

# FOOD FROM ELECTRICITY AND CO<sub>2</sub>

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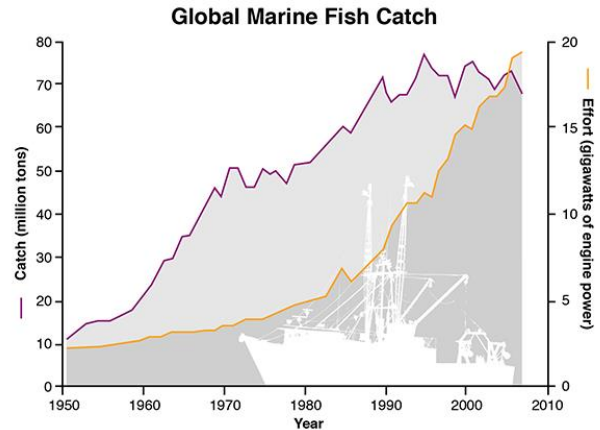


[www.neocarbonfood.fi](http://www.neocarbonfood.fi)

A joint research between Lappeenranta University of Technology (LUT)  
and VTT-Technical research centre of Finland

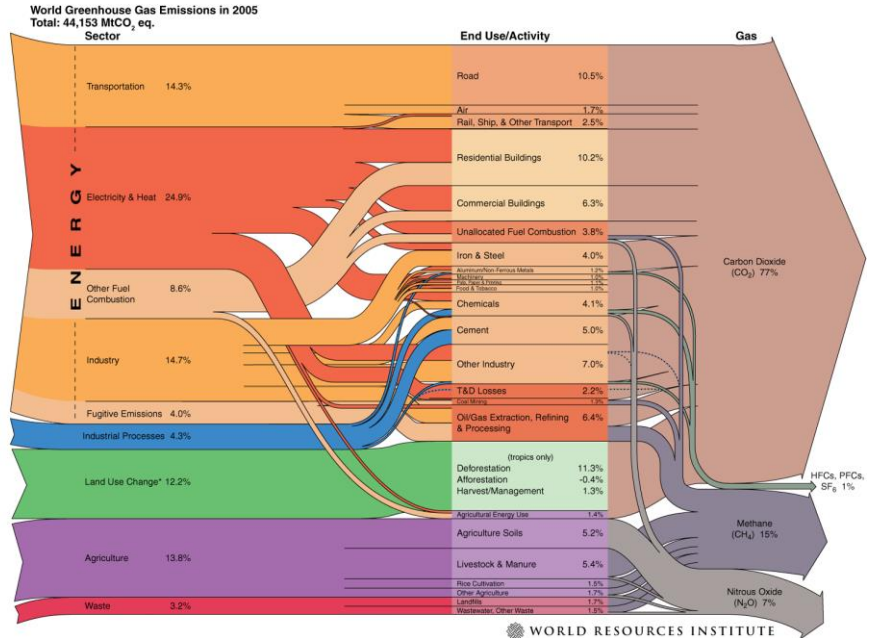
# Background

- Rapid population growth and continuously improving the standard of living leads to higher demand of protein (mainly meat and fish) especially in the developing countries
- The food safety can be endangered by the over fishing and the lack of arable land, fertilizers, and fresh water



# Effect of food production on climate change

- Agriculture (including land use change) is responsible for a quarter of the global GHG emissions



# Principle of bioreactor with in situ electrolysis

- Microbial protein production with gas fermentation is known for decades, but has so far not been able to challenge the traditional farming
- The hydrogen is the source of energy and CO<sub>2</sub> can be from any source

Electricity

CO<sub>2</sub>

Water

Minerals

Microorganisms



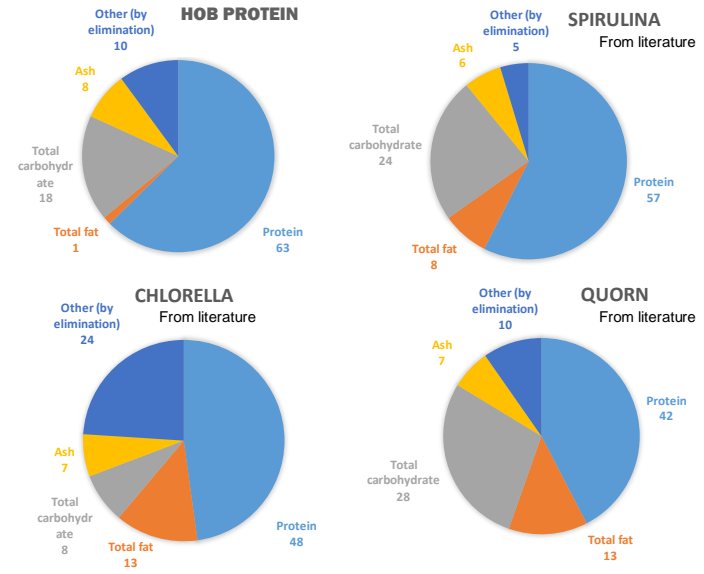
Food & Feed



<https://www.youtube.com/watch?v=b71CBoa1Fas>

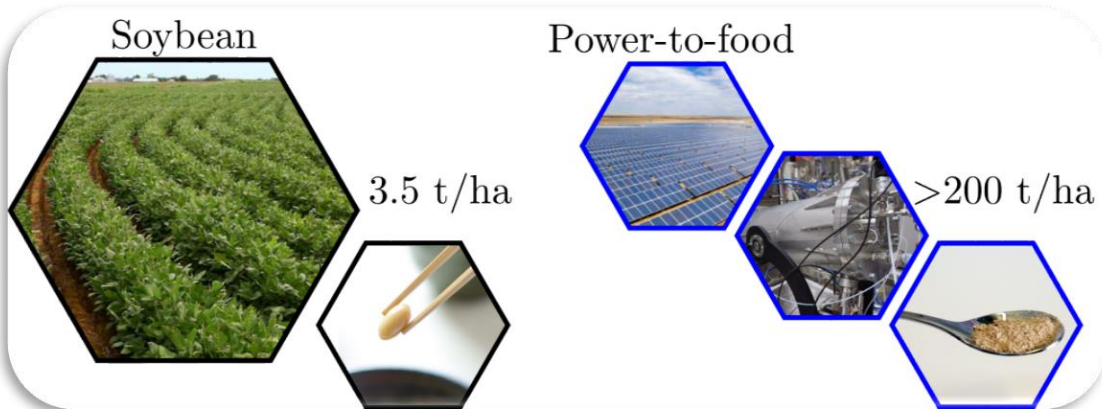
# End product

- MP-based products in market: Spirulina, Quorn, FeedKind®, UniProtein®
- MP produced using electricity has similar biomass composition as MP produced using direct sunlight or sugars.



# Production rate

- The production rate of MP is far higher compared with photosynthesis based production



# Life cycle assessment (LCA)

	Global warming potential [kg <sub>CO2-eq</sub> /kg <sub>protein</sub> ]	Land use [m <sup>2</sup> /a*kg <sub>protein</sub> ]
PtF wind energy	0.89	0.042
PtF solar energy	1.27	0.054
Feedkind	2.23 <sup>a)</sup>	0.1 <sup>a)</sup>
Quorn	16.55 <sup>b)</sup>	2.76 <sup>b)</sup>
Soybean	2.025 <sup>c)</sup>	4.94 <sup>d)</sup>
Pork	20-55 <sup>f)</sup>	40-75 <sup>f)</sup>

<sup>a)</sup> (Cumberlege et al. 2016), <sup>b)</sup> (Head et al. 2011), <sup>c)</sup> (da Silva et al. 2013), <sup>d)</sup> (Mekonnen and Hoekstra 2012), <sup>e)</sup> (Jekeyinfa 2013), <sup>f)</sup> (Mekonnen et al. 2012)

- PtF process itself consumes only small amount of water

# Research questions

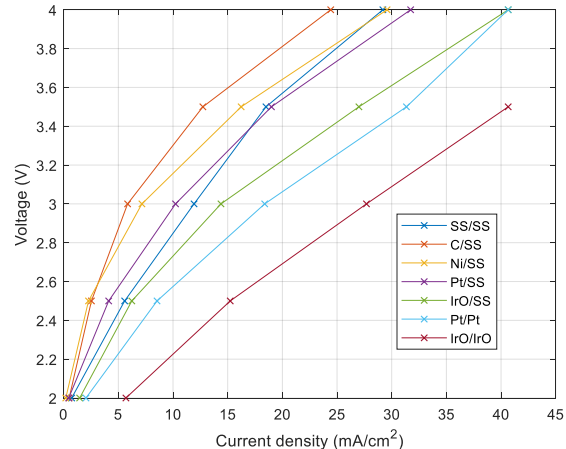
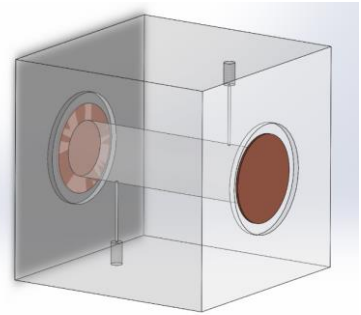
- The most suitable micro organism
- The optimal cultivation media
- Current density limitations
- The effect of electrode materials on the energy efficiency
- The effect of electrode geometry on the energy efficiency
- Process control aspects
- Direct air capture of CO<sub>2</sub>





# Electrode material tests

- Cyclic voltammetry is applied to define the cell voltage as a function of current density
- Low electrolyte conductivity  $\sim 1$  S/m, pH neutral
- Hydrogen production estimated based on current
- Voltage efficiency analyzed as a function of current density
- Various electrode material combinations studied



# Pilot plant



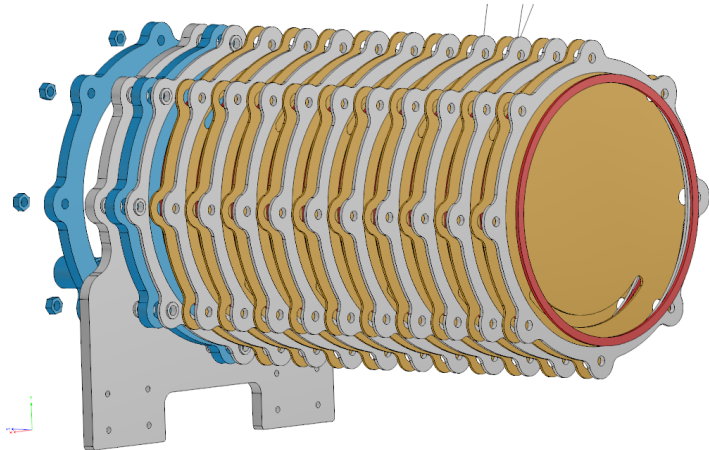
DIRECT AIR CAPTURE

- Pilot plant will be implemented in June 2019 at LUT
  - CO<sub>2</sub> direct air capture & solar electricity
  - MP growth with in situ electrolysis is demonstrated
  - Electricity-to-biomass efficiency is analyzed
  - Continuous process control
  - Post-processing of biomass is not included
- Targets
  - Reactor volume 20 L
  - Productivity 10 g h<sup>-1</sup>
  - Energy consumption 10 kWh kg<sup>-1</sup>
  - Electricity-to-biomass efficiency 60%



# Electrolyzer stack for in situ electrolysis

- Stack structure maximizes the active electrode area
  - Single electrode area  $\sim 380 \text{ cm}^2$
  - 10 cells in series
  - Stainless steel electrodes with catalyst coating



# Mentions in international media

**SUPER**  
Cientistas finlandeses transformam eficiência em comida

Testes ainda possuem baixa produtividade, mas têm missão ousada: acabar com a fome no mundo

by **Luísa Prette**  
02 de Maio de 2018



TTT Technical Research Centre (Reinhold)

Água, dióxido de carbono (o popular CO2) e um tipo de bactéria: corrente elétrica que dá conta de misturar tudo e voilá tem a receita incrível: milhões de pessoas de item dormir com fome. O projeto Electricity, como revela desde o nome, é uma tentativa de pensar finlandeses de produzir comida a partir de energia elétrica. Os resultados ainda iniciais, são animadores. A fórmula resulta em um supel alimentar rico em nutrientes e, principalmente, produzido a um custo relativamente baixo.

**INDEPENDENT** News, Contact, Politics, Voices, **Italy**, Life, Business, Sport

News & Politics  
**World hunger could be solved with food created from electricity and carbon dioxide, say scientists**

The 'protein reactor' is the size of a coffee-machine and currently takes a fortnight to produce a spoonful of powder

Open-Public | Monday, 23 July 2018 05:01 GMT | **380** comments

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**Rit** Cibo e salute

Emergenza | Cooperazione | Prologhi | Diritti Umani | Immigrazione | Volontariato

**Fame nel mondo, si può produrre cibo da elettricità e CO2**

Con poche risorse ed energie rinnovabili, si potrebbe soddisfare il fabbisogno necessario in periodi di carestia, ma la scoperta può essere applicata anche alla produzione di mangimi.

di MARIA LUISA PRETTE



La leggenda | 04 agosto 2017

**ROMA** - Un nuovo cibo, a basso costo e che rispetta l'ecosistema, per risolvere l'ancora piaga della fame nel mondo. Va ricordato che 765 milioni di persone, nel mondo, oggi soffrono la fame: circa una persona su nove non ha abbastanza cibo per condurre una vita sana ed attiva. L'obiettivo è ribalta in prospettiva con un metodo innovativo e di un team di scienziati che annuncia di aver finalmente trovato la soluzione al problema: proteine monocellulari, prodotte utilizzando elettricità e anidride carbonica. La scoperta è frutto di uno studio congiunto dell'Istituto di Tecnologia di Aspinwall (ITIT) e del Centro di Ricerca Tecnica VTT, in Finlandia. La proteina, prodotta ovunque con energia rinnovabile, può essere utilizzata sia come cibo che come mangime per gli animali.




**FOOD**

Despite the headlines, we're making steady progress in the realm of food scarcity and hunger.

This graph below, World Bank data on the percentage of the population that use an inadequate amount of protein, calories, and fat, percent of the population was undernourished in 1991 to 2011, it dropped to 13.8 percent.

**Undernourishment in Developing Countries**



Two and a half, technology is making scarce resources abundant. I've written about bioartificial meat, genetically engineered crops, vertical farming, and agriculture robots and drones. You have examples from 2007 for **HUMAN-FREE FARMS** in a 15-acre remote farm in the UK, Harper Adams University and Precision Dynamics recently harvested their first crop of barley. The herd? This farm is an autonomously managed of human farm workers, feeds five heifers and a droneless vehicle, machine learning algorithms and down to plant, feed and harvest.

**FOOD FROM ELECTRICITY** Another big step in the fight against food scarcity and undernourishment comes out of Finland, where researchers are creating food from electricity. The team, based at researchers from the Lappeenranta University of Technology (LUT) and the VTT Technical Research Centre of Finland, have created a reactor that uses an renewable energy to produce nutrients, single-cell proteins. The system is encapsulated in a variety of environmental hosts to traditional agriculture, and also functions well able to produce food anywhere, from barren secker deserts to space.



Looking at the data, we truly live in the most exciting time to be alive. And if your mindset enables you to see problems as opportunities, the future is even more exciting than the present.

07-30-2018 | 2017-07-30-2012

聯合國糧食及農業組織 (FAO) 估計, 在2014年至2016年, 全球有約8億人营养不良, 最近有來自芬蘭的科學家成功以電力將空氣、二氧化碳、蛋白質營養物, 有望在將來協助解決世界各地長久以來面對的糧食短缺問題。

位於科學商業與創新領導技術大學 (Lappeenranta University of Technology) 與技術研究中心 (VTT Technical Research Centre of Finland - 簡稱VTT), 他們所創立的生物反應器 (bioreactor) 以電力將空氣中的二氧化碳、水汽及氮氣, 轉化成一種蛋白質營養物之營養物。

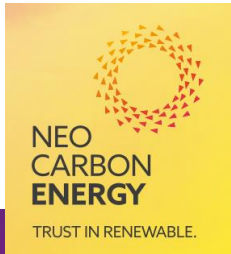


芬蘭國家技術研究中心 (VTT Technical Research Centre of Finland) 的科學家Juhani-Pekka Pitkänen。(從上圖右)

事實上, 所有原料均取自空氣中製成。未來, 這項科技可以應用於邊境其他地區對的社區發展, 根據計劃, 以電力所生產的營養物可以用作魚及成蝦。這項技術對於營養物, 有50%為蛋白質, 25%為碳水化合物, 其他成份為維他命與鐵質。參與研究的VTT科學家Juhani-Pekka Pitkänen。

研究人員正在研究如何將這些營養物轉化成動物人類之食物, 「對傳統農業比較, 這種目前發展中的生產方式不簡單一項容易耕種維持的地位, 不過好處的程度, 還是比傳統之農業」, 位於科學技術大學的教授 Jero Ahola說, 簡單之, 這種生產營養物的方式可以免除傳統農業的污染, 並且可以縮短生產週期, 用作其他用途。

# Power-to-X projects at LUT



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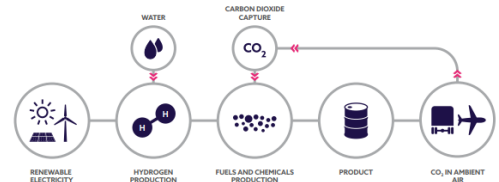


### SOLETAIR PILOT

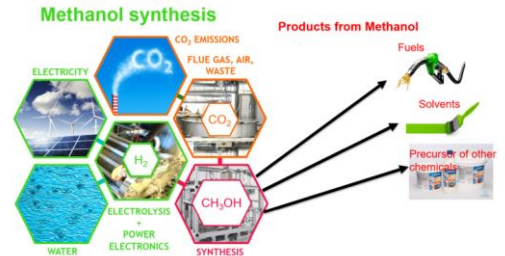
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## Power-to-Methanol Energy Efficiently



# Thank you!



- Spin-off company from the projects in 2017:  
Solar Foods Ltd ([www.solarfoods.fi](http://www.solarfoods.fi))
- Related projects:
  - Microbial Oil and Proteins from Air by Electricity-Driven Microbes (Academy of Finland)
  - Feed and Food from CO<sub>2</sub> and Electricity-Research and Piloting of Future Protein (Technology Industries of Finland Centennial Foundation, Jane and Aatos Erkko Foundation)
  - Smart Energy Transition (Academy of Finland)



# Effect of current quality on the water electrolysis energy efficiency

- Thyristors converters enable high currents, but excite significant current harmonics
- Stack specific energy consumption was increased by 1% at full load and by 10% at partial load because of the 12-pulse thyristor bridge harmonics

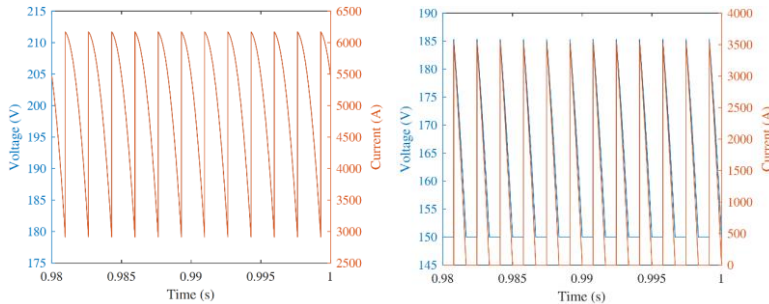


Fig: 12-pulse thyristor bridge voltage and current waveforms at 5000A and 1000A

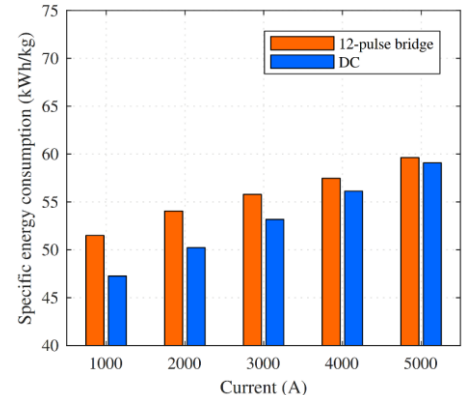


Fig: 12-pulse thyristor bridge specific energy consumption compared with pure DC