach design and construction in an entirely new fashion.”*  
- Detlev Konigorski, Airbus Innovation Manager for Emerging Technologies and Concepts



# FUTURE PROSPECTS AND CHALLENGES



# Perspectives and challenges for the future

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- By 2030: EU aims to provide 25% of transportation energy by 2<sup>nd</sup> gen. biofuels
- and to replace 30% of oil-based with bio-based chemicals
- An expectation of the launch of at least 15 advanced biorefineries by 2024 **1**
- 80% of EU bio-based infrastructure will be rural **1**
- **Rock bottom crude oil prices might tempt governments to reboot the economy with fossil**

## Chemicals industry

- UNEP foresees a “*chemicals intensification of the economies*” **2**
- Global chemical industry could triple in size by 2050 **3**
- **BUT: Sustainability will be a large barrier**

**1** Hassan et al (2019). *Trends in Biotechnology* 37, 231-234.

**2** United Nations Environment Programme (2013). Geneva.

**3** Cayuela (2015) *The Future of the Chemical Industry by 2050*.



- **Biodiscovery resources**

- Earth Biogenome project: “*Sequencing life for the future of life*”
- MIRRI-ERIC will comprise 41 microbial Biological Resource Centres (mBRCs) from 10 different European countries

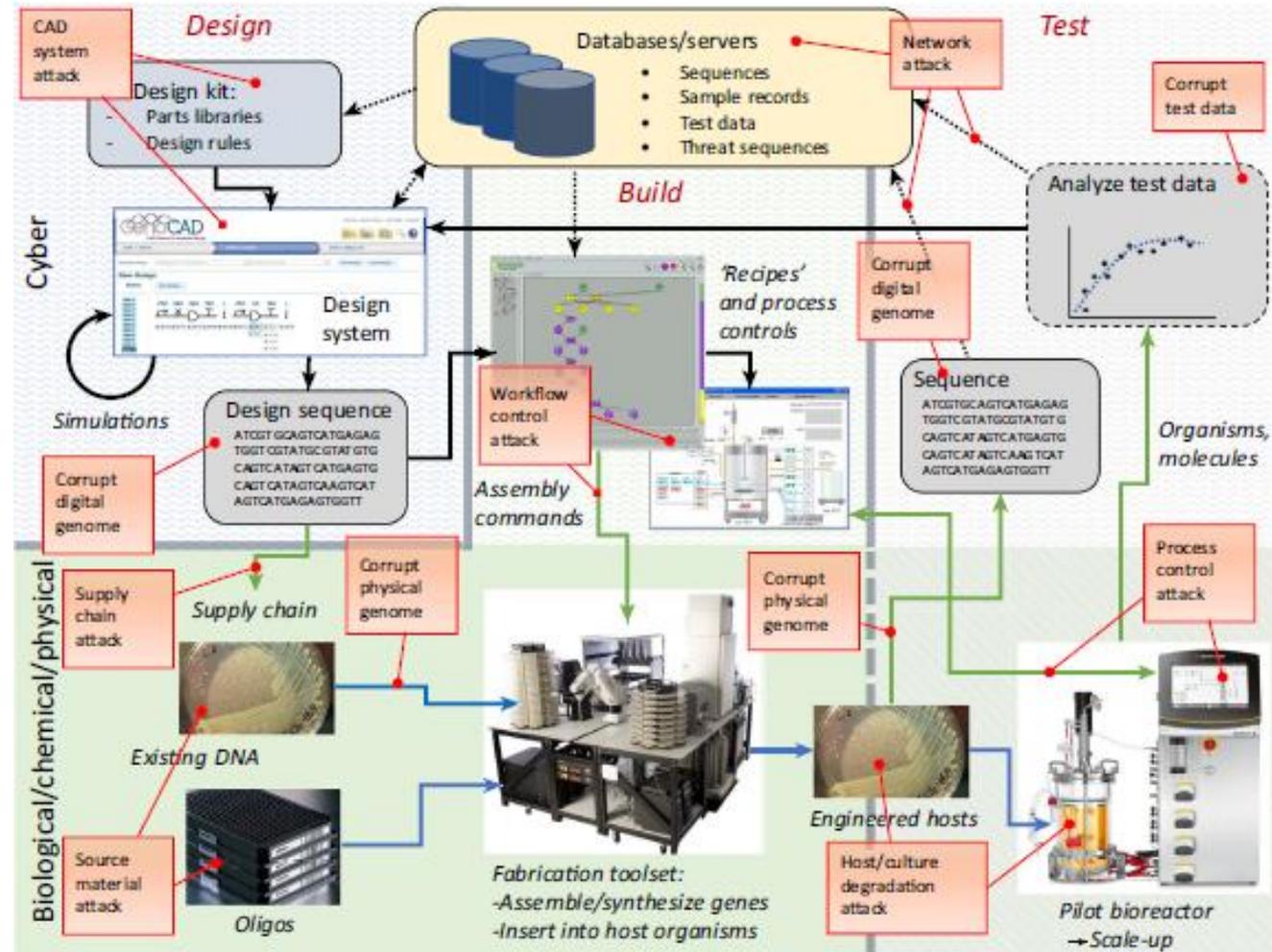
- Acceleration of machine learning, increasing automation of the DBTL cycle
- Decrease in cost of DNA synthesis
- **Information storage in DNA**



# Future challenge: Cybersecurity, a growing concern in an increasingly convergent synthetic biology

Green arrows: the cyber-bio interface

Red boxes: points of attack in the *cyberspace*, the *physical space*, and at the *interface* between cyberspace and physical space.



Either:

- **Forget** sustainability and make bioeconomy a market competition with fossil

Or:

- **Define** sustainability, **measure** it and **measure the bioeconomy**
- *“For politicians, the fundamental justification for public intervention in the bioeconomy is increased sustainability.”*

Marvik and Philp (2020). *EMBO Reports* (in press).

## Define biomass sustainability

The future of the bioeconomy requires global agreement on metrics and the creation of a dispute resolution centre, say **Roeland Bosch**, **Mattheüs van de Pol** and **Jim Philp**.



Bosch et al. (2015). *Nature* 523, 526-527.

 Thank you for your time

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