

“How to make protein from  
geothermal gas”

- The GEOGAS project



prokatín

Dr. Arnþór Ævarsson

Prokatín ehf

GEORG málstofa: Frá úrgangi til verðmæta



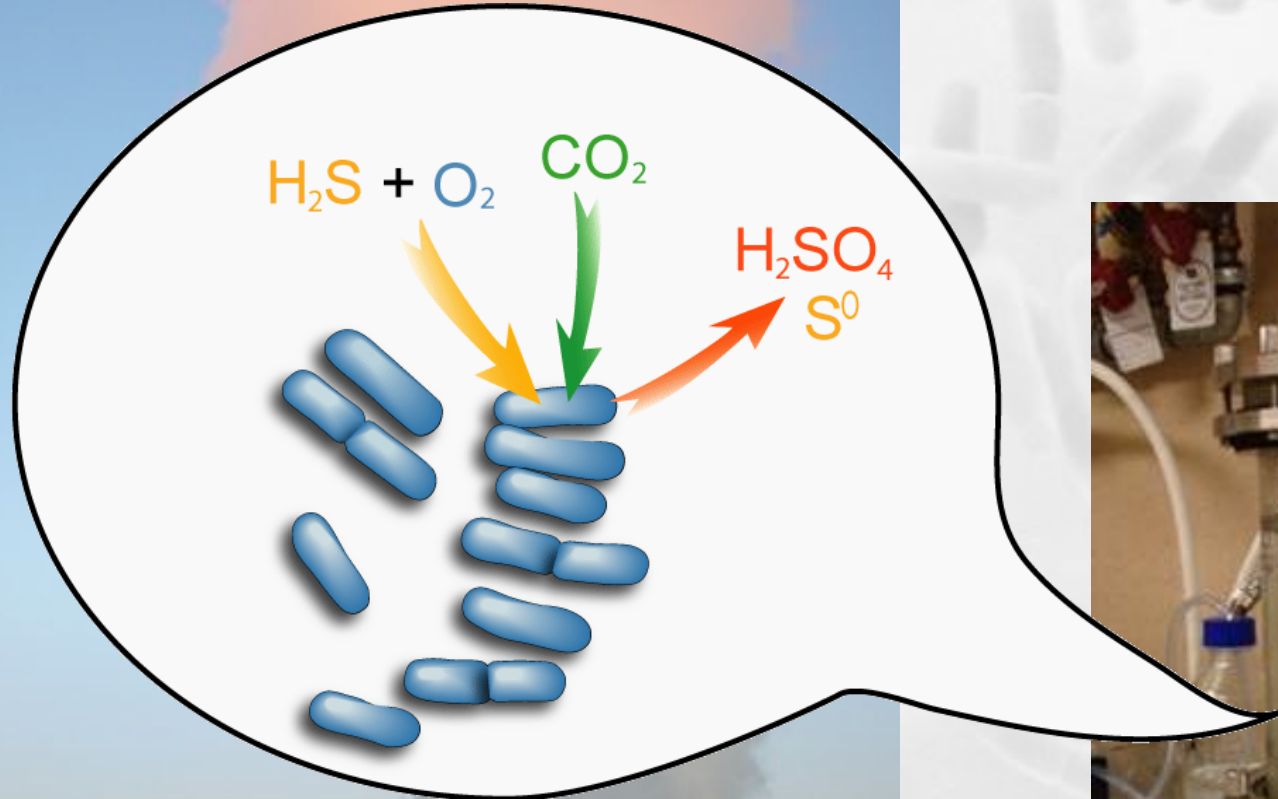
$H_2S$  Hydrogen sulfide  
 $H_2$  Hydrogen  
 $CO_2$  Carbon dioxide

→  
→  
→ **GEOGAS**

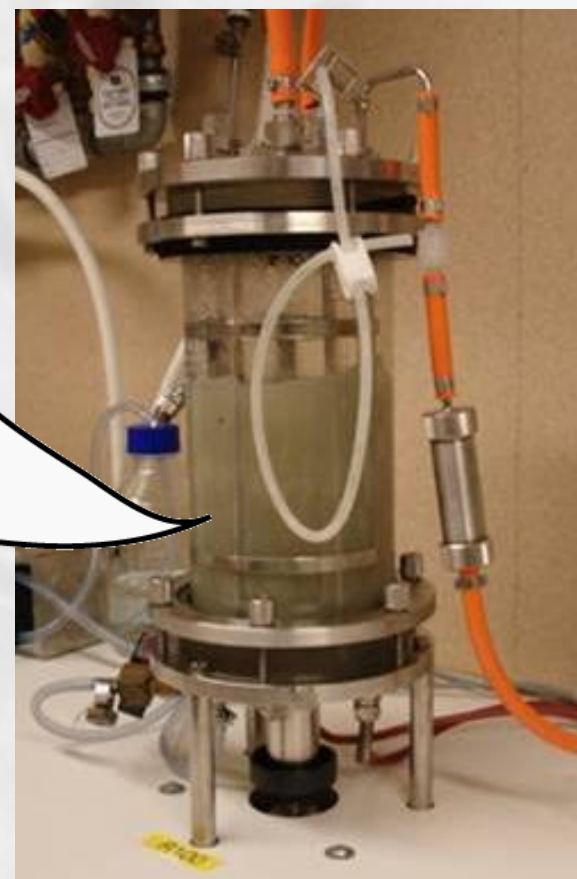
Future geothermal power plants will require control of hydrogen sulfide emission

$H_2S$  Hydrogen sulfide  
 $H_2$  Hydrogen  
 $CO_2$  Carbon dioxide

→  
→  
→  
**GEOGAS**



**Lithotrophic microbes**



Problem:

Geothermal power plants release  
 $\text{H}_2\text{S}$  og  $\text{CO}_2$

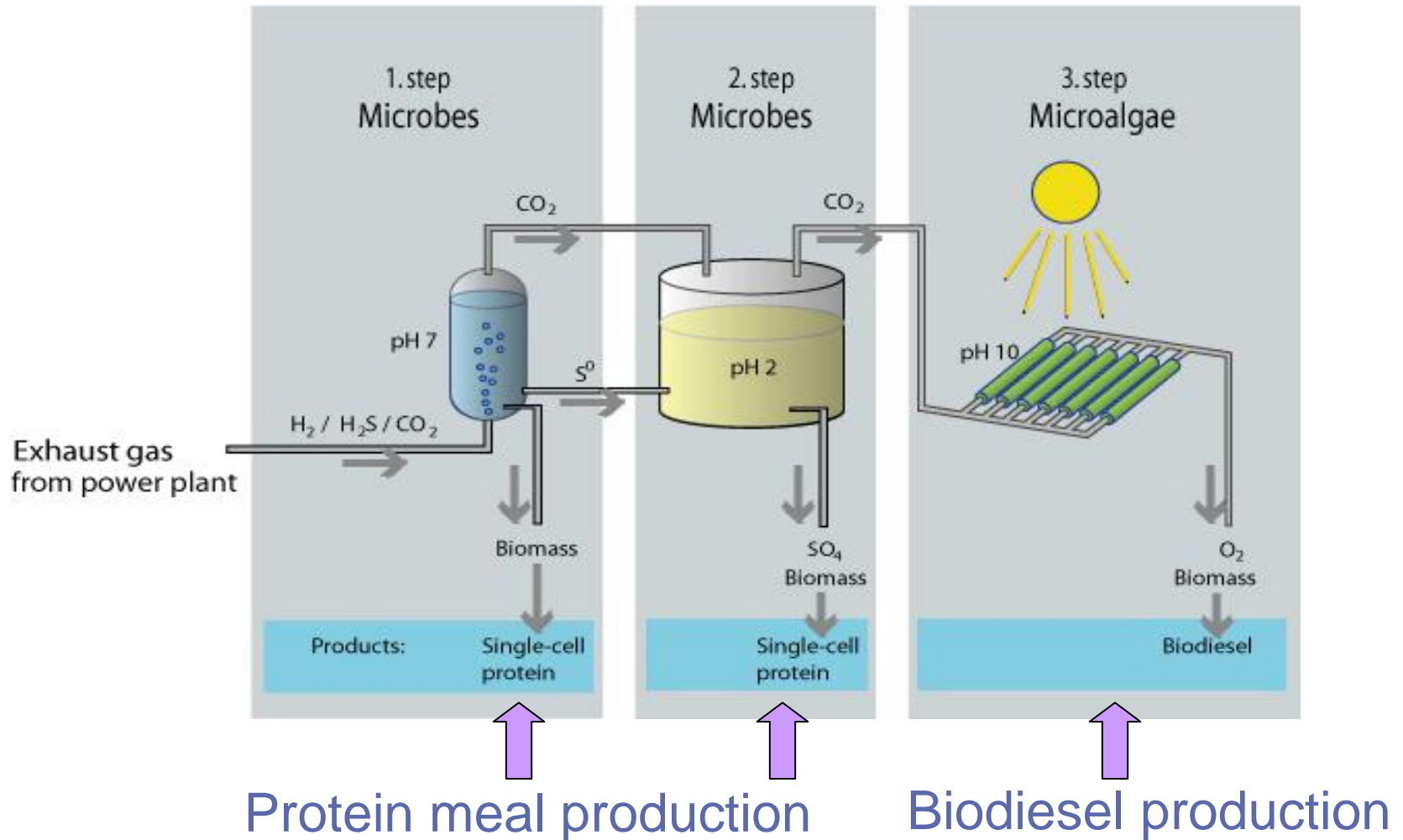
Our solution:

Microbes that “eat”  $\text{H}_2\text{S}$  and bind  $\text{CO}_2$

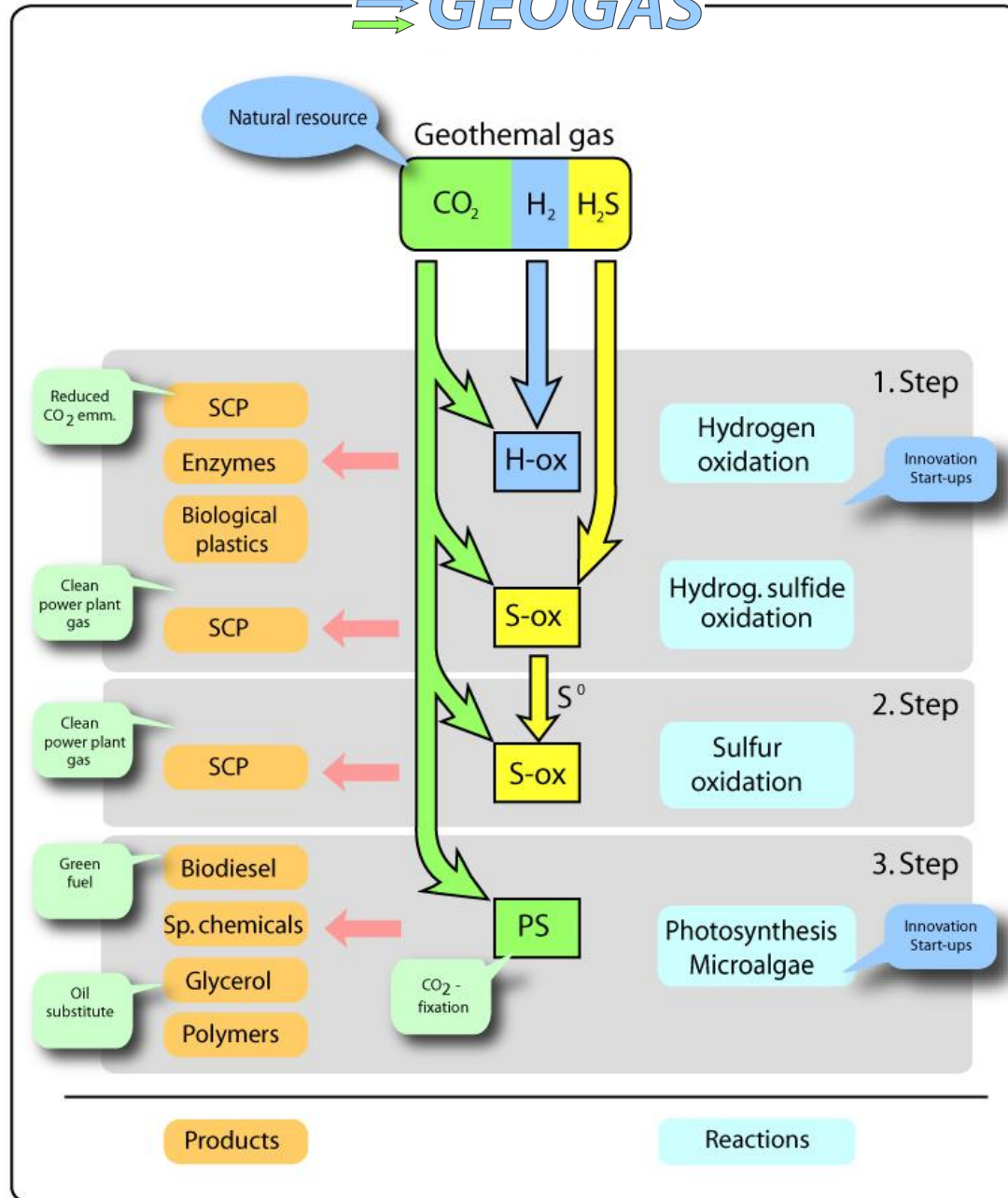
“ $\text{H}_2\text{S}$  and  $\text{CO}_2$  is a resource”

# Future vision: 3-step process

⇒⇒⇒ **GEOGAS**



# GEOGAS



# Natural resources

## Biological diversity

90°C  
pH 2

65°C  
pH 8

$H_2$   $H_2S$   
 $CO_2$

## Thermophilic microbes

50°C  
pH 4

## Geothermal Ecosystems

80°C  
pH 7

# Laboratory at Nesjavellir plant



Orkuveita  
Reykjavíkur

Nesjavellir



Hveraörverur



prokatín

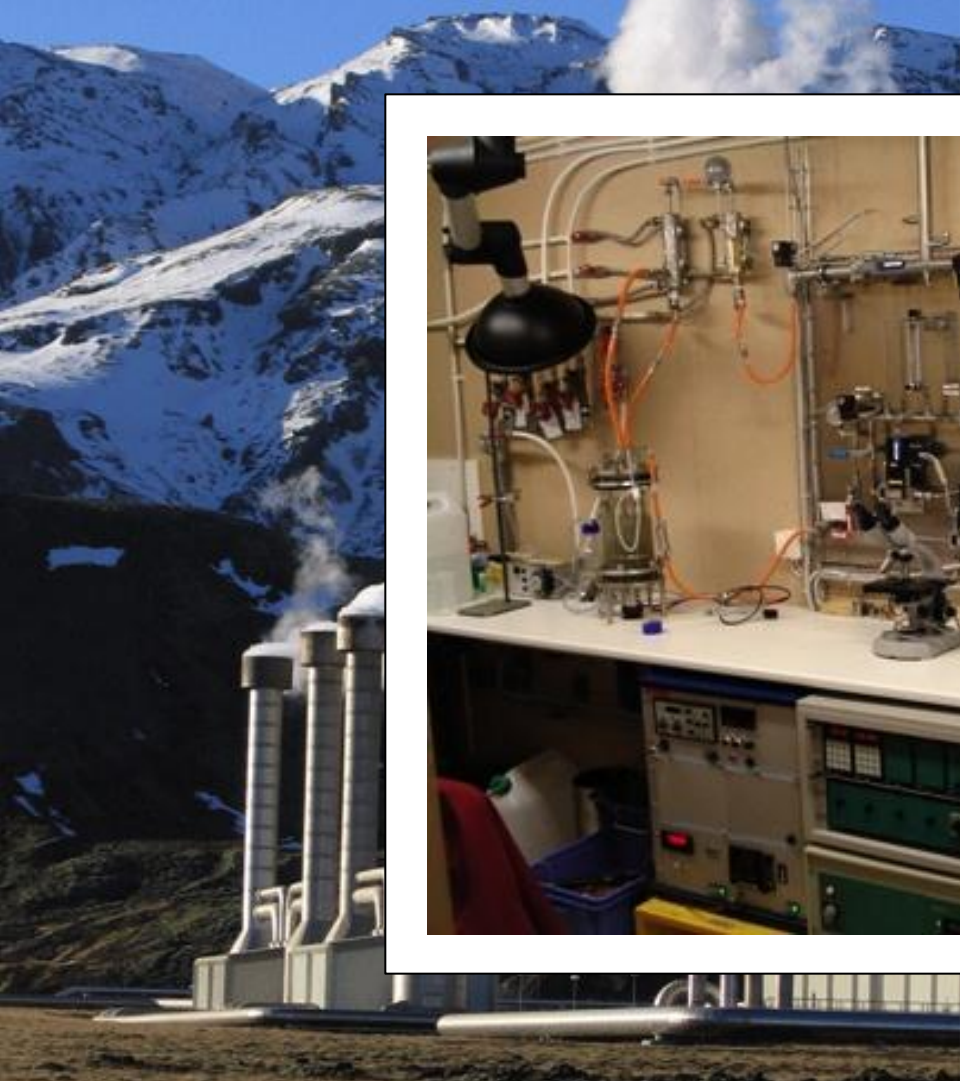




# Laboratory at Nesjavellir plant



Hveraörverur



Nesjavellir

# Pilot Plant Hellisheiði

Pilot scale - 2000 liters



Vísindagarðar, Hellisheiðarvirkjun, mars 2011

# Pilot Plant Hellisheiði



# The Biology works



← **Bakteria  
ca 10<sup>9</sup>/ml**

← **Solid sulfur**

## Chemical reactions:



**Formation of sulfur from hydrogen sulfide**

# Examples of products



**Biologically formed sulfur**

**“Biosulfur”**

**Single-cell protein**

**“Geoprotein”**

# Biosulfur

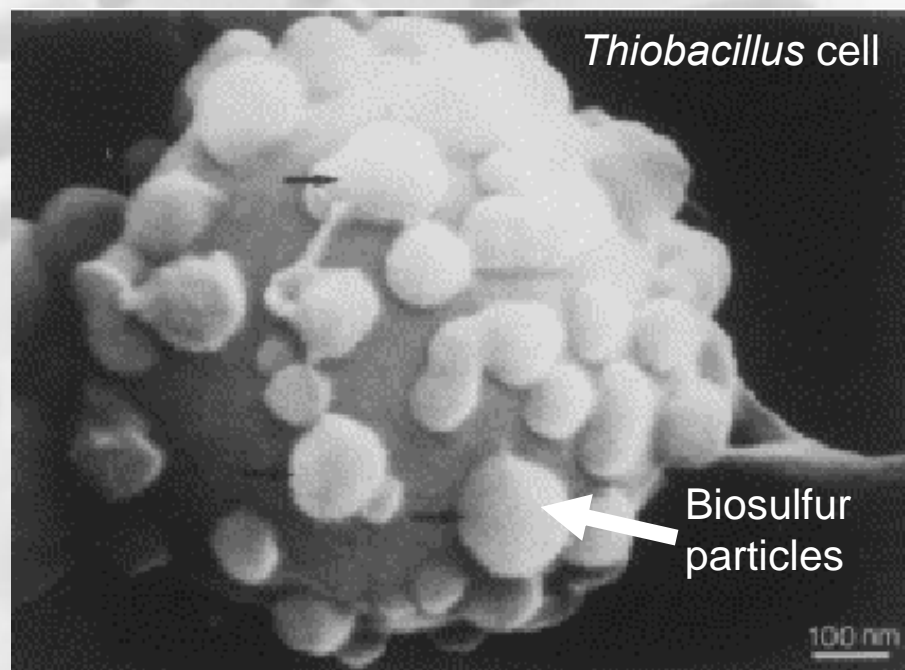
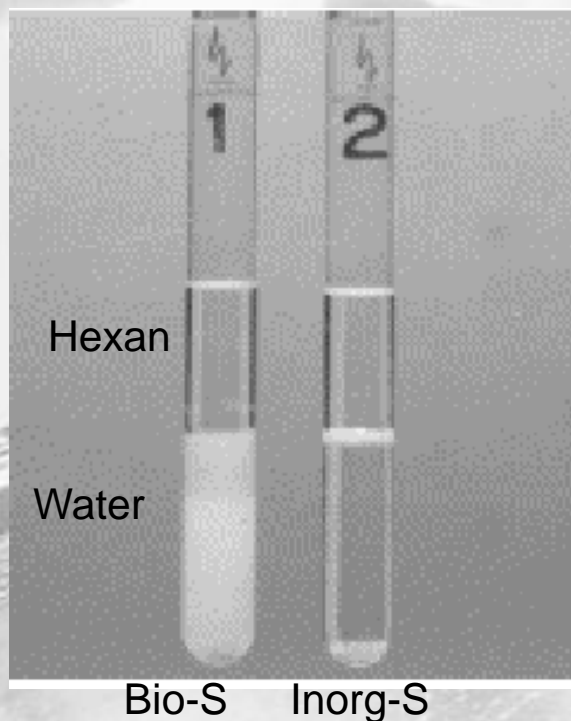


Single-cell protein

# Biosulfur – properties:

Biologically produced sulfur is more soluble than conventional “inorganic” sulfur

The bacteria may produce the sulfur as polysulfides. The sulfur particles may then be coated with polymers such as proteins and secreted from the cell exterior



# Biosulfur: market opportunities ?

- Biologically produced sulfur is considered “organic”
- Makes an excellent fertilizer and fungicide
- Can be land-applied using standard farm equipment
- Non-hazardous for landfilling as a 50wt% to 65wt% cake





# Examples of products



**Biosulfur**

**Single-cell protein**

# Protein rich meal



Biosulfur



Single-cell protein  
"Geoprotein"

# Single-cell protein: methane oxidizing bacteria

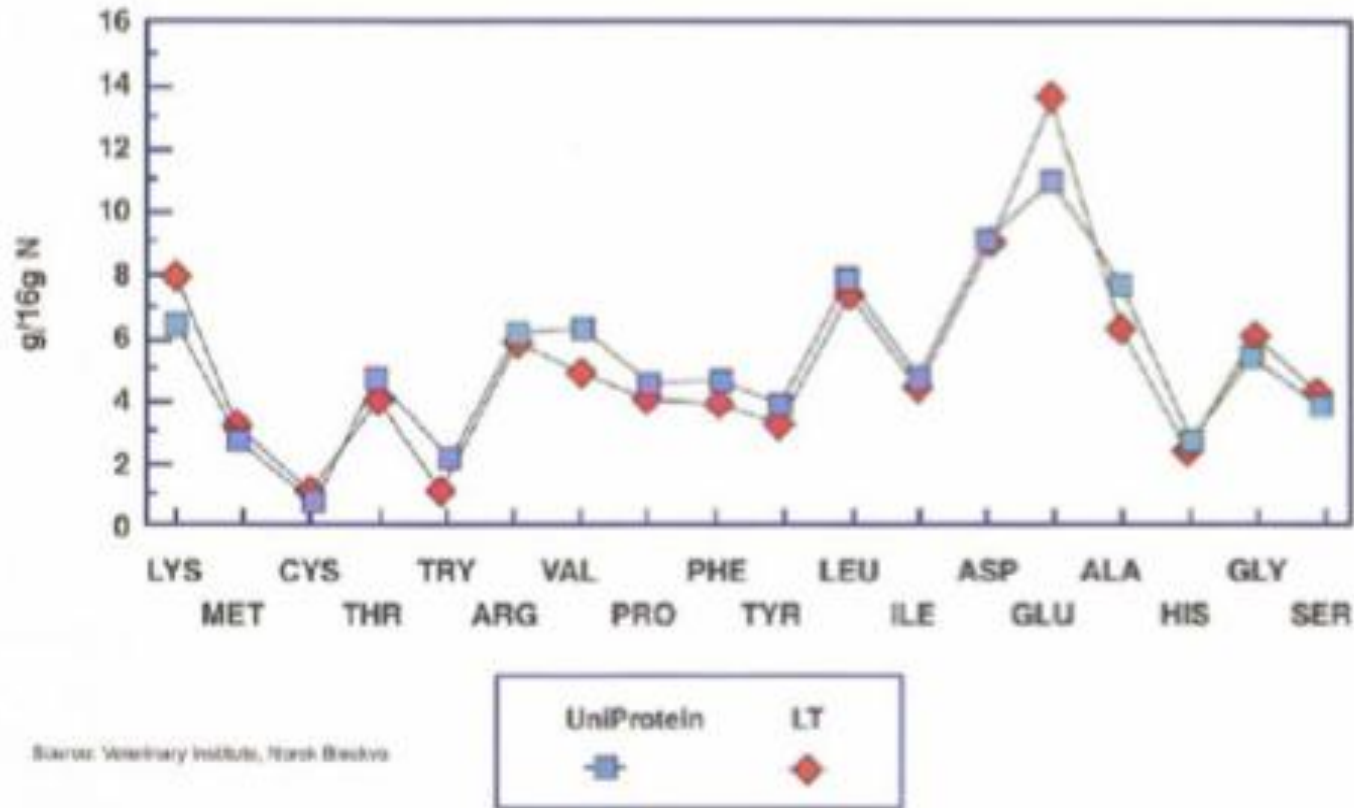
Norferm in Norway

9000 t biomass/year  
250.000 L



# Single-cell protein: methane oxidizing bacteria

AMINO ACID PROFILE IN UNIPROTEIN® AND LT-FISHMEAL



➡ Amino-acid composition similar to fish meal

➡ Single-cell protein certified for use in feed in the EU

# Geothermal gas for production of single-cell protein

# Chemical flow from geothermal plants



Gas release from  
Nesjavellir (120 MW):

- $\text{CO}_2$ : 25.000 tonn / y
- $\text{H}_2$ : 400 tonn / y
- $\text{H}_2\text{S}$ : 7.500 tonn / y



Rich resource for single-  
cell protein production

# Geothermal gas for single-cell protein production

**Average geothermal plant (120 MW) per year:**

**2000 tonn single-cell protein**

**Produce 7000 t. of solid sulfur**

**Fix 4000 t. of CO<sub>2</sub>**

# Large-scale factory?

## **Technical / engineering aspects**

Large scale factory is on the drawing board

Modular design - 200-1000 m<sup>3</sup>

Stepwise implementation

## **Economical aspects**

Comparison with other solutions

Market for biosulfur?



## Large-scale factory?

**Biological aspects**

Other biological systems on same scale

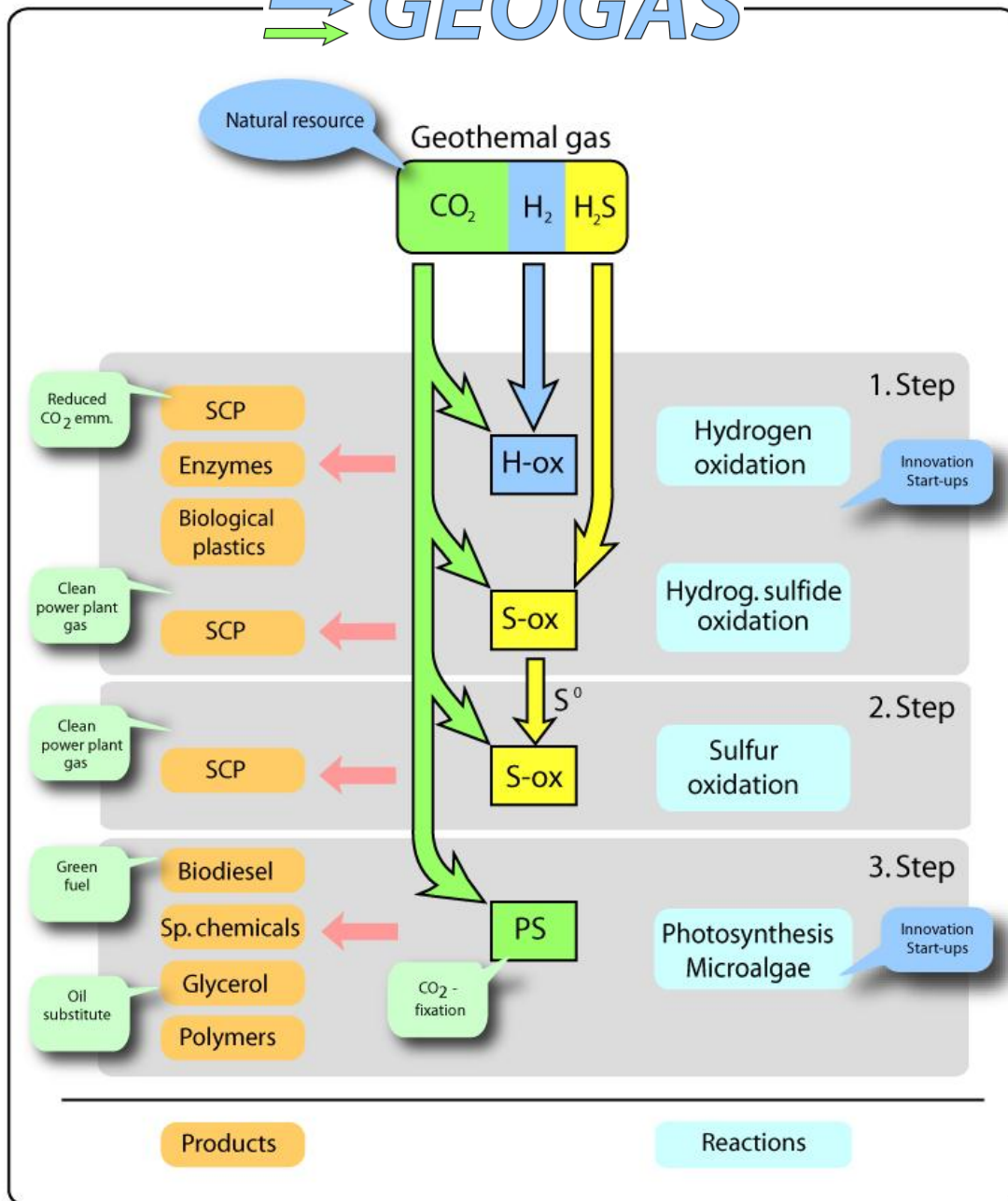
Improve yields

**Less than full-scale factory?**

Combine with other solutions for H<sub>2</sub>S reduction

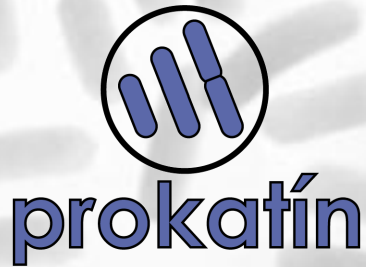
Market-based operation for sulfur products

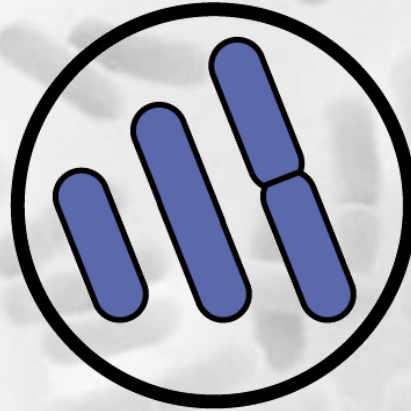
High value products



Future vision of the GEOGAS research and development framework

# Collaboration and support





# prokatín

....Orka og Líftækni