



# Digitalization of biology for a circular economy

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University of Tartu, Estonia



**Estonian Centre  
for Biosustainability**



**Eesti  
Rohetehnoloogiate  
Keskus**

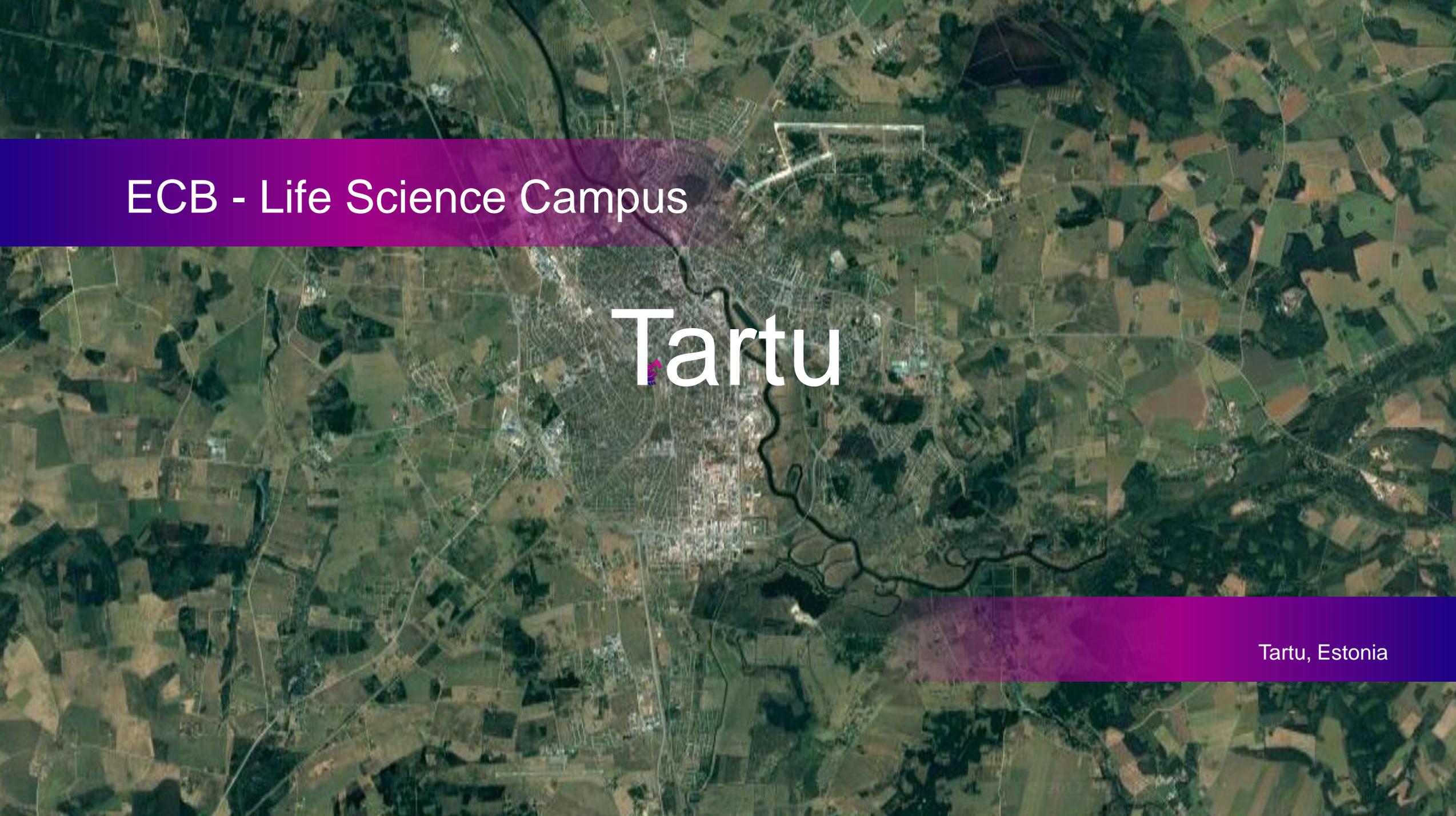


ECB - Life Science Campus

# Estonia

Tartu

Estonia

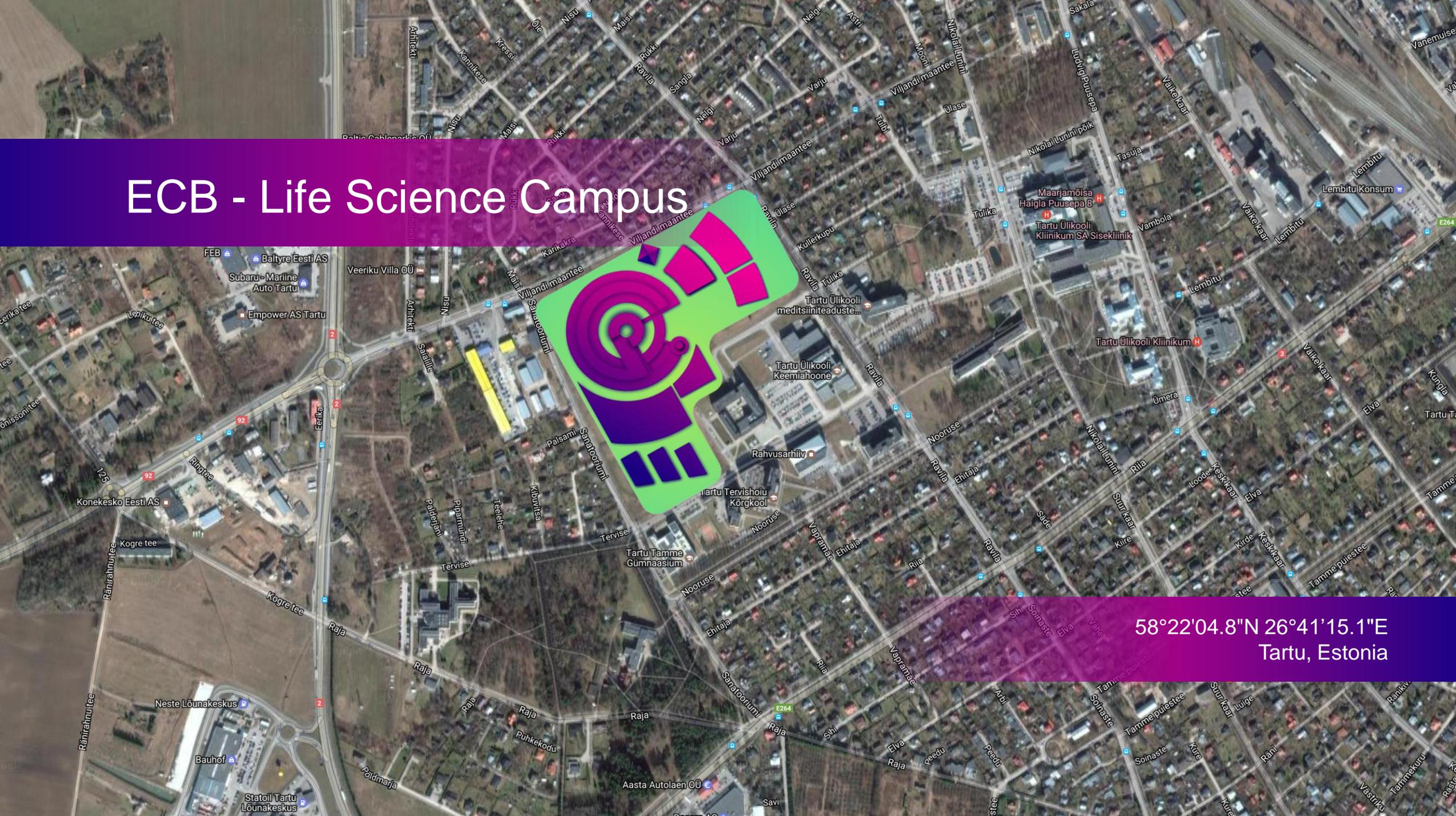


ECB - Life Science Campus

Tartu

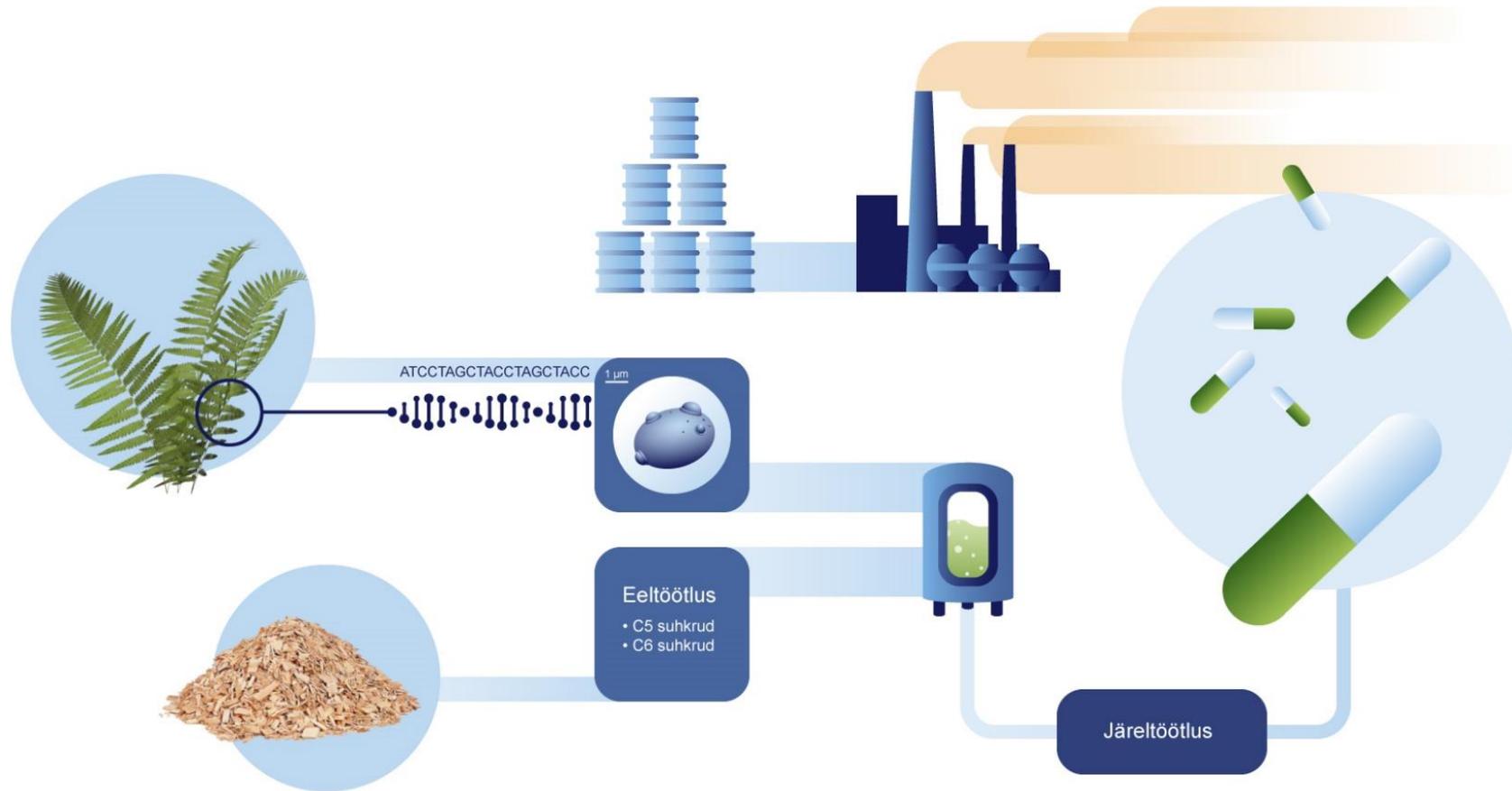
Tartu, Estonia

# ECB - Life Science Campus



58°22'04.8"N 26°41'15.1"E  
Tartu, Estonia

# Traditional oil-(shale) based industry

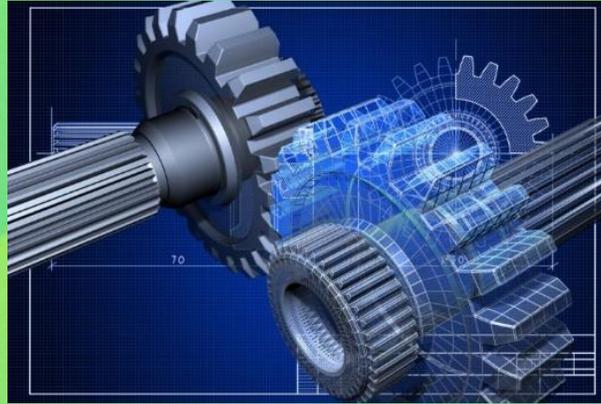


Bio-based industry (e.g. wood sugar valorization)



Biology

+

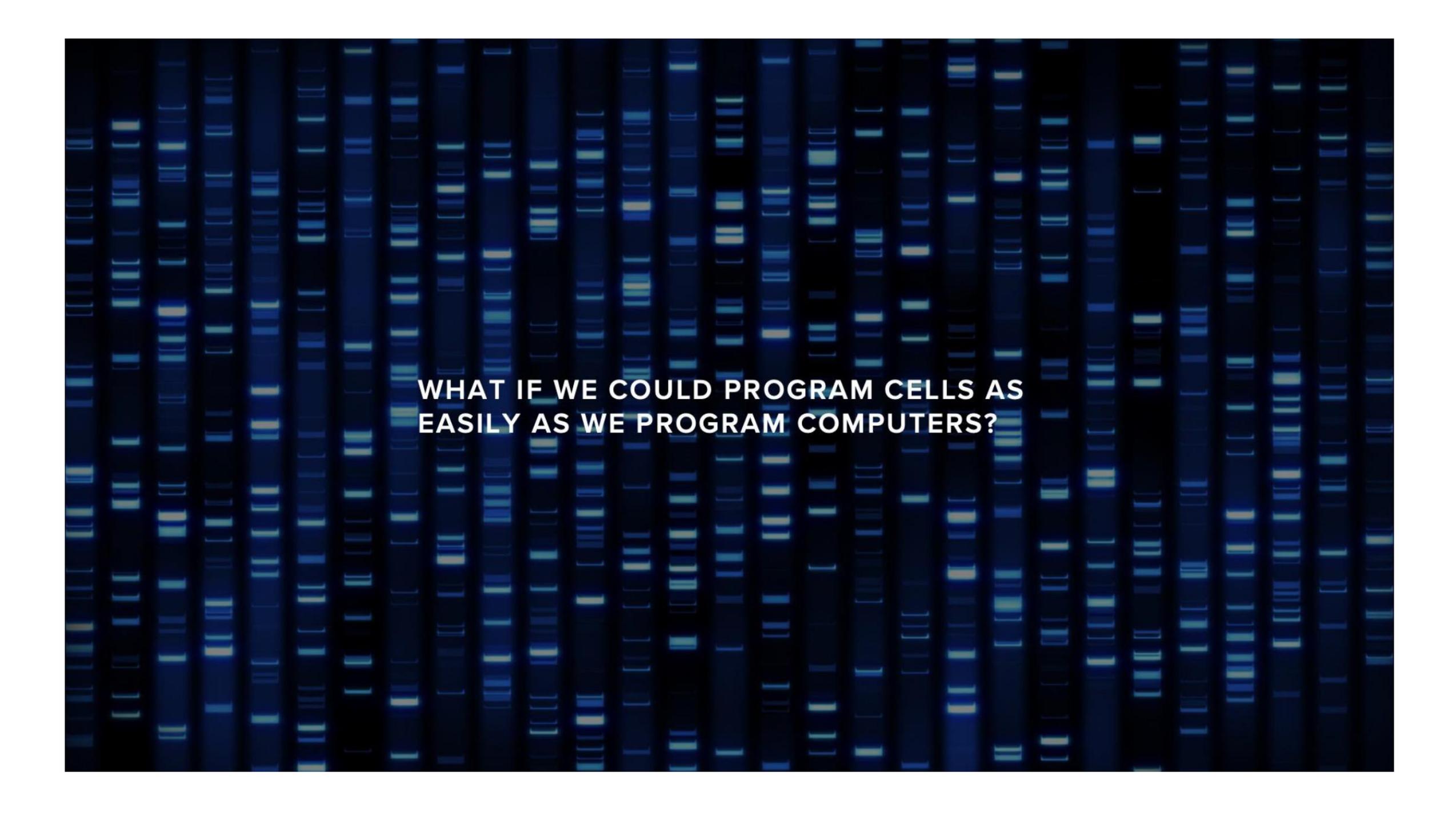


Engineering

=

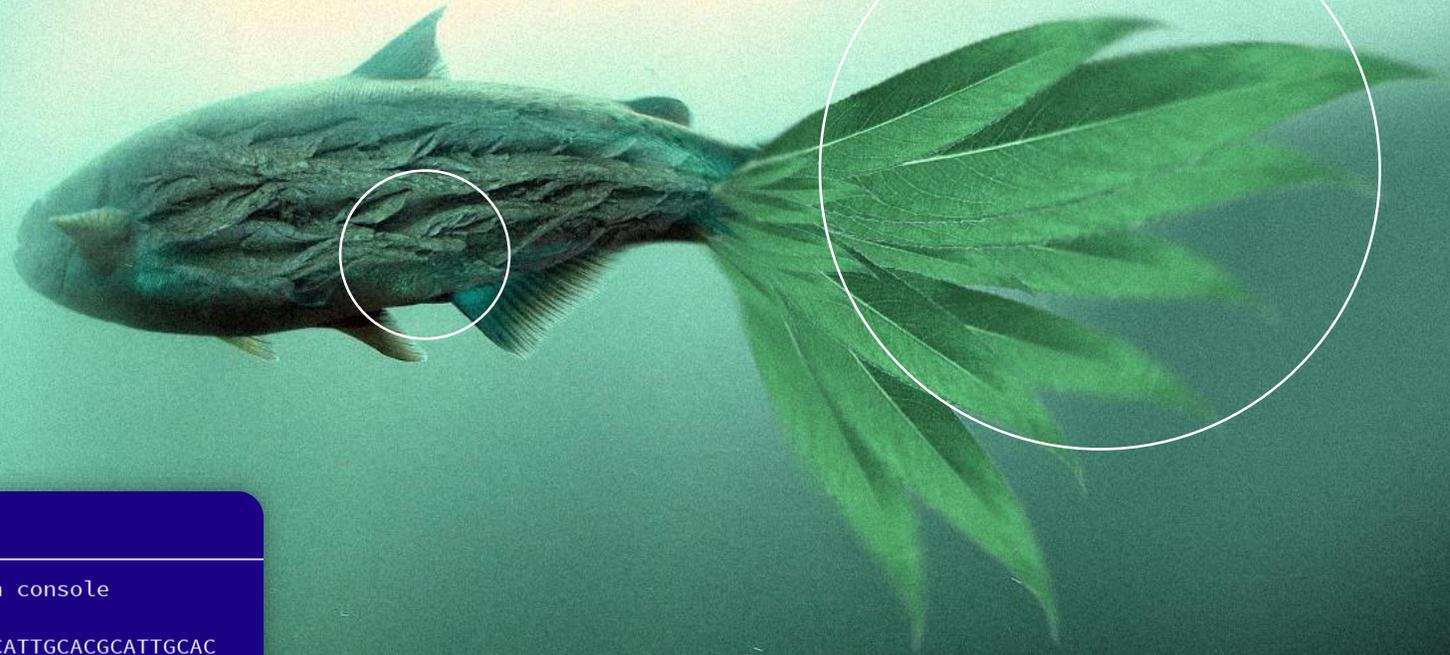


Synthetic biology



**WHAT IF WE COULD PROGRAM CELLS AS  
EASILY AS WE PROGRAM COMPUTERS?**

# Reprogramming life



○ ○ ○

last login 10.05.2017 on console

User:~

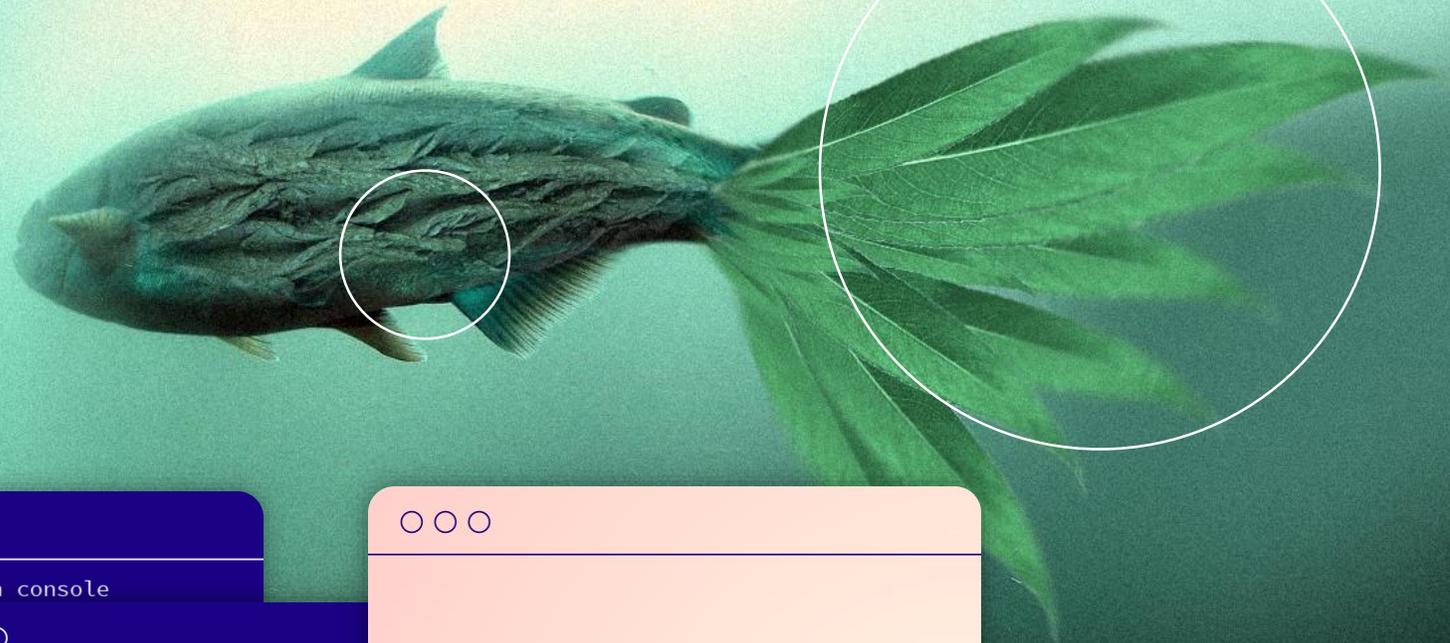
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# Reprogramming life

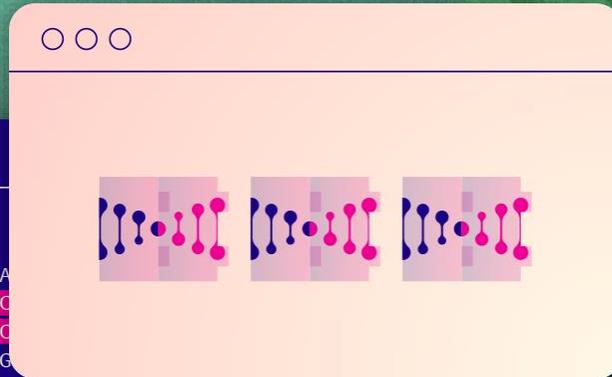


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last login 10.05.2017 on console
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TGCACGCATTGCACG
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CGCATTGCACGCATTGCACGCATTGCACGCATTGCACGCA
TTGCACGCATTTGCTTGCCCCGCATTAATTGCACGCA
```

# Reprogramming life



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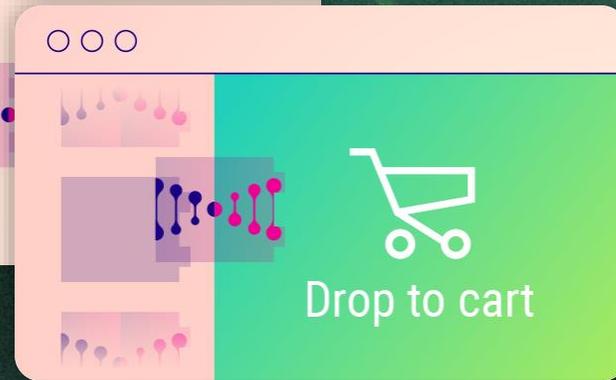
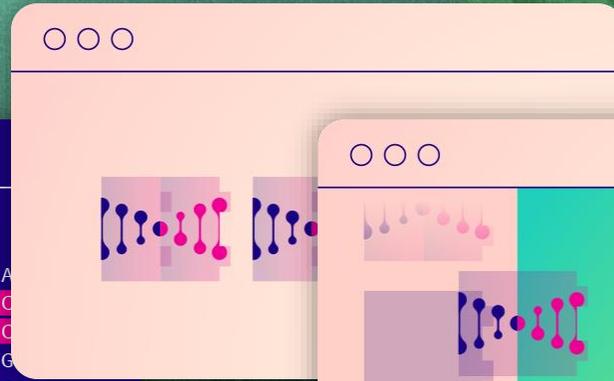


# Reprogramming life



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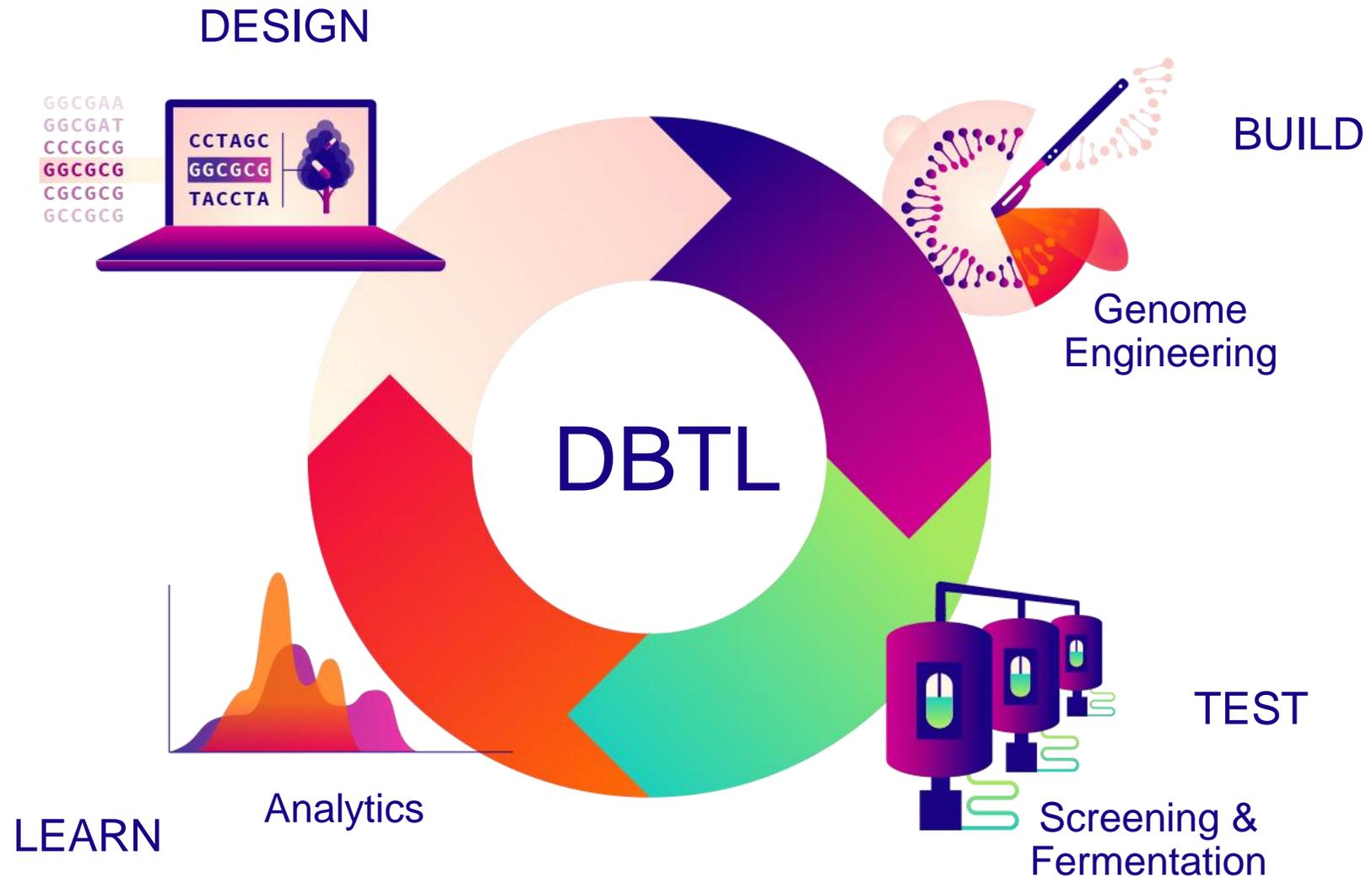
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last login 10.05.2017 on console
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TGCACGCATTGCACGCATTGCACGCATTGCACGC
CGCATTGCACGCATTGCACGCATTGCACGCATTG
TTGCACGCATTTGCTTGCCCCGCATTAATTGCACGCA
```



To be fair, humans have only spent about ten thousand years developing technologies. Biology has had a 4 billion year head-start on us.

Humans, however, have recently invented two very important technologies—reading and writing DNA.

# Design-Build-Test-Learn cycle



## OECD report “Digitalisation in the bioeconomy: Convergence for the bio-based industries.”

Combination of digitalisation and biotechnology provides a powerful opportunity to tackle challenges of biosustainability.

Integration of automated genome engineering, phenotype screening, high-throughput analytics, and informatics for generation and analysis of big data represents a paradigm shift – biology becomes a data-driven engineering discipline aiming to design disruptive biomanufacturing solutions.

This will transform entire sectors of human life and the world economy by solving many global challenges, from biomaterials to food, and healthcare.

# Digitalization of biology

## Discovery

- Sequence/Knowledgebase
- Retrobiosynthesis

## Computer-Aided Design

- BioCAD

## Genetic Parts

- Reporters, Markers
- Promoters, Terminators
- RBS, Codon Usage algorithms

## Genetic System

- DNA transfer
- Modular plasmids
- Homologous recombination, CRISPR

## Advanced Toolbox

- Multiplexing
- Genome-wide
- Genetic circuits

## Rapid Prototyping

- Cell-free protein synthesis

## AI

- Machine Learning

## Modelling

- Genome-scale
- Kinetic
- Technoeconomic

## Systems Biology

- Multi-Omics
- Enzymology

## Automated Strain Evolution

- Automated Strain Evolution

## Automated Strain Engineering

- Biofoundry

## Miniaturization

- Microfluidics



# European competitiveness at stake!

US leading the way in digibio



 **GINKGO**  
BIOWORKS  
\$17.5B

 **zymergen**  
\$3.5B

**LanzaTech**   
\$200M

 **geno.**  
\$700M

**amyris**  
\$800M



Amyris.com

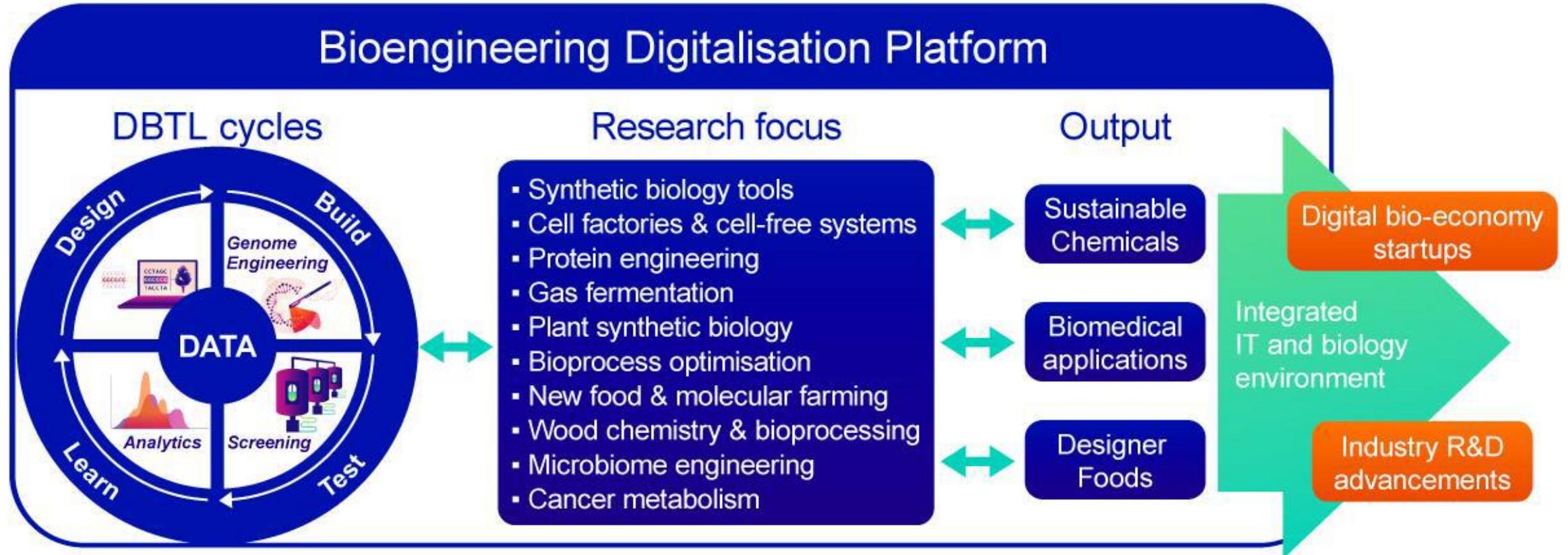


In collaboration with a leading  
centre for synthetic biology

Novo Nordisk Foundation Center for Biosustainability (CFB)

# Teaming partnership:

- University of Tartu (Estonia)
- Tallinn Technical University (Estonia)
- Novo Nordisk Foundation Centre for Biosustainability (DTU, Denmark)



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## ECB ecosystem – Horizon 2023-2028



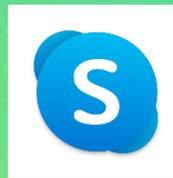
# WHY ESTONIA?

Decades of  
molecular biology  
education and  
research excellence

World-class  
IT startup industry,  
environment and  
education

Abundant biomass  
and wood industry  
waste streams as  
input for circular  
economy

# Estonian digi startup ecosystem



pipedrive

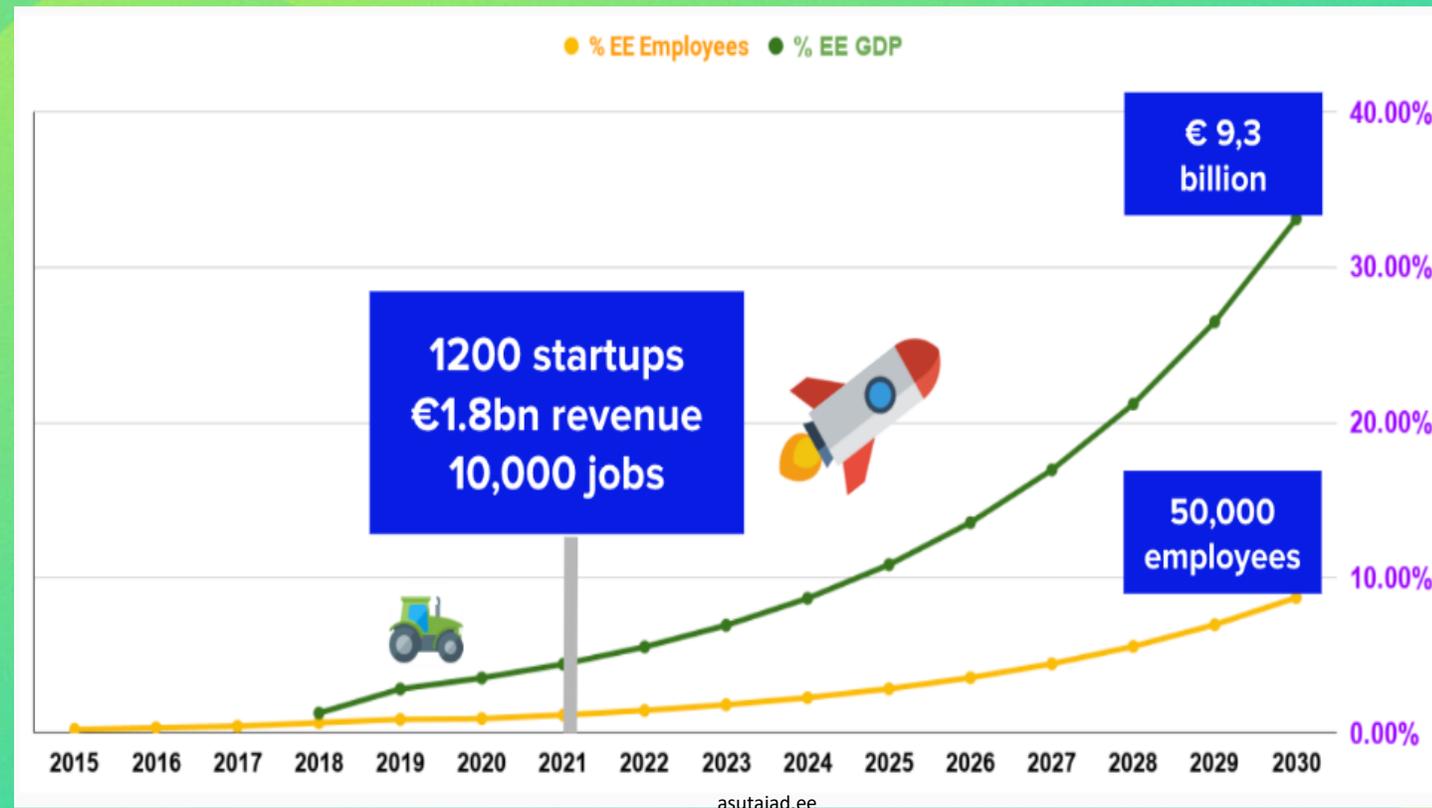
Bolt

ID.me

wise



- 10 unicorns - #1 per capita in Europe
- 1200+ startups
- ~€3.5B funding raised since 2010
- ICT sector – 7% of GDP with 6% of employees





# International, innovative curricula combining molecular biology, IT, and engineering

Following the  
examples of the  
leading universities

Undergraduates from 40+  
countries students + masters  
and Ph.D programs

International education iGEM  
centre for bioprocess  
optimization

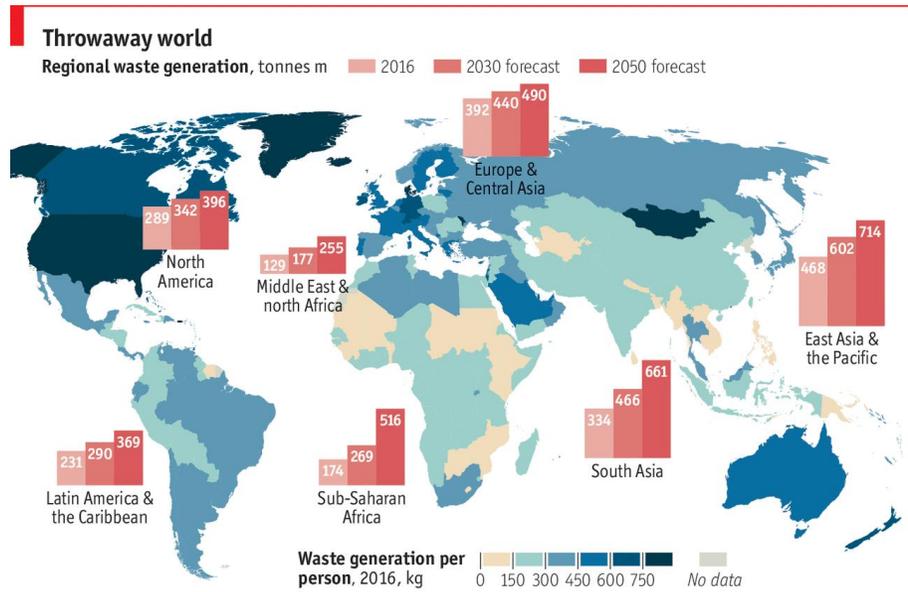
# The waste problem



wikipedia.org



epa.gov



Source: World Bank  
The Economist



Bioenergyconsult.com

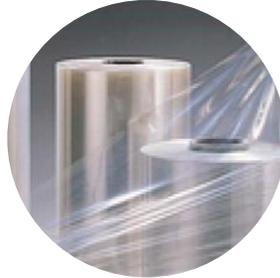


www.energynext.in

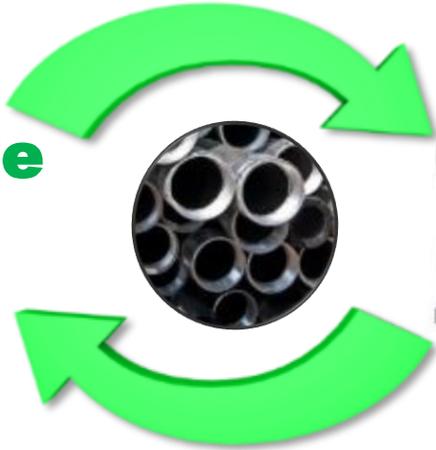


Sciencealert.com

# Putting Carbon in the Circular Economy



Recycle



Make



# Designer foods

## Alternative meat

## Alternative dairy

Plant-based



Fermentation



Cultivated



## Feed



A recent McKinsey report estimates: up to 60% of the physical inputs to the global economy could be produced via biological systems predictably having an economic impact of trillions of dollars over the next 20 years.

The cell programming industry is driven by government interest, especially in the United States, which holds about 40% of the global biotech market share. Demand for cell programming biotech is growing rapidly in the Asia Pacific, specifically in India and China.

For EU, to stay in competition, there is an urgent need to develop analogous and even more advanced bioengineering platforms.

Synthetic biology in Estonia:  
a historical opportunity

Local substrate



Value added chemicals



