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SYNECO2 Consortium

Design and engineering of synthetic hybrid photo-electro organisms

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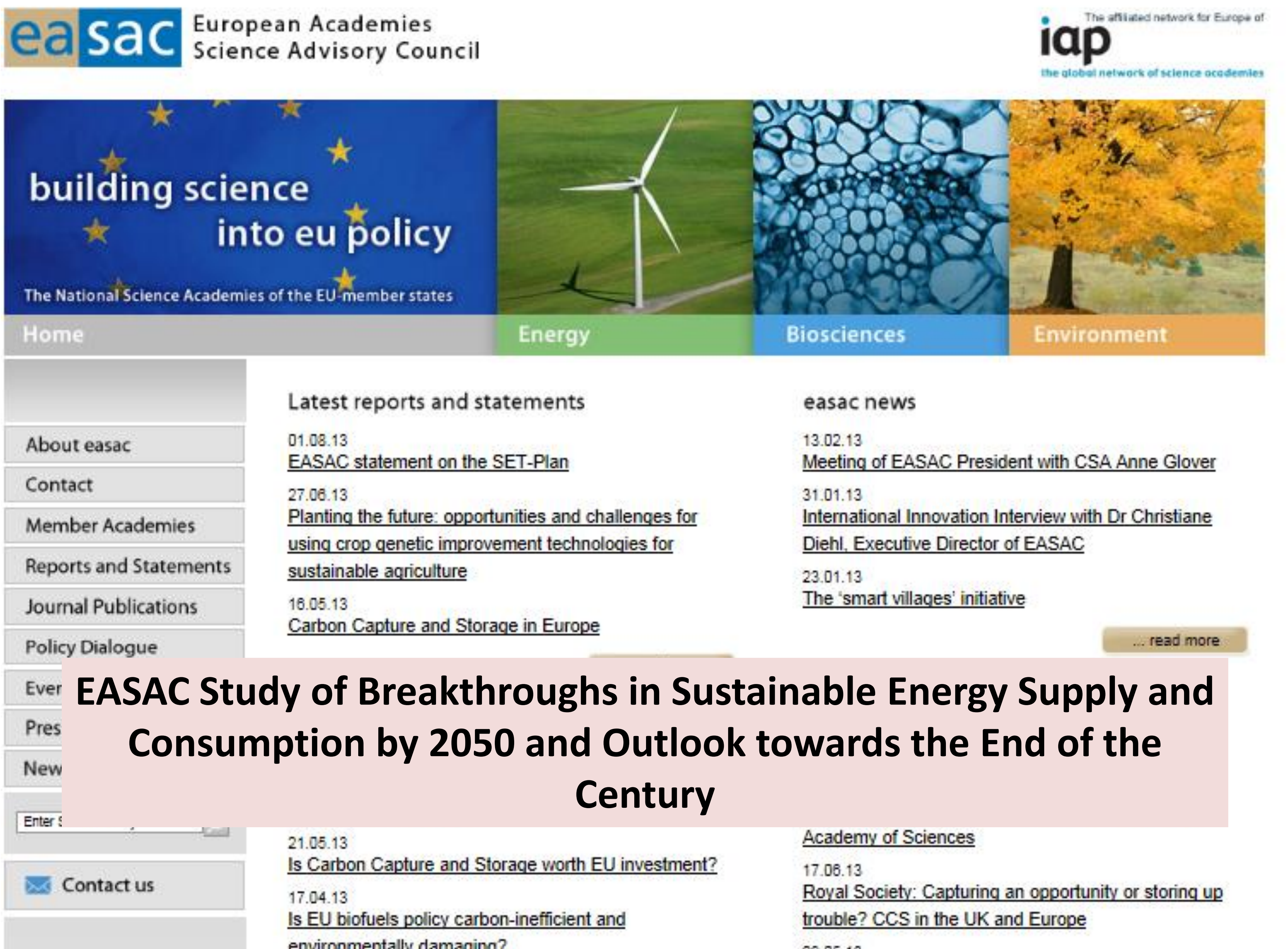
EASAC Study of Breakthroughs in Sustainable Energy Supply and Consumption by 2050 and Outlook towards the End of the Century



Renewable energy options

Electricity by photovoltaics, thermal, hydro, geo, wind, waves etc. **Storage is a big problem!**

Fuels (liquid or gas as energy carriers)

- Biomass (photosynthesis).
- H_2, CO, CH_4 by artificial leaf (man-made photosynthesis).
- H_2 by photosynthetic microorganisms.

- Bulk of liquid energy will come from carbon fixation in natural oxygenic photosynthesis ⟶ synthetic biology to produce e.g. alkanes in "designer" microalgal cells.
- Electrofuels by Microbial electrosynthesis (MES) ⟶ synthetic biology to produce various electrofuels.

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Electrofuels

- **Microbial electrosynthesis (MES)** can directly generate liquid fuels from bacteria, carbon dioxide (CO_2), water, and sunlight.
- *Shewanella* bacteria, for example, can sit directly on electrical conductors and absorb electrical current.
- This current, powered by solar panels, gives the bacteria the energy they need to process CO_2 into liquid fuels.
- CO_2 is pumped into the system, in addition to water and other nutrients needed to grow the bacteria.
- Today, various bacteria systems are under development– for example to produce fuel molecules that have properties similar to gasoline or diesel fuel--making them easier to incorporate into the existing fuel infrastructure.

Berkeley – Lawrence Laboratories

- These molecules are designed to spontaneously separate from the water-based culture that the bacteria live in and to be used directly as fuel without further chemical processing once they're pumped out of the tank.

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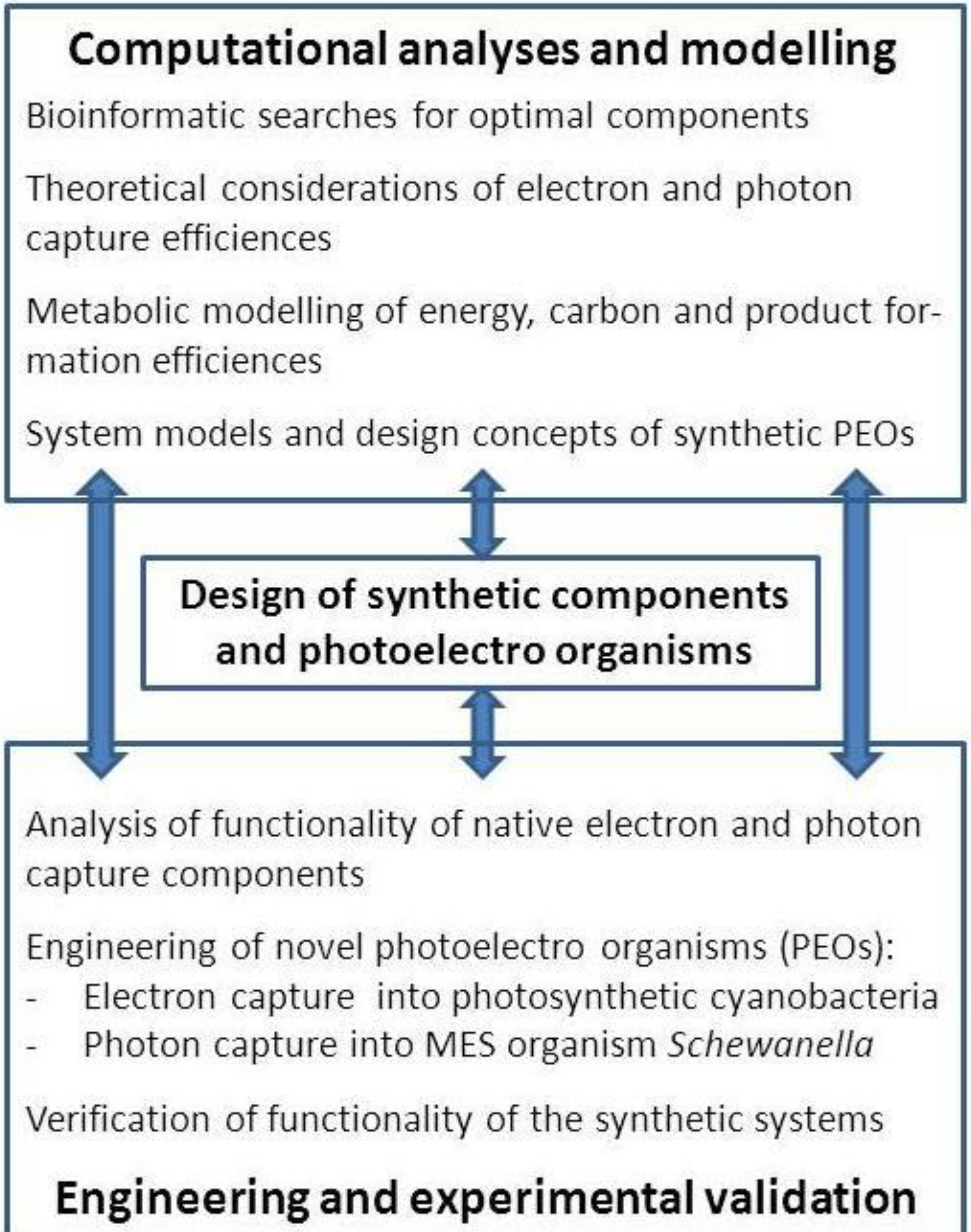
Design and engineering of synthetic hybrid photo-electro organisms (PEO)

In design and engineering of novel synthetic PEOs we will employ two different approaches:

A) to engineer an electron capture system into a photosynthetic organism (cyanobacterium)

B) to engineer a photon capture mechanism into a MES organism.



MES-based production system is predicted to become limited by the availability of ATP!

In addition to MES, we need an extra ATP producing system

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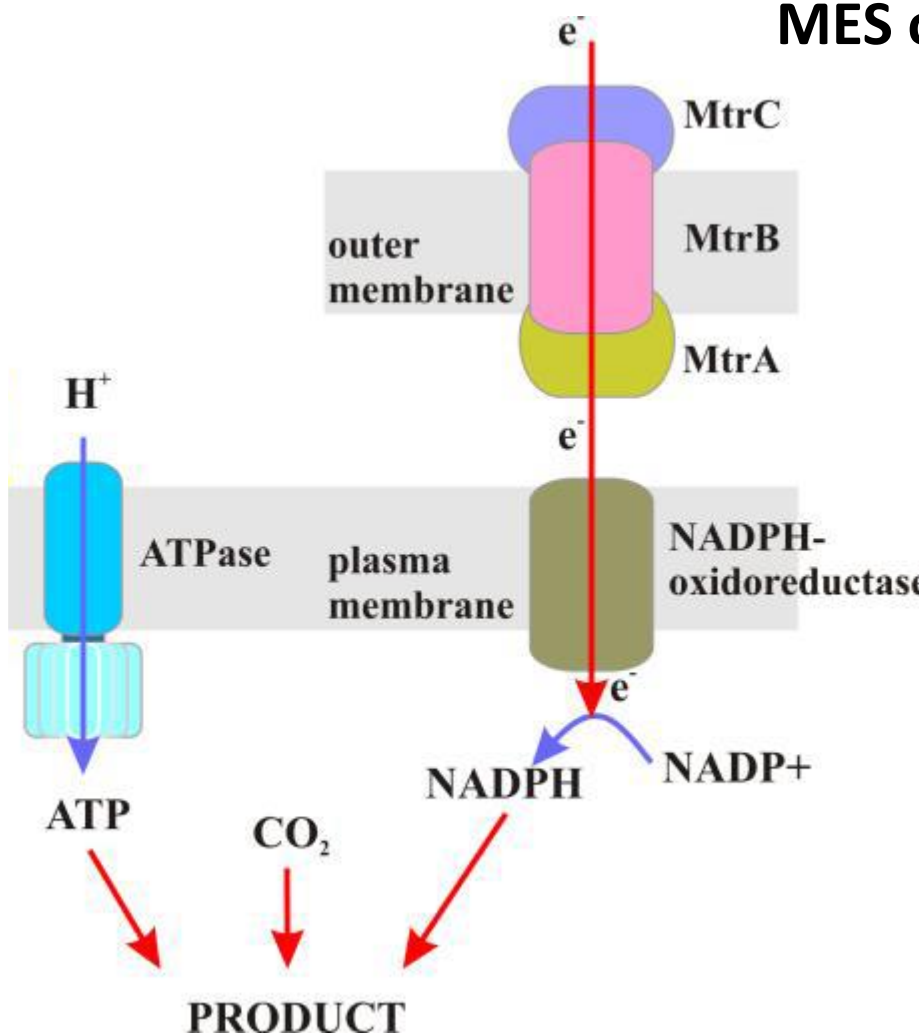
PEO NO 1.

MES organism



Literature searches to find the most suitable rhodopsin

Start with *Clostridium ljungdahlii – Electro-bioreactors have been established in VTT*

-- Transformation technique under development

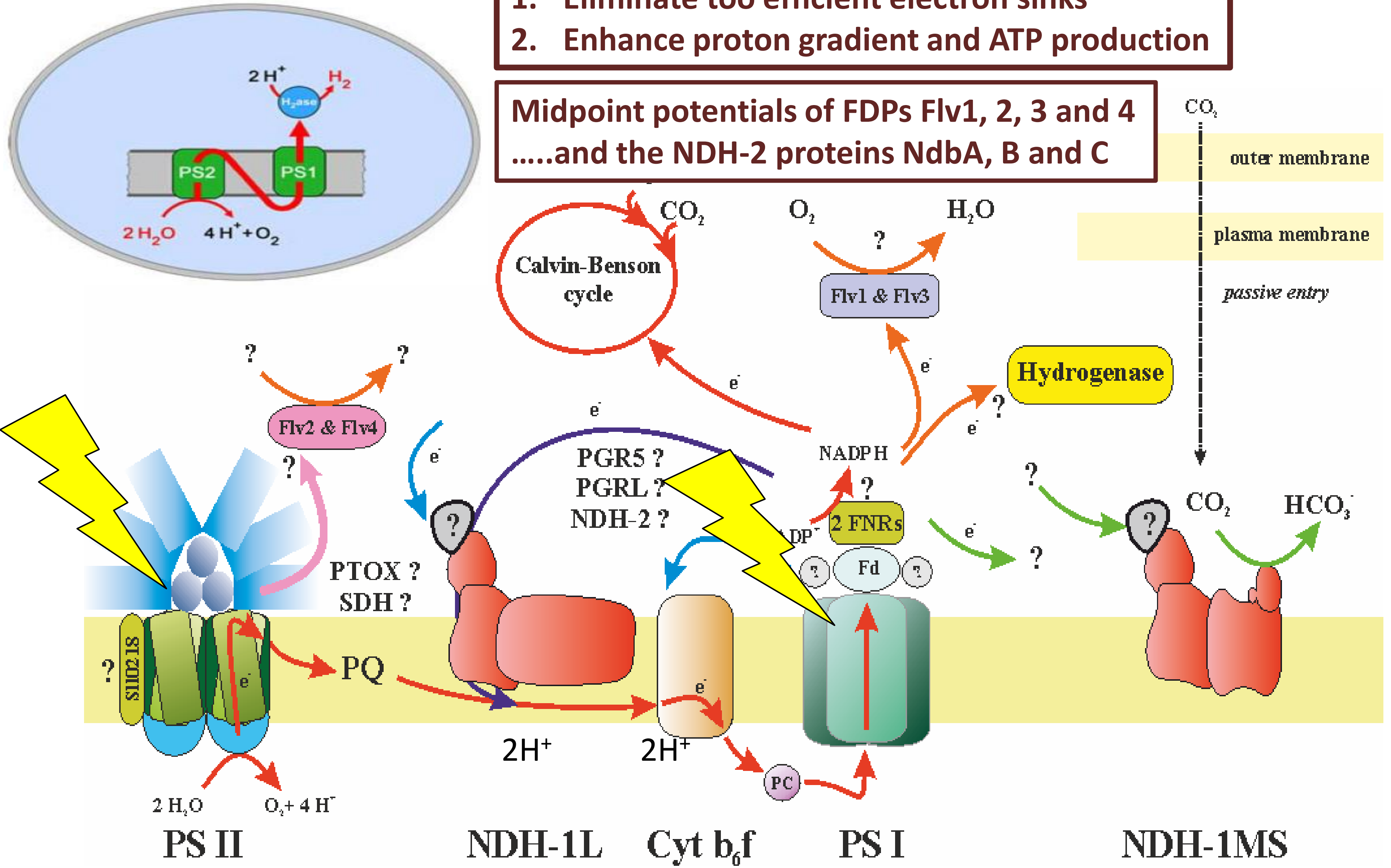
PEO NO 2.

- **This PEO would combine the photosynthetic machinery of *Synechocystis sp. 6803* and an electron transport pathway (*e.g.* Mtr pathway of *Shewanella oneidensis*)**
  – The photosynthetic machinery is used to enhance the production of ATP in the hybrid organism …………. alternative approaches to be designed.

Photosynthetic light reactions in *Synechocystis* thylakoids

1. Eliminate too efficient electron sinks
2. Enhance proton gradient and ATP production

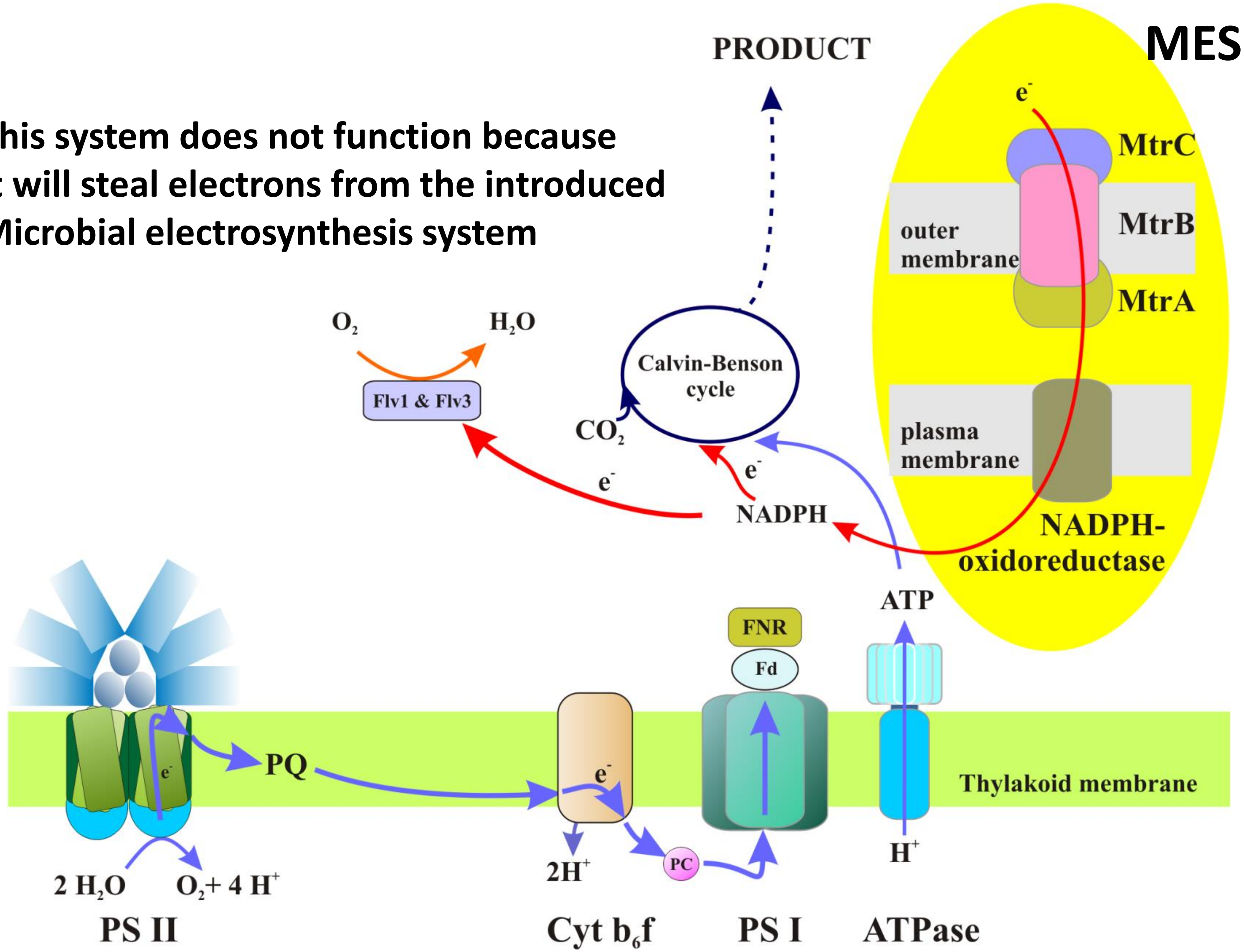
Midpoint potentials of FDPs Flv1, 2, 3 and 4
…..and the NDH-2 proteins NdbA, B and C



Allahverdiyeva et al., 2011, JBC; Zhang et al., 2012 Plant Cell; Allahverdiyeva et al., 2013, PNAS.

Microbial electrosynthesis to Synechocystis

This system does not function because
It will steal electrons from the introduced
Microbial electrosynthesis system



PEO NO 2.

If anaerobiosis is required!

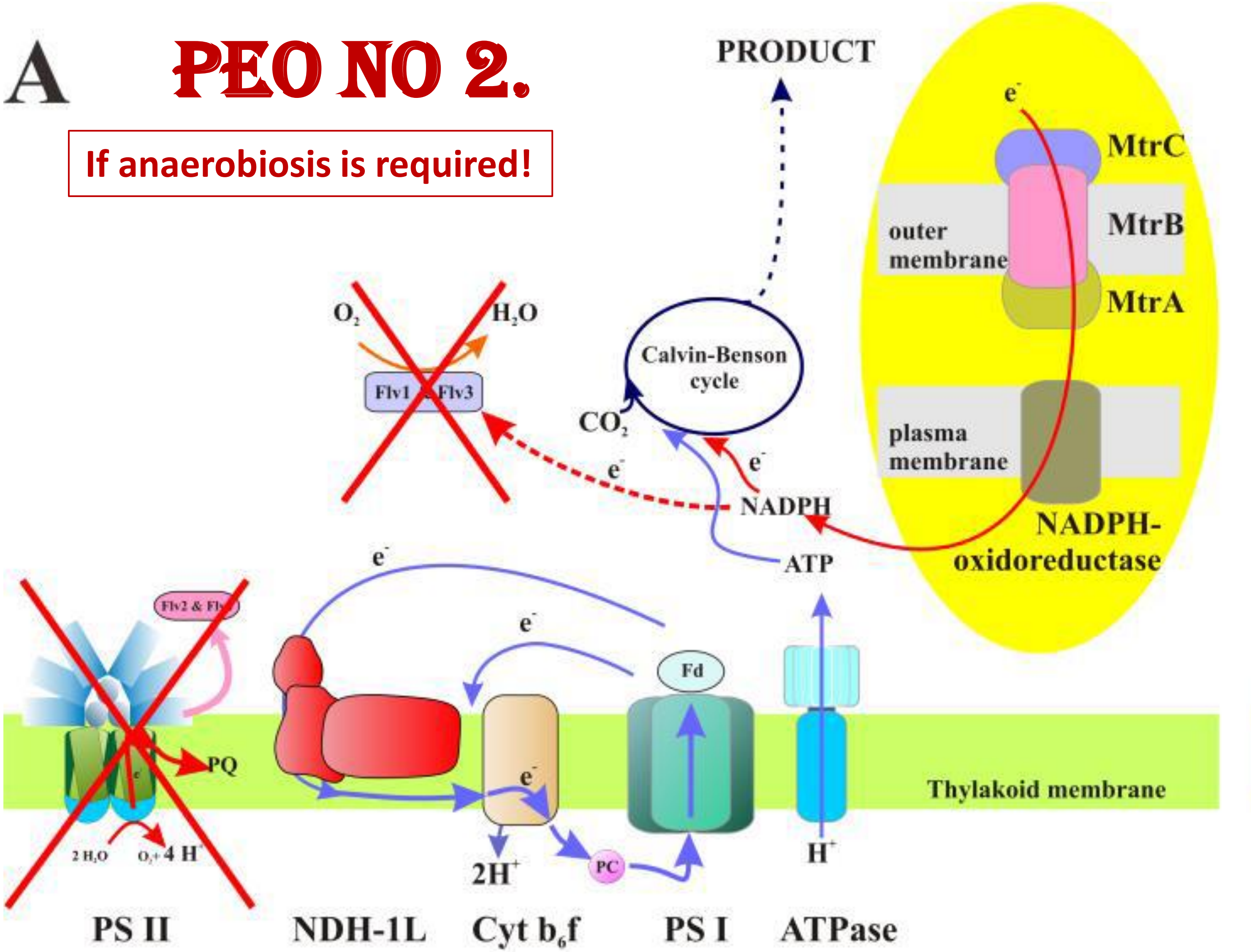


Figure 1. Construction of the MES pathway (shown in yellow background) into Synechocysis. ATP production in the thylakoid membrane (A) by cyclic PS I.

PEO NO 2.

If anaerobiosis is NOT required!

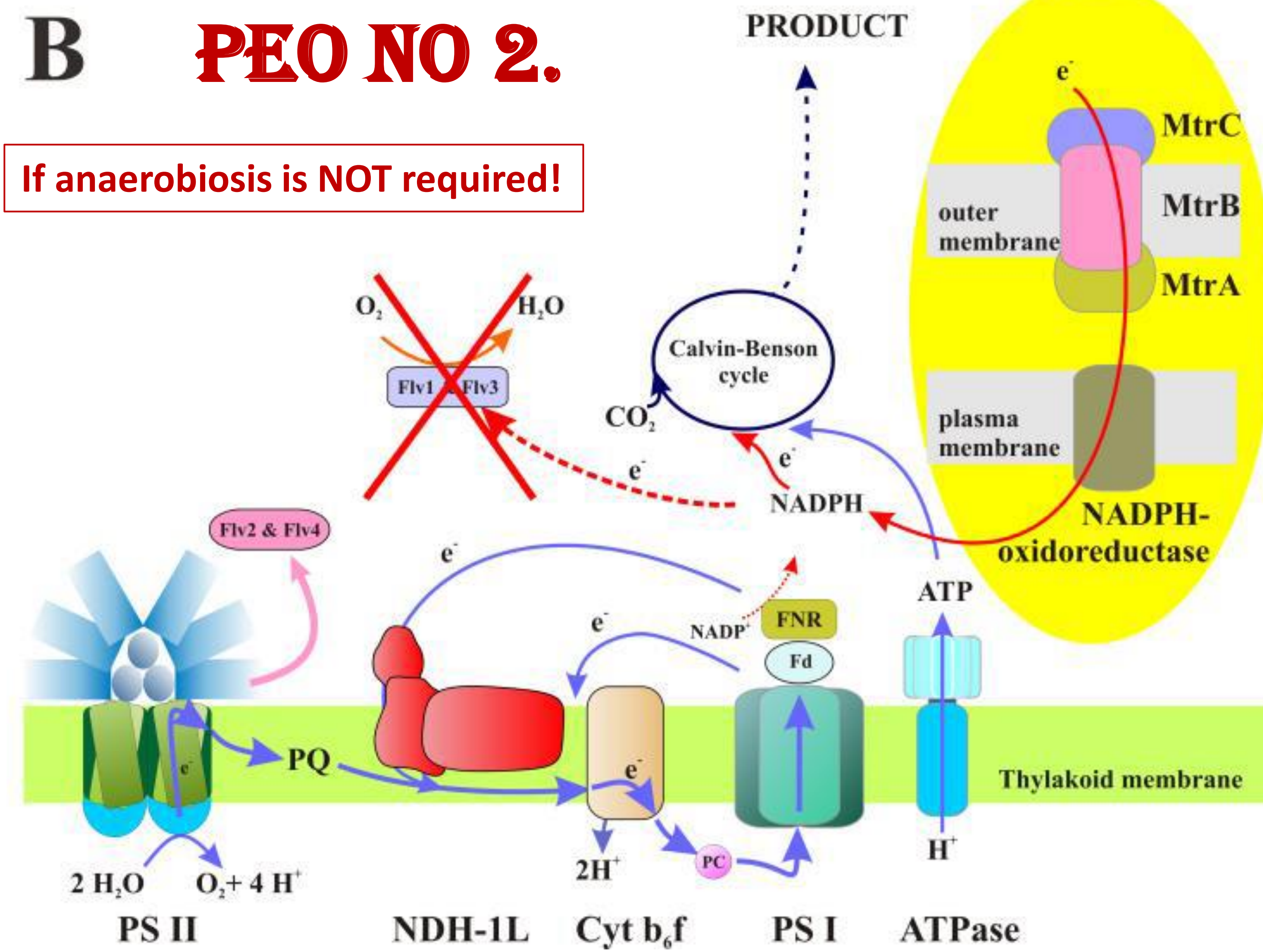
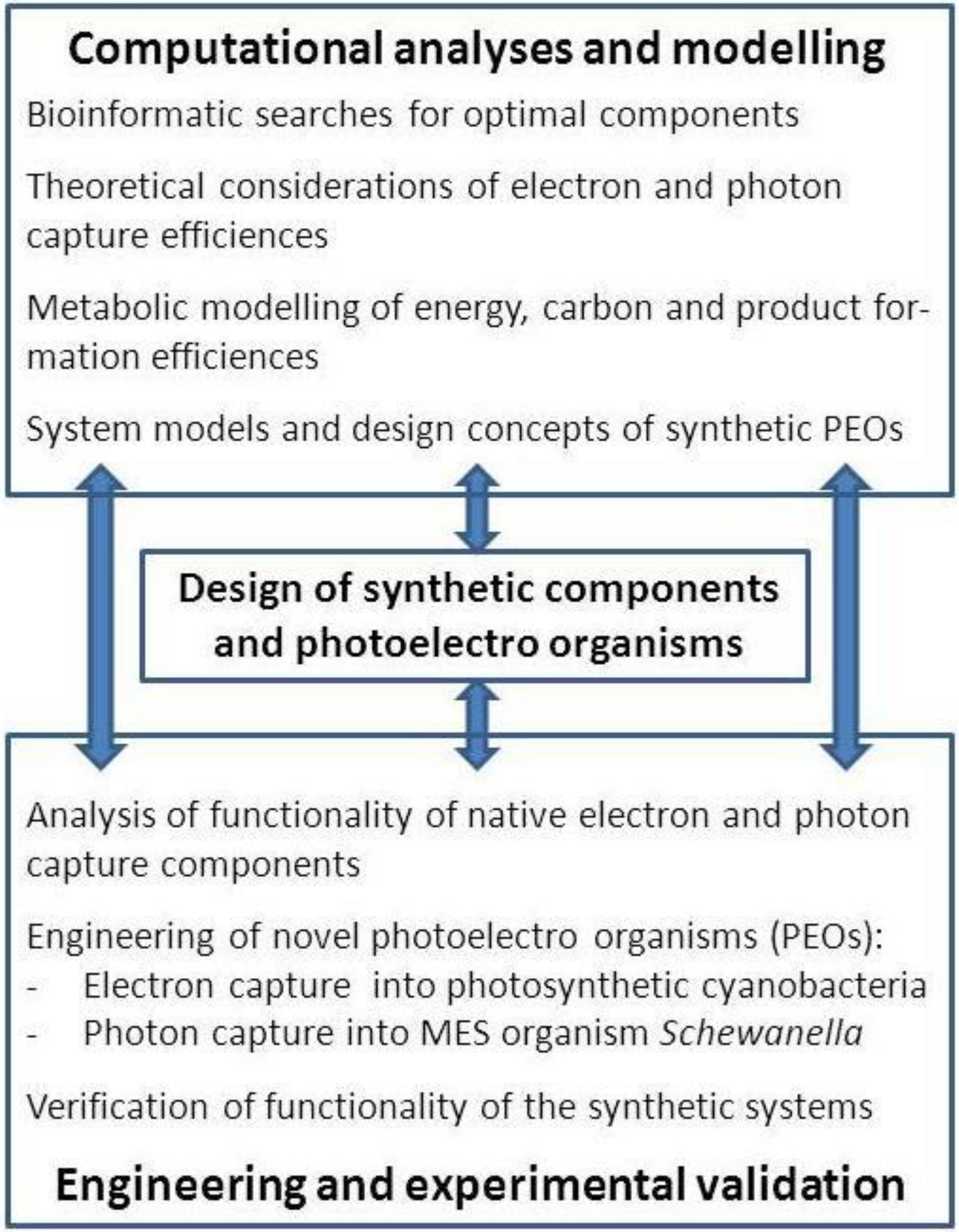


Figure 1**. Construction of the MES pathway (shown in yellow background) into Synechocystis. ATP production in the thylakoid membrane* ***(B) *by involving PS II and the Flv2/Flv4 heterodimer.*


Computational analyses and modelling
Bioinformatic searches for optimal components
Theoretical considerations of electron and photon capture efficiences
Metabolic modelling of energy, carbon and product formation efficiences
System models and design concepts of synthetic PEOs
Design of synthetic components and photoelectro organisms
Analysis of functionality of native electron and photon capture components
Engineering of novel photoelectro organisms (PEOs):
- Electron capture into photosynthetic cyanobacteria
- Photon capture into MES organism *Schewanella*
Verification of functionality of the synthetic systems
Engineering and experimental validation

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Thank You!

SUOMEN
AKATEMIA

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