Appendix Q

Applicability of EcosimPro to simulate a Life Support System

Victor Guirado Viedma
(NTE, Spain)

Abstract

The project MELiSSA Adaptation for Space Phase II (ESTEC/contract 20104/06/NL/CP) carried out by NTE (Barcelona, Spain) consists of finding a preliminary design of a Life Support System (ECLSS) for a future Moon base providing 100% air closure, 90% water closure and a 5% food production first and a 40% food production in a second steps. The study is mainly based on MELiSSA know-how but using as well other European sub-systems as the Air REvistalisation System (ARES), the Gray Water Treatment Unit (GWTU) and the Urine Treatment Unit (UTU). In our modeling approach, each of these sub-systems is composed of several components that can actually be combined and joined to finally obtain a robust and efficient ECLSS.

These different sub-sytems have been modeled at component level and interconnected using EcosimPro to generate a mass balance static model. Using this software tool, several designs have been created and simulated in order to evaluate which configuration is the most appropriated regarding efficiency, size, mass and energy consumption (i.e ALISSE criteria).

The implementation of a mathematic model for each component has been one of the more important and difficult steps. The difficulty came not only due to the complexity of the processes that take place but also due to the fact that many technologies are under study and several assumptions had to be done. This issue specifically raised the management of the degree of confidence and the need to add specific function for uncertainties calculations.

Another difficulty turned up when the whole system was closed due to the algebraic loops and because the EcosimPro mathematic solver needs the indication of which are the variables to iterate to find a solution to the equation system.

In the European Workshop on Thermal and ECLS Software, it is intended to expose in general terms how the EcosimPro works, how it has been used, as well as the difficulties found and the solutions performed. The library created in EcosimPro contains the models of several subsystems for different ECLS technologies, and endeavors to be a tool base to develop more sophisticated models, which will allow system engineers to evaluate ECLSS architecture and anticipate the ALISSE criteria.

Applicability of EcosimPro to simulate a Life Support System.

Victor Guirado Viedma

Can Malé , s/n · 08186 Lliçà d'Amunt · Barcelona (España) · Tel. +34 938 60 90 01 · Fax. +34 938 60 90 19 · www.nte.es

MELiSSA Adaptation for space phase II

GLOBAL OBJECTIVE

- The main objective is to design a preliminary Life Support System design for future Moon base providing:
  - 100% Air Closure
  - 90% Water Closure
  - 5% Food Production (1st phase)
  - 40% Food Production (2nd phase)
- To distinguish which design is the optimum, ALISSE criteria is used:
  - Efficiency
  - Size, Mass of the Whole System
  - Mass Supply
  - and Energy Consumption

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What is Ecosim Pro?

- It is a software created by Empresarios Agrupados, EA, (Madrid)
- Consist of basically making a “component” where take place the mathematical model
  - A component may be simple, for example an electrical resistor or capacitor (with a couple of equations); or it may be very complex, for example the pressurized cabin of a space vehicle (with dozens of physics equations and many events)
- Ecosim Pro uses an own language called EcosimPro Language (EL)
- It is thought to dynamic systems but can be useful for static systems too
- In Ecosim are several libraries with different components already created and available to be used
- The version used has been 4.4.0

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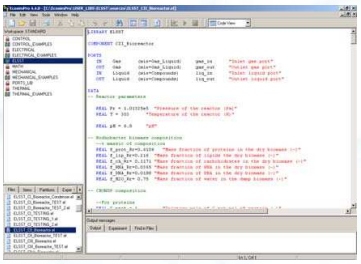
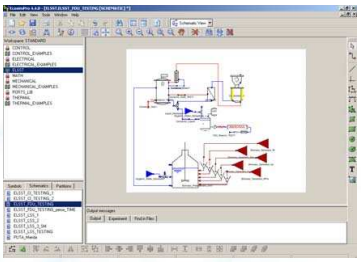
What is Ecosim Pro?

Ecosim Pro can be divided in three parts:

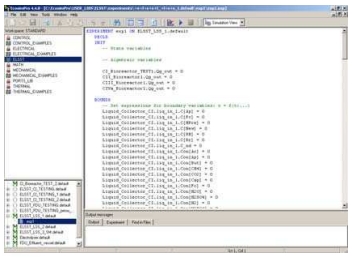
Code View



Schematic View



Simulation View



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What is Ecosim Pro?

- Code View
  - Creation of:
    - **Components** → It is the most important element in Ecosim Language. It represents a subsystem model by means of variables and equations
    - **Enumerative Types** → They are valid for representing a set of names valid of this type. For example: the chemical compounds that can participate in the System (NH3, CO2, O2, etc)
    - **Functions** → It is a piece of code that carries out operations and optionally returns values. It has been used to do common operations in the different components
    - **Ports** → It connect components and must have a mode, either IN (implies inward flow) or OUT (implies outward flow)

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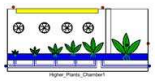
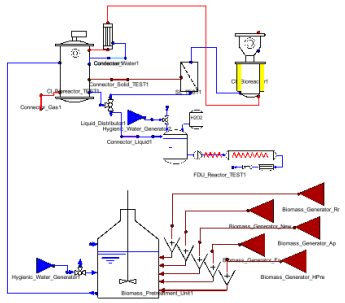
What is Ecosim Pro?

- Schematic View
  - Creation of:

Symbols → It is the drawing representation of a component



Schematics → It is the creation of a block diagram where the symbols are connected by means of their ports



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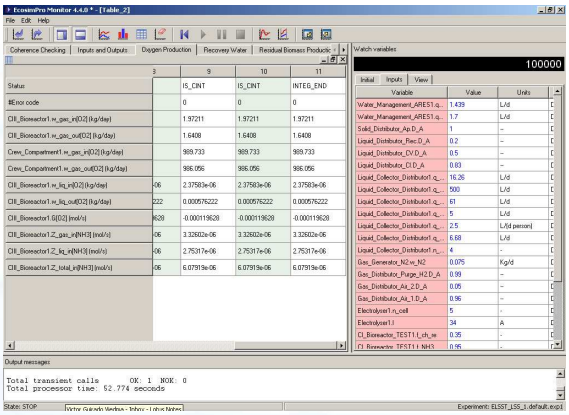
What is Ecosim Pro?

- Simulation View
  - Creation of:
    - **Experiments** → Here you can choose several characteristics to run the simulation and to view the results in different ways (for example using **Ecomonitor** where you can see tables and graphs)



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Applicability of EcosimPro

ACTIVITIES

1. Review of Technologies to be modeled
   - MELiSSA (MicroEcological Life Support System Alternative)
   - ARES (Air REvitalization System)
   - GWTU (Grey Water Treatment Unit)
2. Use and/or elaboration of a mathematic model for each subsystem of each technology
3. Implementation of the model in EcosimPro (components creation)
4. Simulation and validation of each subsystem separately (coherence of mass balances and fitting with the experimental data)
5. Design and simulation of an optimum configuration for the two phases of the study

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Applicability of EcosimPro

Review of each Technology

- MELiSSA (MicroEcological Life Support System Alternative)
  - Compartment I (Liquifying)
  - Compartment II (Removal of dissolved organic carbon)
  - Compartment III (Transform the ammonia into nitrate)
  - Compartment IVa (Produce oxygen and edible biomass)
  - Higher Plants Chamber (Produce oxygen, edible biomass and water)
- ARES (Air REvitalization System)
  - CCA (Carbon dioxide Collection Assemble)
  - CRA (Carbon dioxide Reduction Assemble)
  - OGA (Oxygen Generation Assemble)
- GWTU (Grey Water Treatment Unit)

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Applicability of EcosimPro

Elaboration of a Model for each Subsystem and its Implementation in EcosimPro

STEPS:

1. Simplification and adaptation of existing knowledge based models (MELiSSA)
2. Elaboration of mathematical models for other technologies (ARES, GWTU, etc)
3. Generation of Components in EcosimPro using the mathematical models
   - capable to represent the real subsystem
   - capable to connect one another in order to check what connection is most suitable under different operational conditions
4. Creation of new components that represents interface subsystems (Gas Collector, Valves, etc) and other that represent a subsystem that does not exist but is necessary.

→ There are about 35 subsystems modeled and get together in a library within EcosimPro

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Applicability of EcosimPro

Component Modelling Overview

Steady State

ASSUMPTIONS

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EQUATIONS

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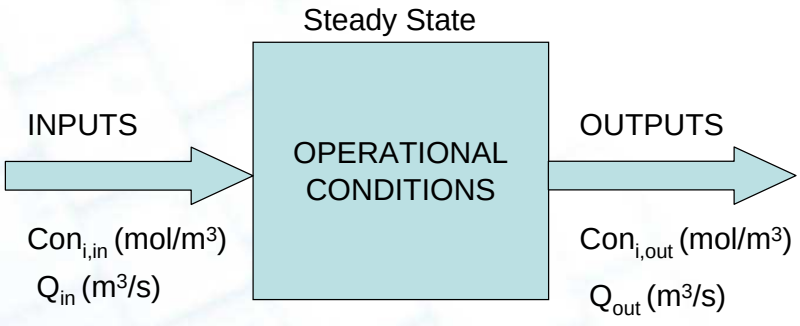
Applicability of EcosimPro

Component Modelling Overview



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Applicability of EcosimPro

Simulation and Validation of each Subsystem Separately

- Coherence of mass balances → Checked for all Components
- Fitting with the literature experimental results → Checked for some Components

Design and Simulation of an Optimum Configuration for the Two Phases of the Study

- 1 Preliminary design for the 1s phase (5% of food production)
- 1 Preliminary design for the 2nd (40% of food production)

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Applicability of EcosimPro

Steps to Simulate a Configuration with an Optimum Preliminary Design

1. Creation of a block diagram
2. Creation of a Partition (Election of: boundary variables, algebraic variables, etc)
3. Generate an Experiment (Election of the time stop, initial time, etc)
4. Run the simulation
5. Check the coherence of the whole system (mass balances and requirements achieved)
6. Optimization of the System (to change some operational data and maybe some connections to improve the results)
7. Interpretation of the Results

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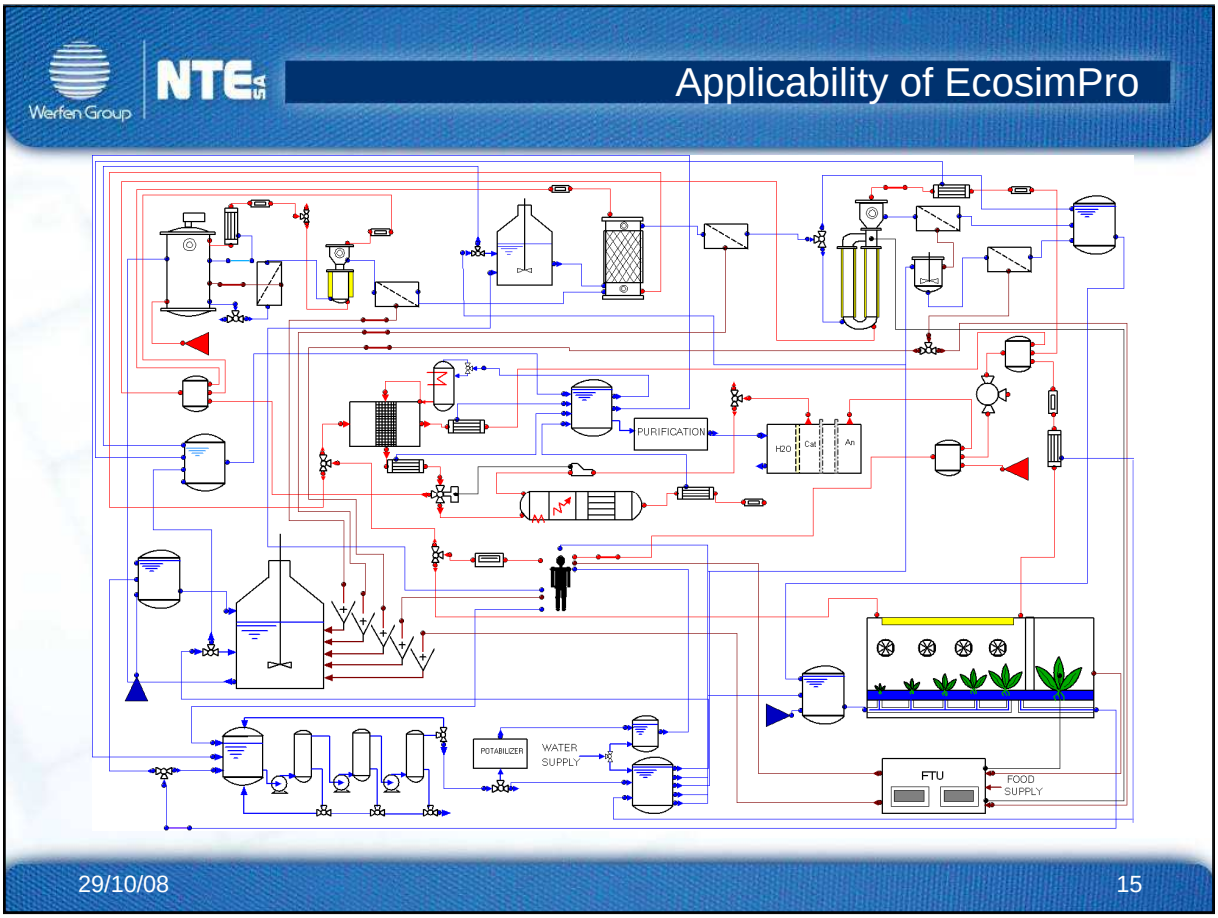
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PURIFICATION
H2O
Cat
An
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WATER SUPPLY
FTU
FOOD SUPPLY
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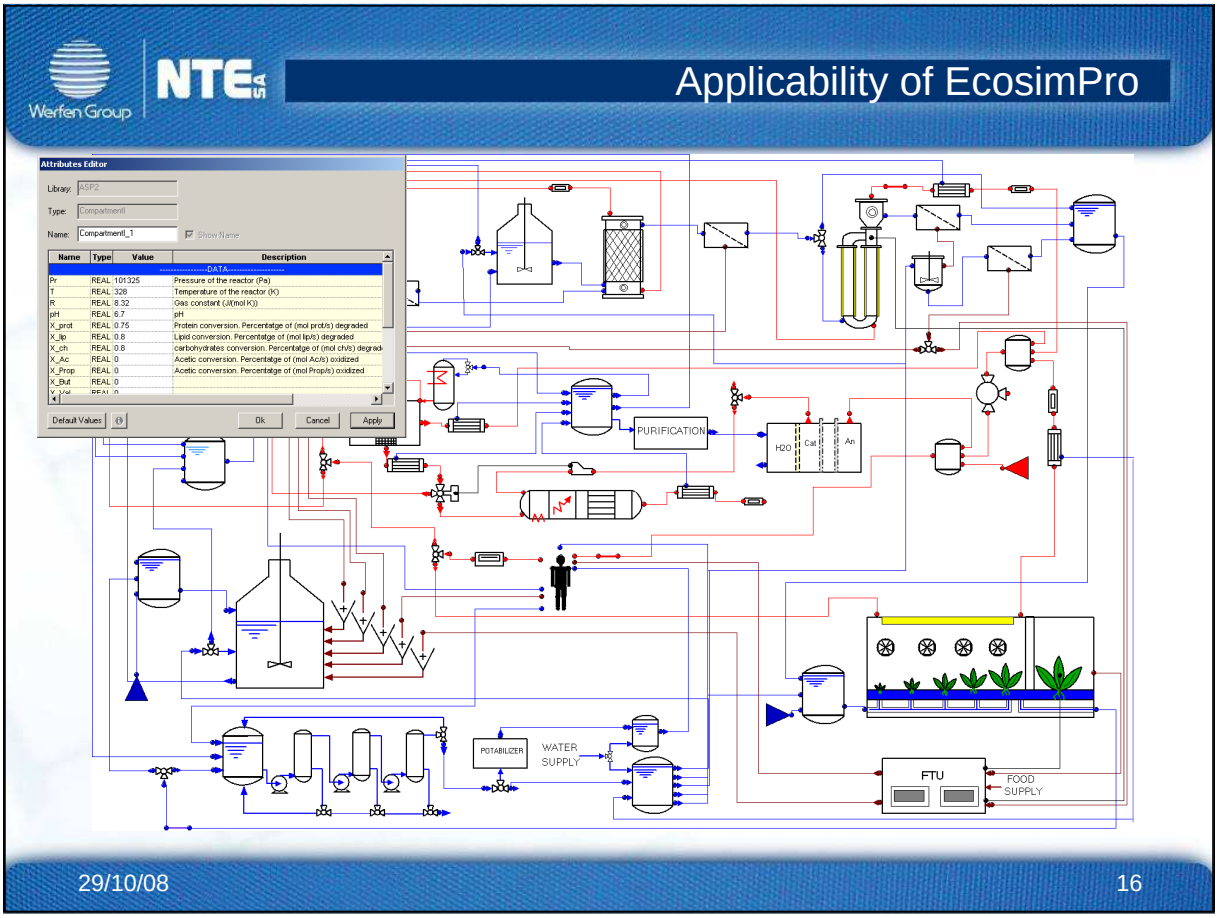
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Attributes Editor
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Default Values
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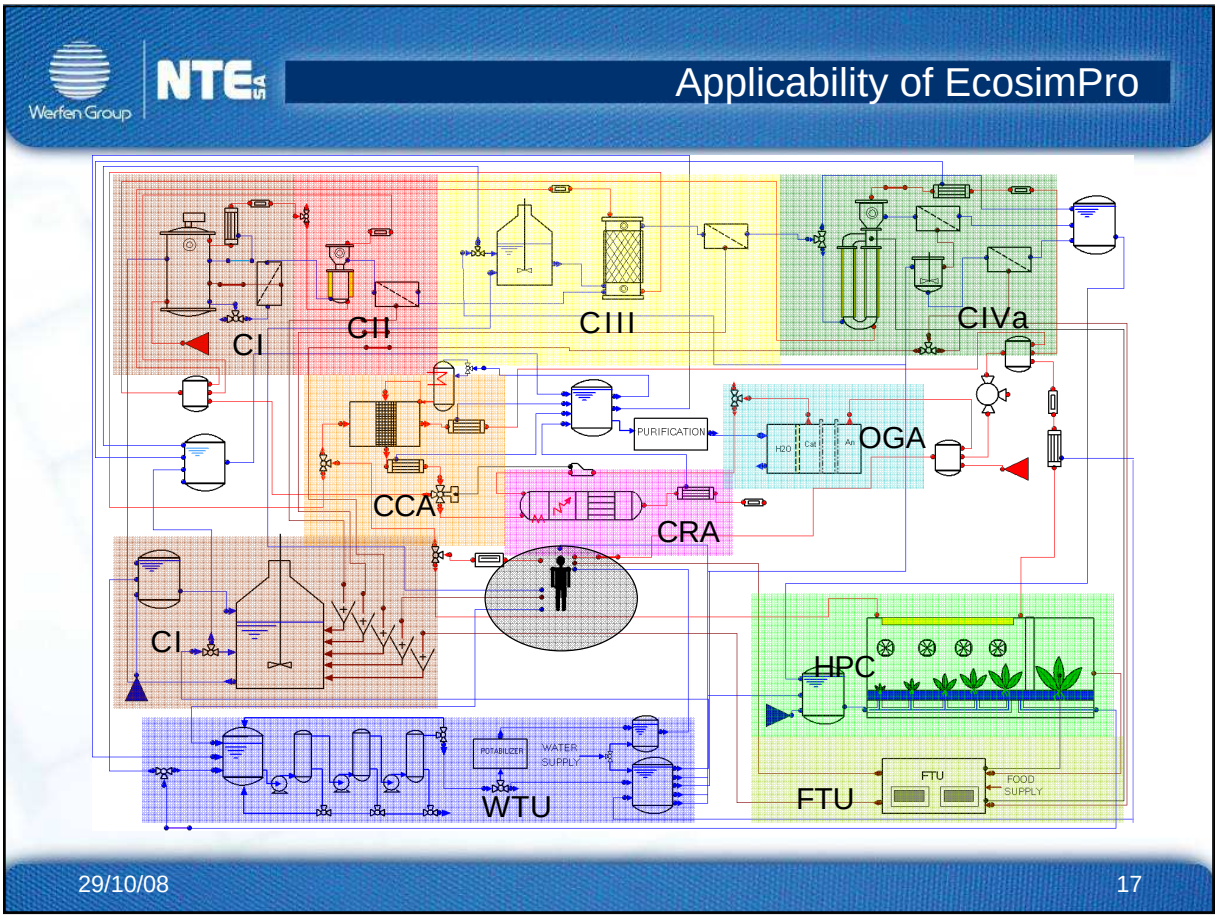
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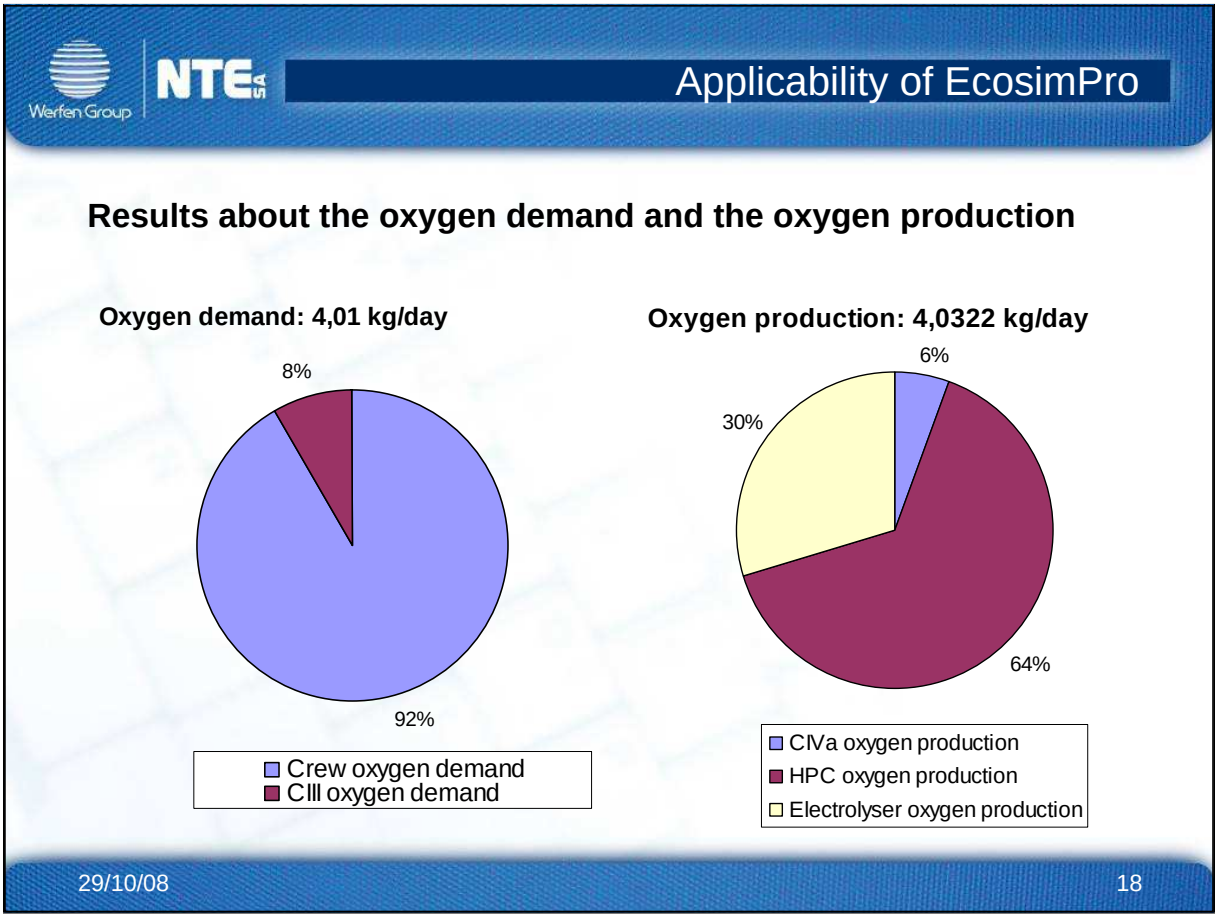
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Results about the oxygen demand and the oxygen production
Oxygen demand: 4,01 kg/day
8%
92%
Crew oxygen demand
CIII oxygen demand
Oxygen production: 4,0322 kg/day
6%
30%
64%
CIVa oxygen production
HPC oxygen production
Electrolyser oxygen production
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Applicability of EcosimPro

Difficulties found & Solutions Performed

Difficulty	Solution	Consequence
Error message when the denominator is zero:	Creation of a function to return zero, when the denominator is zero.	▪ The program works properly
Algebraic Loop generated in some Components: ▪ Several variables to be iterated ▪ Too high computation time ▪ The system does not converge	Reorganize the equations to force the system to iterate only one variable. ▪ A good knowledge about the mathematical model and about the process that takes place is necessary to choose the variable to be iterated	▪ The equation system does not always converge: The results obtained are limited to certain inputs

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Applicability of EcosimPro

Difficulties found & Solutions Performed

Difficulty	Solution	Consequence
Algebraic Loop generated in the whole system when it is closed: ▪ A component needs inputs that are actually the outputs of the previous component	Creation of a dynamic Component: ▪ It's a dynamic component that delays the inputs: ▪ For long times the outputs are equal to the inputs	▪ The results are good for long times

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Applicability of EcosimPro

Conclusions

- EcosimPro is a good tool to run simulation about any system:
  - You can have a previous idea about the design of a system and about its feasibility
  - You can compare between different design and distinguish which is better depending on your criteria
  - You can take advantage from the models already elaborated to simplify it or to get it more complex

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Applicability of EcosimPro

Thank you for your attention

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