MELiSSA
MICRO-ECOLOGICAL LIFE SUPPORT SYSTEM ALTERNATIVE

CREATING A CIRCULAR FUTURE

Microalgae-based biofaçade

A solution to support sustainable access to food, energy, and water in urban centers

Flora GIRARD – PhD student
University of Nantes
GEPEA Laboratory, UMR-CNRS 6144 (France)

Outline of the presentation

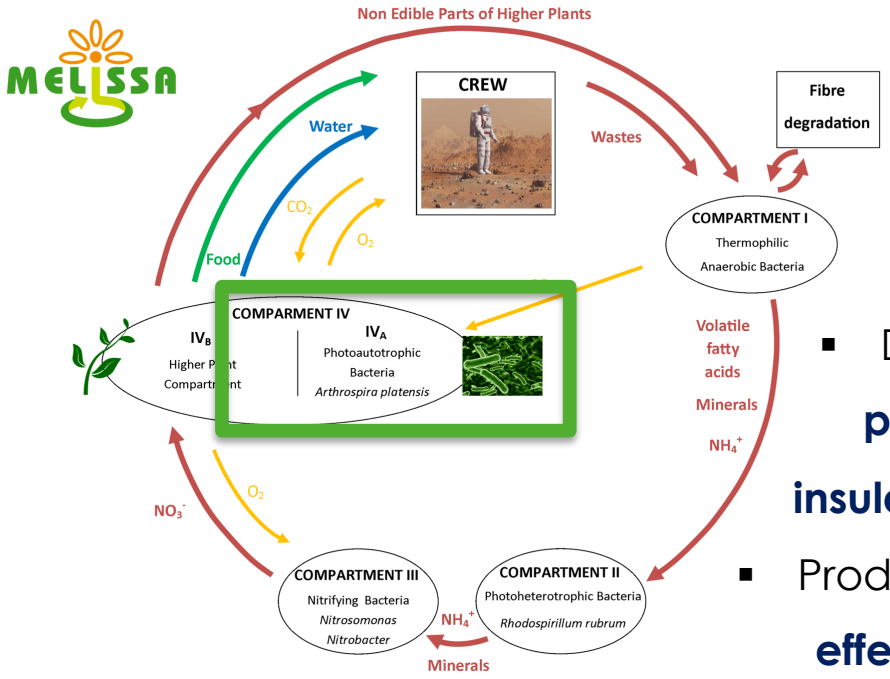
I. Microalgae-based biofacade : context and technical aspect

II. Research topic : aim, results and perspectives

III. Conclusion

2

Biofaçade : context



Terrestrial application of MELiSSA loop concepts

A vertical flat-panel **photobioreactor (PBR)**, on the external **wall** of a building : Set a circular economy between **building metabolism** and **microalgal metabolism**

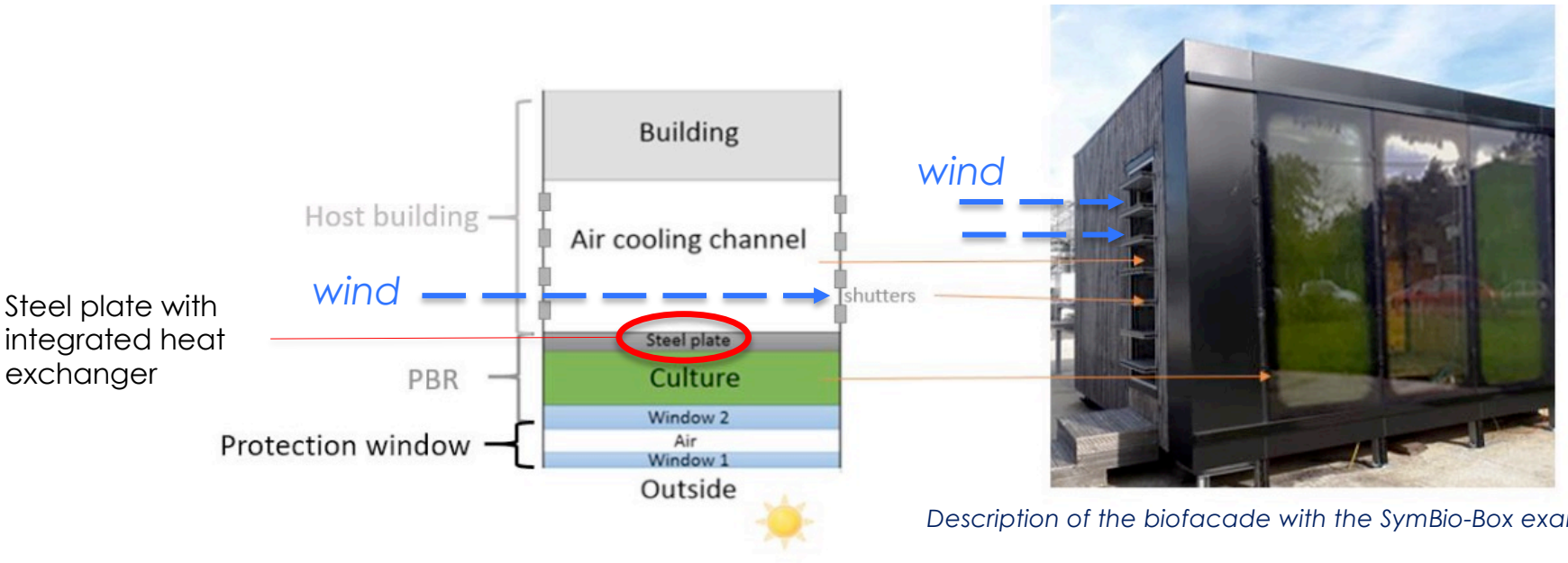
- Decrease human footprint by **improving building energy performances** thanks to the biofacade that can act as an **insulator** and a **waste treatment plant** (waste water and flue gas)
- Produce **high quality and quantity of edible biomass with a cost-effective process** that helps to decrease the cost of microalgal culture in closed PBR thanks to the building

How does it work ?

Biofaçade : technical aspect

European joint patent : « Curtain wall for the industrial optimized production of microalgae on building wall »

By XTU Architects and GEPEA (UMR CNRS / Université de Nantes / ONIRIS / IMT Atlantique)



Description of the biofacade with the SymBio-Box example

Create a double layer ventilated façade on the building wall to cultivate microalgae

4

Biofaçade : background

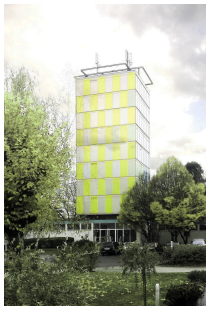
a  b  c 

Figure – facade photobioractors a) SymBIO-BOX in Saint-Nazaire, b) CSTB building in Champs-sur-Marne (2016), c) Future building ALGUESENS project, Paris

SymBio2 project

2008	2013	2016-2019	2020-2023
European joint patent between X-Tu Architects, University of Nantes and CNRS	**SymBIO-BOX** A pilot Algosolis : a R&D facility dedicated to the development of sustainable microalgal industry in Saint-Nazaire	**E. TODISCO's PhD thesis** Demonstration and optimization of microalgal growth in façade photobioreactor Pilot : 200m^2 biofacade on CSTB building (Paris)	**My PhD thesis** System modelling approach to evaluate the integration of microalgal culture in its host building

ALGOSOLIS MICROALGAE R&D FACILITY

5

My PhD thesis : objectives

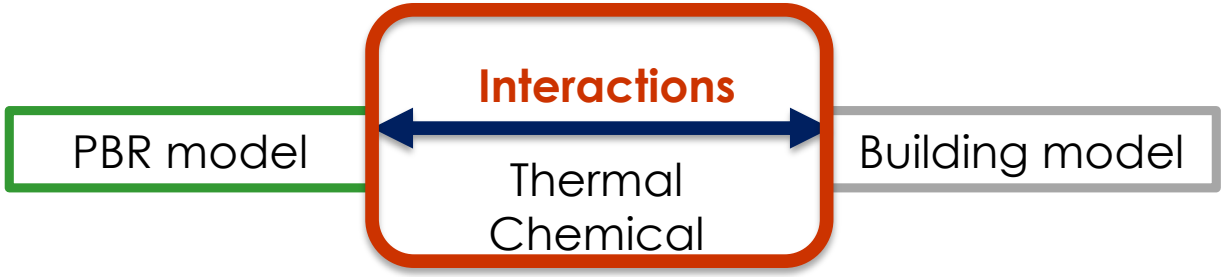
Problematic :

How to optimize the integration of microalgal culture in its host building by a system modelling approach led at the building scale ?

Context :

DISCUS project : international collaboration between research teams based in Nantes (France) and in Los Angeles (University of California Los Angeles).

Objectives :



Methodology :

MODELICA

Object oriented and equation-based language

ADVANTAGES

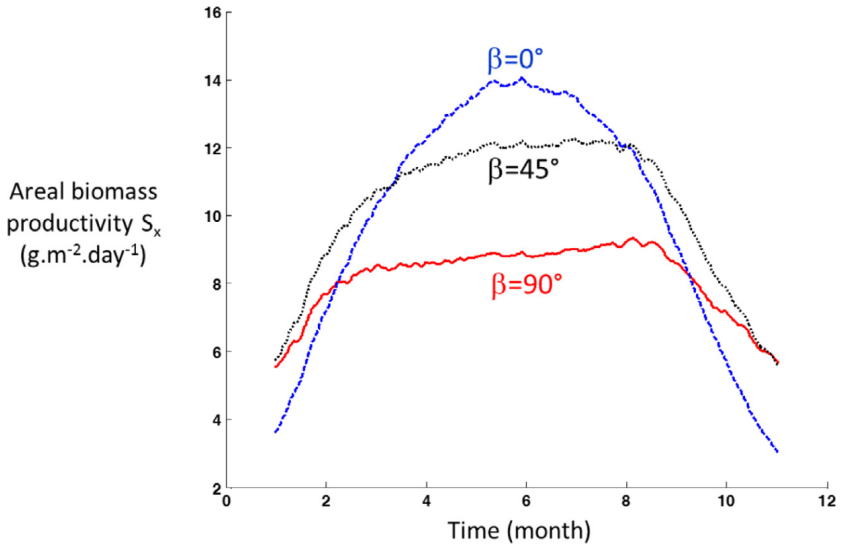
- Multi-domain
- Dynamic
- New and reusable components

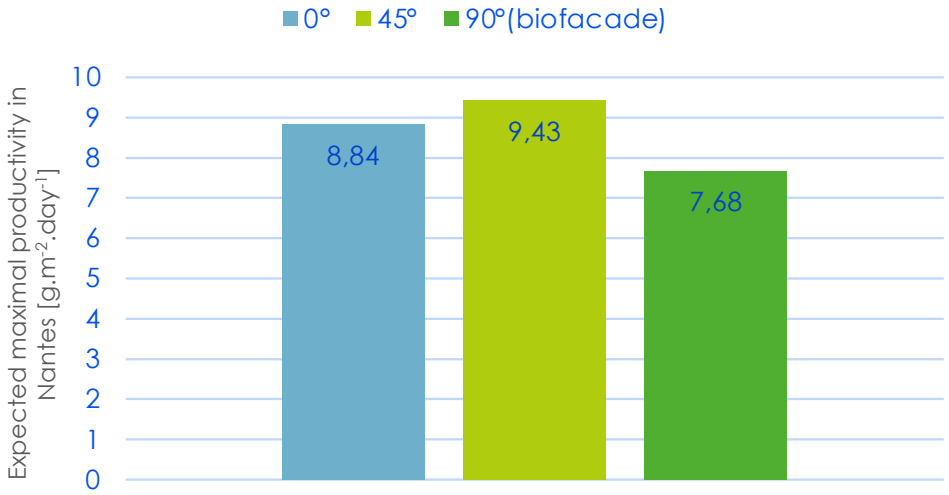
6

BACKGROUND : previous results (1/2)

Biomass production is based on knowledge model developped within the framework of MELiSSA and extended to the solar case

Pruvost, J., Cornet, J.F., Goetz, V., Legrand, J. Modeling dynamic functioning of rectangular photobioreactors in solar conditions. AIChE Journal (2011)





Pruvost, J., et al. « Microalgae Culture in Building-Integrated Photobioreactors: Biomass Production Modelling and Energetic Analysis ». Chemical Engineering Journal 284 (2016)

Estimate productivity for a 100L (2.6m^{-2}) PBR in Nantes : 7,9kg/year = 3 kg.m^{-2}.year^{-1}

BACKGROUND : previous results (2/2)

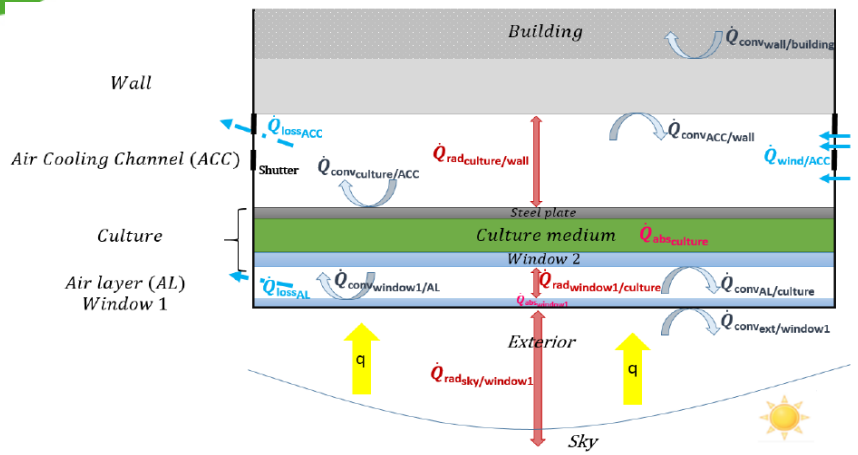
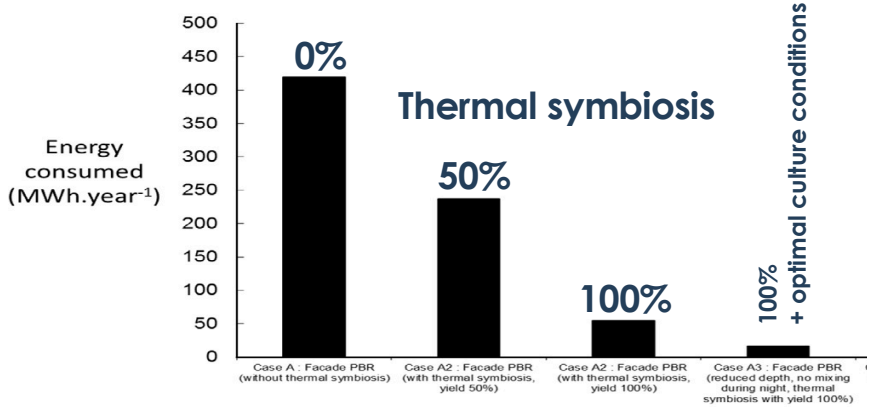
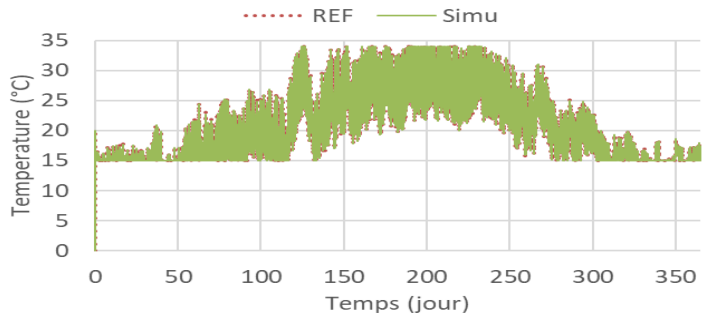
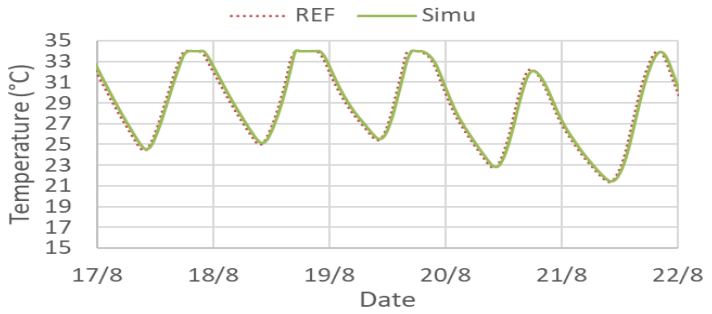


Figure : heat exchanges used in thermal model Todisco et al. (2020)



J. Pruvost et al. (2016) Energy required to produce one ton of biomass per year.





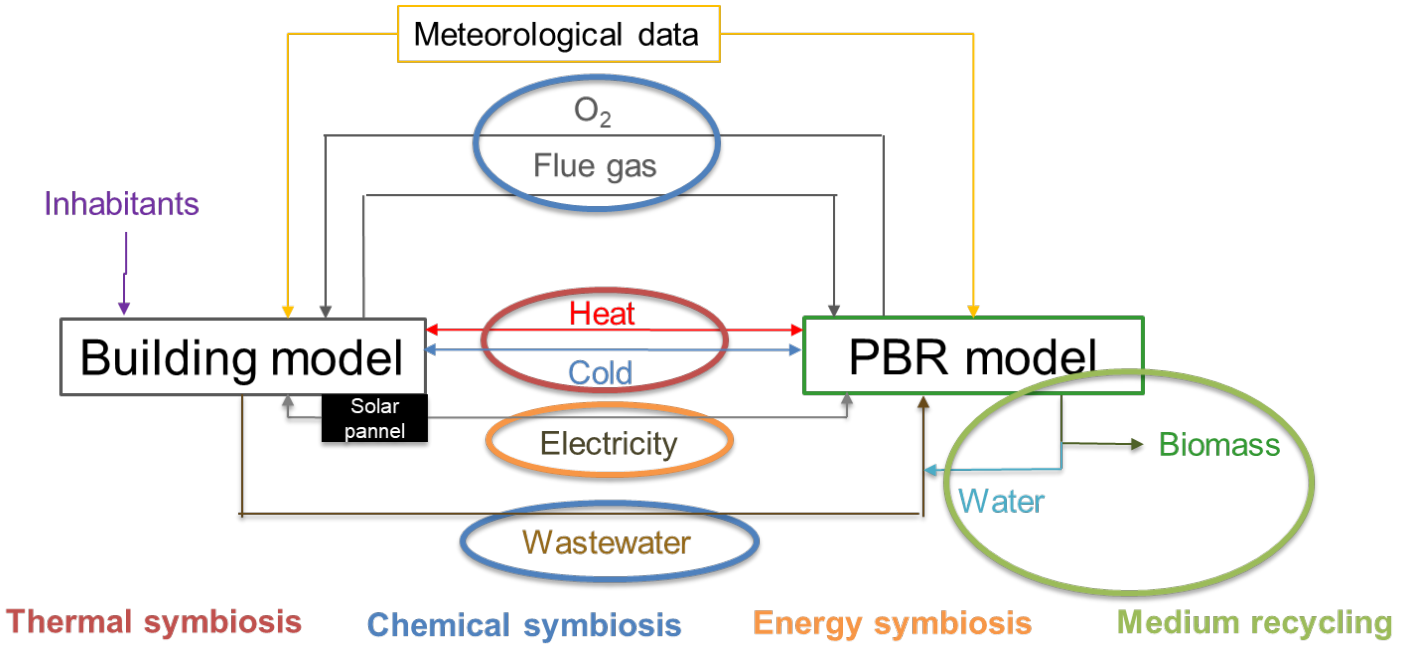
Thermal model prediction acceptable accuracy, above **94%**

Figure : culture medium temperature evolution a) one year b) zoom on a five days period, to validate the thermal model

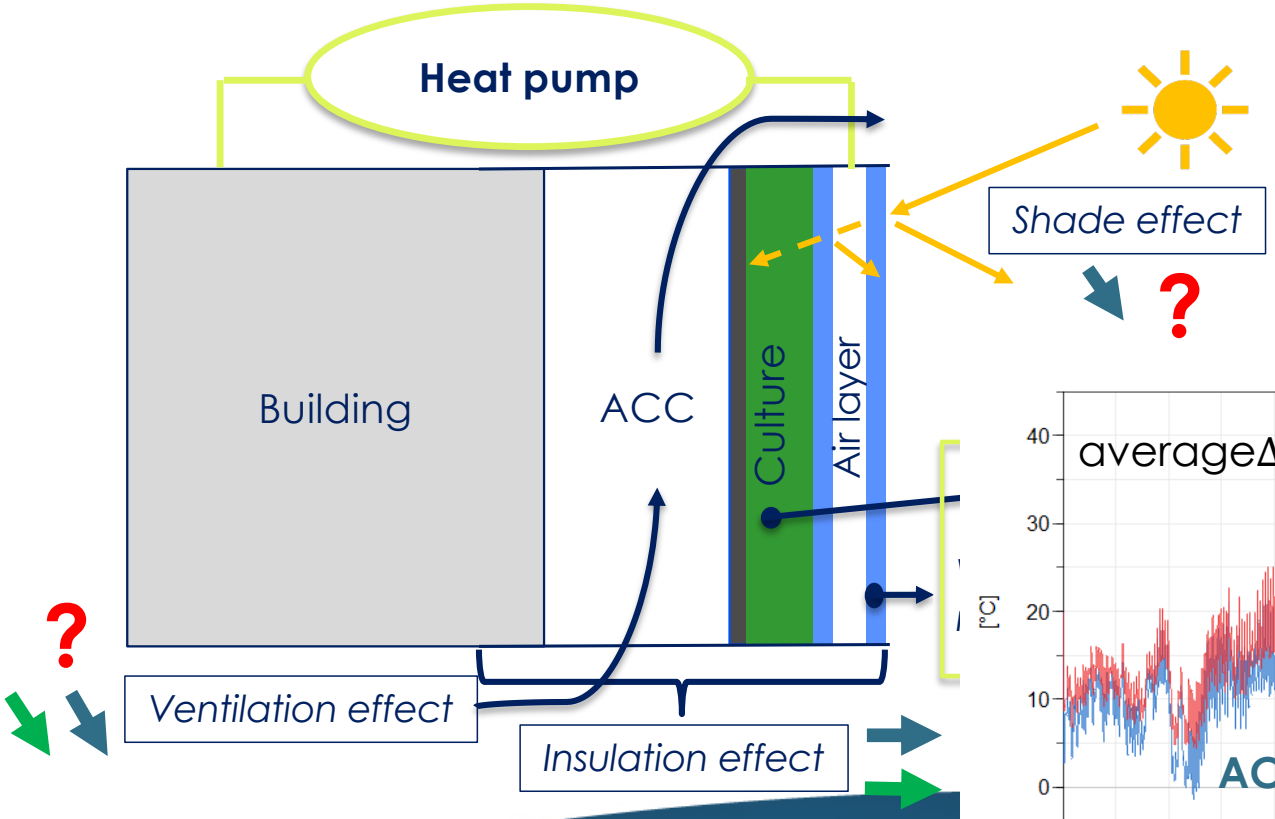
By improving **integration of the facade photobioreactor in its host building** the process energy consumption is significantly decrease

Biofaçade : perspectives

Establish interactions (creating symbiosis) between the building and the PBR for a sustainable system

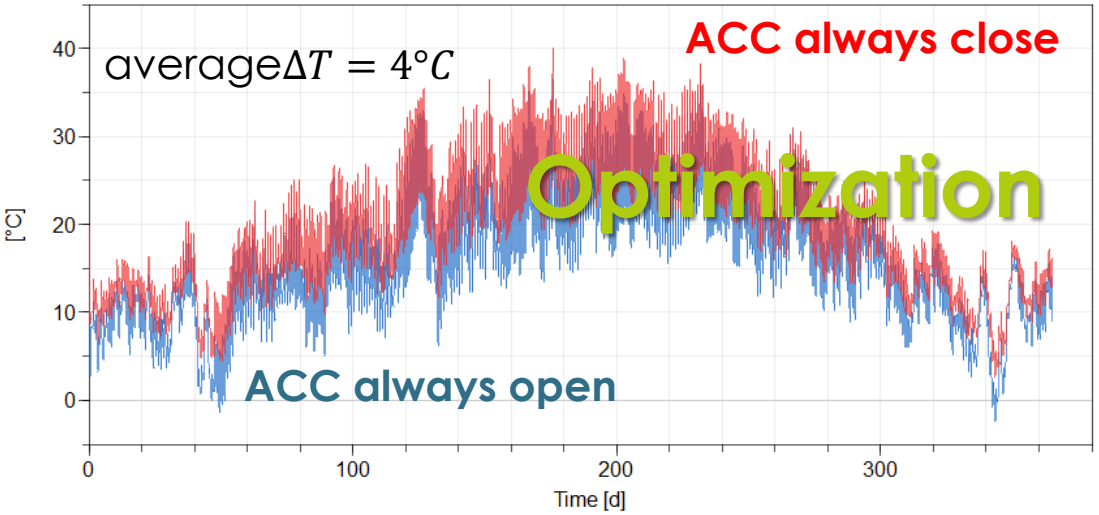


Thermal symbiosis



Increase thermal exchanges between PBR and building to decrease energy consumption related to the regulation of :

- **Building temperature**
- **Culture medium temperature**



Chemical symbiosis : scenario

Flue gas utilization

CO_2 Carbon source
pH regulator

PRE-TREATMENT
CO_2 separation

Building CO_2 emission : 2,3t/year
10 000kWh/year with a natural gas condensation boiler

i.e natural gaz combustion :
$CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$ + Heat

O_2

Growth medium
Source of liquid and nutrients : N, P, S

Example 300m² Biofaçade

Estimate productivity in Nantes : 1t/year

Consumption C.vulgaris:
- ***CO_2 : 1,8t/year***
- ***NH_4^+ : 119 kg/year***
- ***PO_4^{3-} : 28 kg/year***
- ***SO_4^{2-} : 20kg/year***

Yellow wastewater
COD = 5.2g/L
NH_4^+-N = 4.7g/L
PO_4^{3-} -N = 0.26g/L

3 times dilutio
Antifoam ad
Magnesium c
N:P ratio adju

Wastewat

Urine production for 1 person 1.5L/day = 547L/year

NH_4^+ : 2.5kg/year
PO_4^{3-} : 0.142kg/year

≈45 people

TREATMENT
Addition of GAC*
6g/L to remove organic mat
Treatmer
Remediate
+ microalgal residues

Water consumption reduced by 77%

Harvesting

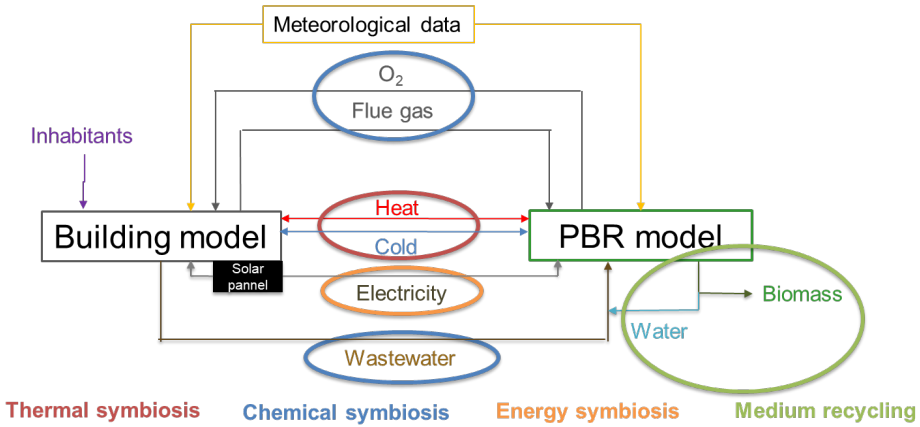
Solid algal biomass

Medium recycling

Hadj-Romdhane, et al. Bioresource Technology 123 (2012)

Perspectives and challenges

In silico engineering at the building scale to **size** these exchange loops and evaluate the impact toward the setting of **sustainable building**



- **Building** and meteorological conditions **dynamic** VS **microalgal metabolism**

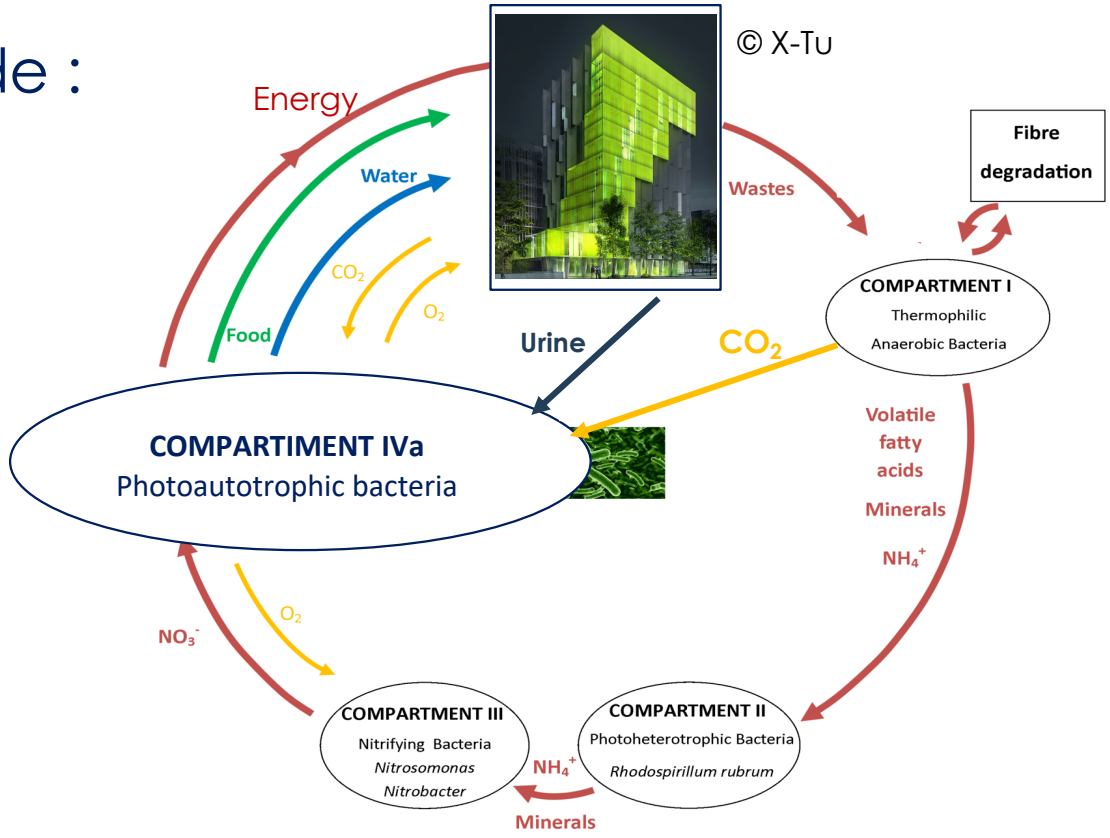
i.e supply discontinuity for flue gas from heating devices according to season (winter heating) and day time (morning shower…)

- Flue gas and wastewater **storage**?

Conclusion

The microalgae-based biofacade :

- **Robust** development based on MELiSSA's models
- **Terrestrial application** : MELiSSA loop concepts in urban centers
- System modelling approach to **optimize** the integration and **develop** the waste treatment potential of this biofacade



13

MELISSA

MICRO-ECOLOGICAL
LIFE SUPPORT SYSTEM
ALTERNATIVE

THANK YOU.

Flora GIRARD, PhD student
GEPEA laboratory
flora.girard1@etu.univ-nantes.fr

www.**melissafoundation**.org

Follow us

GEPEA Environnement • Énergie Agro-alimentaire • Mer
UNIVERSITÉ DE NANTES
IMT Atlantique Bretagne-Pays de la Loire École Mines-Télécom
Oniris École Nationale Vétérinaire, Agroalimentaire et de l'Alimentation Nantes Atlantique
cnrs

http://www.gepea.fr/

PARTNERS

IN COOPERATION WITH

esa European Space Agency

MELISSA FOUNDATION

ENGIN SOFT

GHENT UNIVERSITY

SCK·CEN STUDIECENTRUM VOOR KERNENERGIE CENTRE D'ÉTUDE DE L'ÉNERGIE NUCLÉAIRE

SEMILLA IPSTAR Circular Systems™

SHERPA ENGINEERING

University of Antwerp

UAB Universitat Autònoma de Barcelona

UCA Université Clermont Auvergne

UNIVERSITY of GUELPH

UMONS Université de Mons

Unil UNIL | Université de Lausanne

vito