— EcoDyco—

Economic Simulation in a World of Finite Resources

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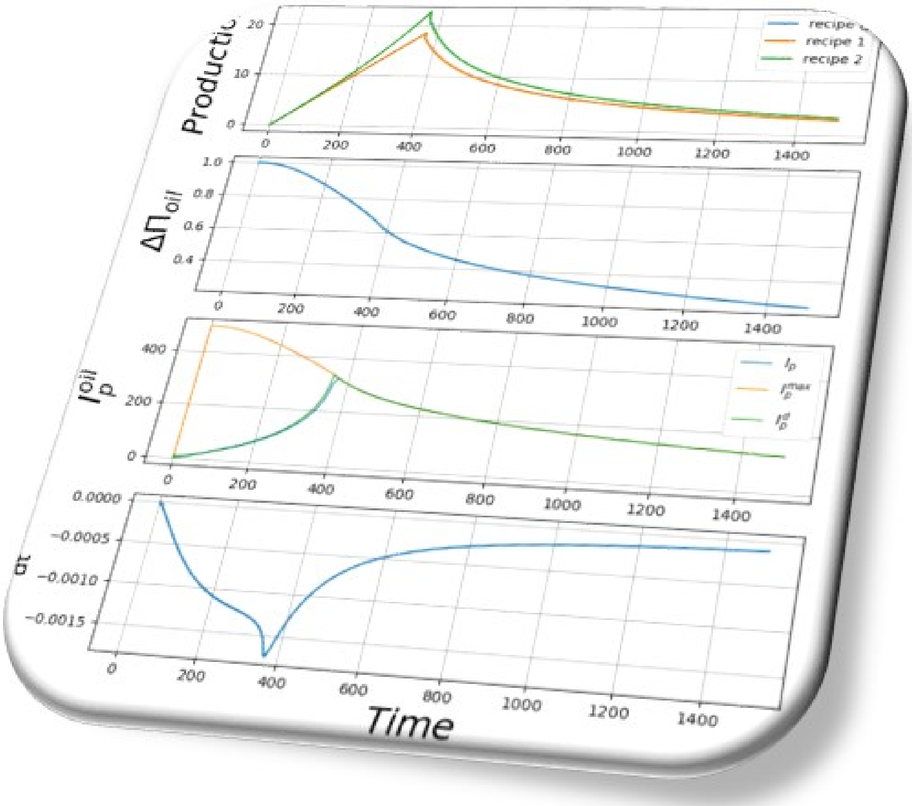

User Manual v1.0

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All the material necessary to run the following examples, including this manual, can be found at `https://github.com/dyco-uparis/EcoDyco`.

Contents

1 EcoDyco: Economic Simulation in a World of Finite Resources

The model EcoDyco was designed on the basis of five findings:

1. If the physical world is modified by the application of the laws of the economy of the economy, the fact remains that its evolution is governed by physical laws.

2. The physical world is finite, this is true for all material resources resources and for fossil energy resources.

3. In a finite world, the definition of a production function must take into account the state of the resources. Production is contingent on the available resource.

4. The intensity of withdrawal from a resource is a major factor on the fate of the resource.

5. If the economy is not strictly describable by thermodynamics, thermodynamics can provide it with some useful categories, and in particular the In particular, the distinction between *quantity* and *quality*, themselves linked to the intensive or extensive character of the variables.

These findings form the basis for the structure and operation of the model EcoDyco.

1. The descriptions of the physical and economic spheres of the model are disjointed. They communicate through specific variables and parameters.

2. Each resource is described in its own sheet. The collection of sheets thus obtained is the physical sphere. Each sheet quantifies the usable fraction and the used fraction of the Each sheet quantifies the usable fraction and the used fraction of the resource, which we will call waste. The used fraction can only be used again used again only after recycling.

3. It is defined a production query function called "demand", which replaces, for the physical dimension, the production function. The structure and the parameterisation The structure and parameterisation of the production function are fixed by the specific choices The structure and parameterisation of the production function are fixed by specific choices made in the economic area of the model.

4. It is defined an intensity of operation of the economy which governs the whole of the physical sheets.

5. The quantities of resources are also associated with qualities, which, like the first and second principles, are the image of the first and second principles of thermodynamics, define, the difference in quality of a resource and its state of transformation, towards a transformation, towards a product or towards a waste.

2 General structure of EcoDyco

The model is structured in sheets of stock type and flow type, linked to the economic module. Its overall architecture is shown figure 1.

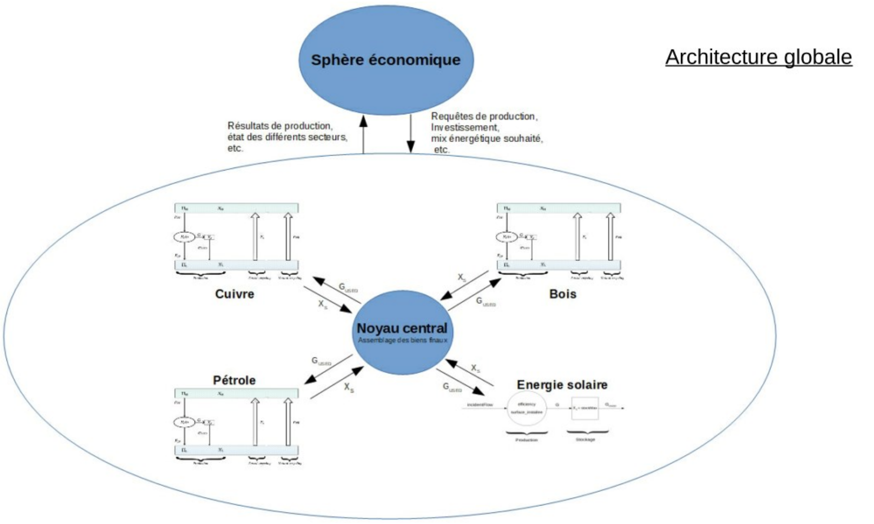


Figure 1: text

2.1 Structure of a Stock sheet

Stock sheets are intended for most resources, mineral, fossil or not, whose quantity on the planet is finite and of variable dispersion.

On a typical stock sheet (figure 2), there is a high zone containing the resource in quantity X_H and quality Π_H and a zone of used resource in quantity X_L and quality Π_L. The resource flows of F_{HP} and the waste flows F_{LP} constitute, together with the production flow G, the whole of the resource flows in its implementation for production. The quantity of resource used in excess constitutes a stock X_S. Recycling can be natural F_{NR}, or forced, F_R, according to specific laws. We call the difference of potentials the quantity $\Delta\Pi = \Pi_H - \Pi_L$.

2.1.1 Stock sheet parameters

A stock sheet is initially defined by the set of limited parameters listed below, values are given as an example.

- *type : stock*
- *name : copper*
- Total quantity — *total stock : 500000*

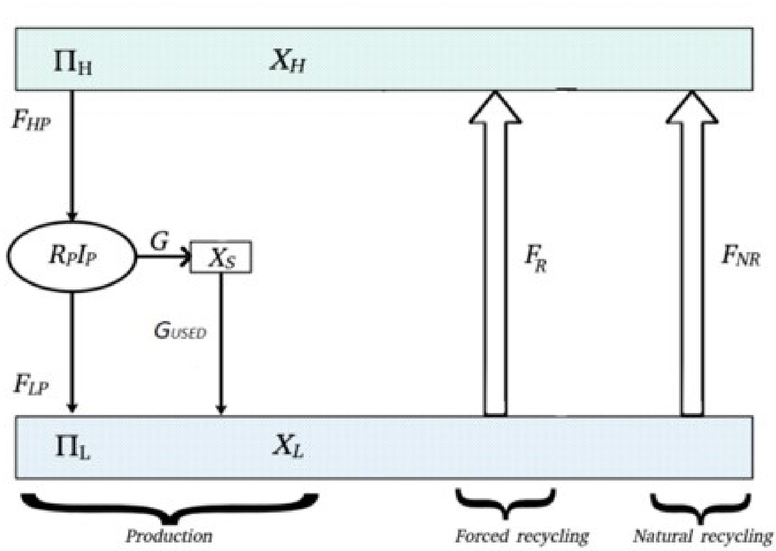


Figure 2: text

- Initial quantity of high level — *Xh_init : 500000*
- Initial quantity of sink — *Xl_init : 0*
- Production dissipation resistance — *Rp0 : 0.003*
- Initial capital associated with the production apparatus — *K0 : 1*
- Recycling energy ratio (number of energy unit to recycle 1 unit of the resource) — *recyclingEnergyFlux : 1*
- Usable as energy (*e.g.* for oil) — *isEnergy : False*
- Natural recycling rate (r=0 : no recycling) — *r : 0*
- Caracteristic time — *to : 9*

The description and use of these parameters is described in detail in the in the annexes to this document. However, special attention is paid to particular attention is paid to R_P.

2.1.2 Dissipation resistance $\mathbf{R}_P$

The dissipation resistance is a term that intervenes, via the production intensity, in the form $R_P I^2$. This term indicates the fraction of the resource that is not used for the production of consumer goods, even though the resource has been taken from the planet. R_P leads to a limitation of the capacity of a production tool that cannot operate at high intensity. An efficient production tool is associated with a low value for R_P. As a main parameter that drive the production tool R_P is therefore directly linked to capital. It follows that R_P

naturally increases over time under the effect of the degradation of the capital. For the same reason, investment efforts lead to reduce R_P. The same is true of technical progress which results in a sudden drop in R_P under the effect of the implementation of this new method. Finally, with constant technical progress, the multiplication of production site corresponds to the setting in parallel of several resistances, which leads to a reduction of the global resistance by the same factor, thus allowing work to be carried out at a higher intensity since it is spread over the production sites. If a high value of R_P reflects a production tool that is not compatible with in a production-intensive economy, inversely, it is clear that a low value of R_P is not necessarily an enviable situation from an ecological point of view, in the sense that the very large capacity of the production tool is also leads to increase massively the resource extraction. The accelerated scarcity of the resource of this sheet then leads to a pinch of production.
Four main effects can be attributed to the presence of R_P:

1. Degradation of the capital which results in an increase of R_P. This imply consequences on the quality of exploitation of the resource.

2. Innovation effect which results in a decrease of R_P. This imply consequences on the quantity of increased withdrawal of the resource.

3. Increase in production capacity, at constant progress, which results in a decrease of the global R_P. This imply consequences on the quantity of increased withdrawal of the resource.

4. Effect of the investment which results in a decrease of R_P. This imply consequences on the quantity of increased withdrawal of the resource.

It should also be noted that whatever the value of R_P, a decrease in production yields is observed for production intensities above a certain threshold. In this sense, R_P contributes to the Ricardian character of the appearance of diminishing returns. It is important to note that the limitation of yields also originates in the mechanism of resource scarcity, which is highlighted by the decrease in the difference in potential R_P.[1]

2.2 Structure of a flow sheet

The flow type sheets (see figure 3) are intended for resources that are available on the planet in the form of a flow. The most common one is of course the solar energy.

[1]The question of the capacity for indefinite growth thus finds its main ingredients here, namely:

1. The decline in yields as a function of the intensity of harvesting, beyond a certain threshold.

2. The drop in production due to the unavailability of the resource (pinch) is present at the heart of the mechanism of each of the sheets. It thus appears that the flow of extraction of the resources depends at the same time on the capacities of production (via R_P) installed and on the difference of potential $\Delta\Pi$.

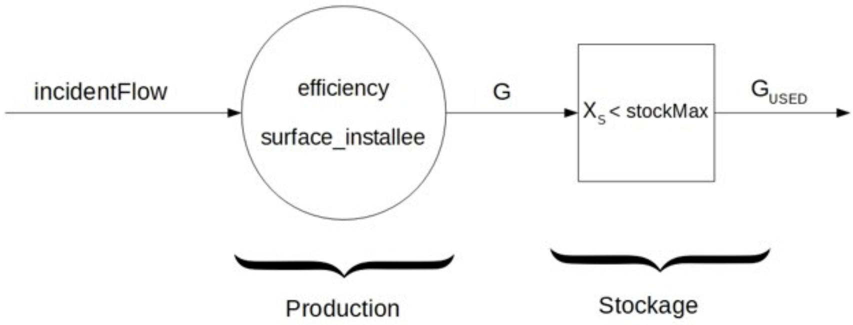


Figure 3: text

2.2.1 Flow sheet parameters

A flow sheet is initially defined by the set of limited parameters listed below (the values are given as an example):

- *type : flow*
- *name : solar energy*
- Incident flow — *incidentFlow : 1e10*
- Conversion efficienc — *eff_init : 0.15*
- Installed surface — *surface_installee : 1e-9*
- Usable as energy — *isEnergy : True*
- Maximum storage capacity — *stockMax_init : 50*

2.3 Structure of the physical core

The physical core is the place where manufactured goods are made. The structure diagram of how this area works is shown in the figure 4.

The "recipes" for the production of manufactured goods are indicated in the sheet *world.txt*. The *main.py* program carries out automatically the realization in respect of these "recipes".

2.4 Structure of the economic zone

The economic zone is the place where the economic model is coded. To illustrate this point, two examples are given :

1. Goodwin

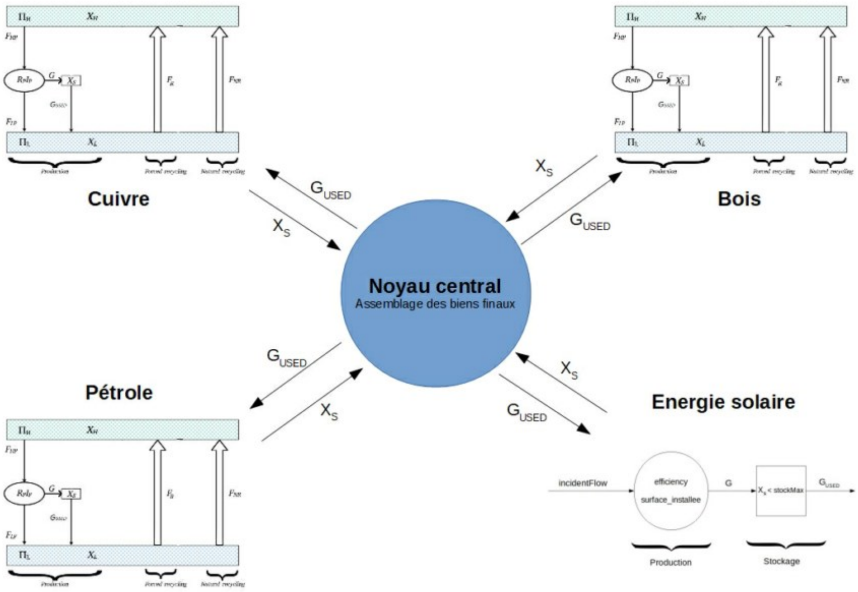


Figure 4: text

2. Sollow

The advanced user can build his own model following the general structure of an economic structure of an economic sheet (see Appendix A)

3 Simulate with EcoDyco

3.1 List of files

You must have in a folder:

- the python scripts :
  - the file **PhysicalWorld.py**
  - a file describing your economic sphere. In this manual we will use the Goodwin model, described in **Goodwin.py**.
  - the file **main.py**
- as many parameterization files as necessary. At least one resource sheet must be used.
  - **world.txt** (required)
  - **oil.txt** if you have an oil sheet

– **copper.txt** if you have a copper sheet

The file **main.py** can then be run to launche the simulation. The time step *deltat*, and the temporal extent of the simulation *tmax* can be mofied in **main.py**.

3.2 Physical sphere settings

To modify the physical parameters (cell parameters, and global parameters of the physical sphere), it is necessary to modify the ***.txt** files.

3.2.1 Add a cell

Parameter setting of the new cell:

1. to create a stock cell, take the template **StockCell.txt**, enter the desired parameters, and save under the name of the resource (*e.g.* **copper.txt**)

2. To create a flow cell, do the same with the template **FlowCell.txt**

3. then, add in **world.txt** your new cell in the *cells* table.

4. finally, add the column corresponding to recipeMatrix in **world.txt**

3.2.2 Retract a cell

1. Delete the cell in the cells table in **world.txt**

2. Delete the corresponding column from recipeMatrix in **world.txt**

3.2.3 Modification of the parameters and initial values of the variables of the physical sphere

- The global parameters and initial values of the global variables of the physical sphere are stored in the **world.txt** files.

- The parameters and initial values of the variables of the sheets are stored in the files **Name-Of-The-Sheet.txt**.

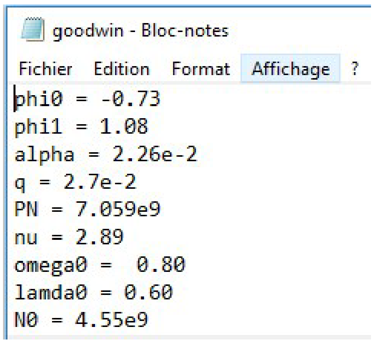
- Don't forget to save the file ***.txt** after modifying a value.[2]

- The message `" world successfully created "` is printed when the model has been initialized.

[2]Caution, reading the parameters in the files is unstable. You must be careful to respect the spacing, not to add a line break at the end, etc. In particular, the strings in the cell array (e.g. " copper.txt ") are then used to redirect to the file " copper.txt " for the initialization of the copper sheet. The name of the file containing the parameters of the sheet must therefore be the same string as the one that appears in cell.

3.3 Setting up the economic zone: the Goodwin case

We show figure 5 an example of *goodwin.txt* file that set the parameters of the Goodwin economic model.



```
goodwin - Bloc-notes
Fichier  Edition  Format  Affichage  ?
phi0 = -0.73
phi1 = 1.08
alpha = 2.26e-2
q = 2.7e-2
PN = 7.059e9
nu = 2.89
omega0 =  0.80
lamda0 = 0.60
N0 = 4.55e9
```

Figure 5: text

- $phi0$ and $phi1$ are the parameters of the Philipps curve
- $alpha$ is the growth rate of labor productivity
- q is the growth rate of the population
- P_N is the maximum value of the population (the real growth rate of the population N is $q\,(1 - N/P_N)$))
- nu is the productivity of capital
- $omega0$, $lambda0$ and N_0 are the initial values of the wageshare, employment rate and population

4 Elementary case study

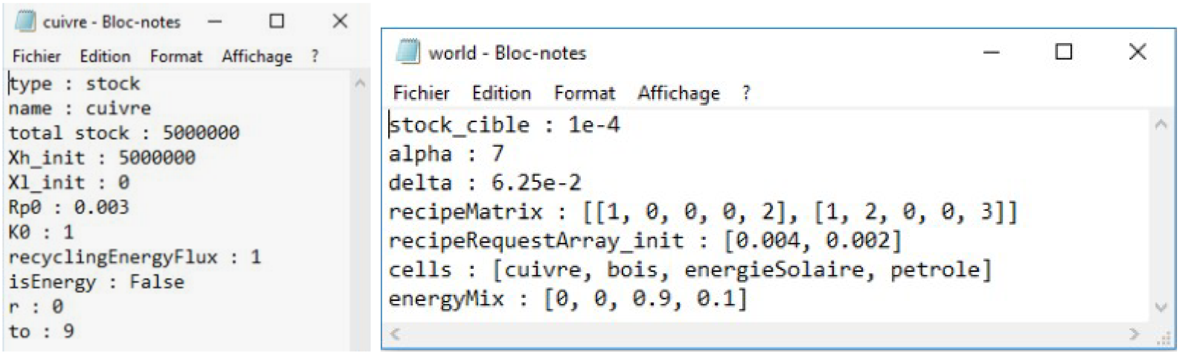
4.1 Parametrization

We propose to illustrate the functioning of EcoDyco by a case study based on the following:

- Four resources. Two are material, (copper Co and wood Wo), and two are energies (oil Oi and solar energy So)
- Recipes are build on energy conservation. Three recipes for three different goods are considered :
  - Good 0 can be obtained with 1 unit of copper and 2 units of energy,

- Good 1 can be obtained with 1 unit of copper and 2 units of wood and 3 units of energy
- Good 3 (copper recycling) can be obtained with 1 unit of energy

- Target energy mix Mix énergétique cible, is composed of 90% solar and 10% oil.



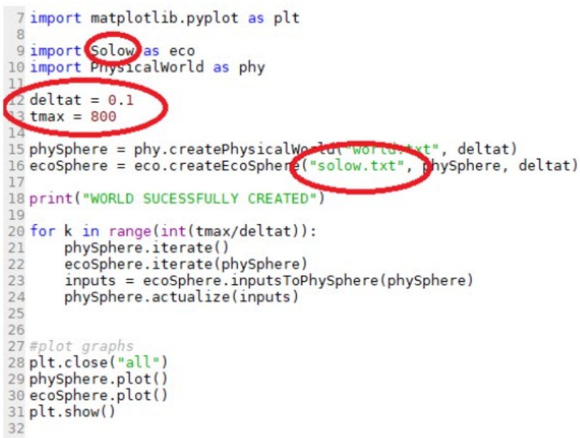
```
cuivre - Bloc-notes
Fichier Edition Format Affichage ?
type : stock
name : cuivre
total stock : 5000000
Xh_init : 5000000
Xl_init : 0
Rp0 : 0.003
K0 : 1
recyclingEnergyFlux : 1
isEnergy : False
r : 0
to : 9
```

```
world - Bloc-notes
Fichier Edition Format Affichage ?
stock_cible : 1e-4
alpha : 7
delta : 6.25e-2
recipeMatrix : [[1, 0, 0, 0, 2], [1, 2, 0, 0, 3]]
recipeRequestArray_init : [0.004, 0.002]
cells : [cuivre, bois, energieSolaire, petrole]
energyMix : [0, 0, 0.9, 0.1]
```

Figure 6: text

Screenshots of **world.txt** and **copper.txt** parametrization are shown in figure 6. In the main file **main.py**, the following parameters (see figure 7) must be set :

1. Economic model. Here *Solow*, parameterized by the correspondinf file **solow.txt**
2. Time step and the duration of the simulation



```
import matplotlib.pyplot as plt

import Solow as eco
import PhysicalWorld as phy

deltat = 0.1
tmax = 800

physSphere = phy.createPhysicalWorld("world.txt", deltat)
ecoSphere = eco.createEcoSphere("solow.txt", physSphere, deltat)

print("WORLD SUCESSFULLY CREATED")

for k in range(int(tmax/deltat)):
    physSphere.iterate()
    ecoSphere.iterate(physSphere)
    inputs = ecoSphere.inputsToPhysSphere(physSphere)
    physSphere.actualize(inputs)


#plot graphs
plt.close("all")
physSphere.plot()
ecoSphere.plot()
plt.show()
```

Figure 7: text

4.2 Results

Running the simulation via the module **main.py** leads to the results shown in figure 8 for production and energy. All the information related to each sheet being recorded, it is then possible to follow the specific evolution of their parameters, for example see in figure 9 for oil.

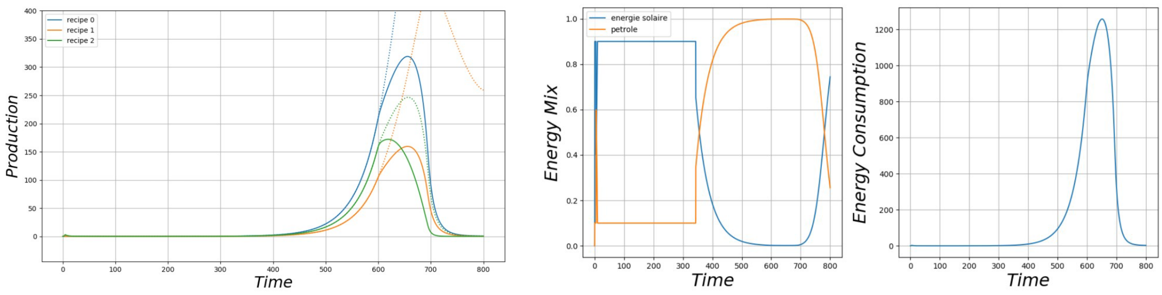


Figure 8: text

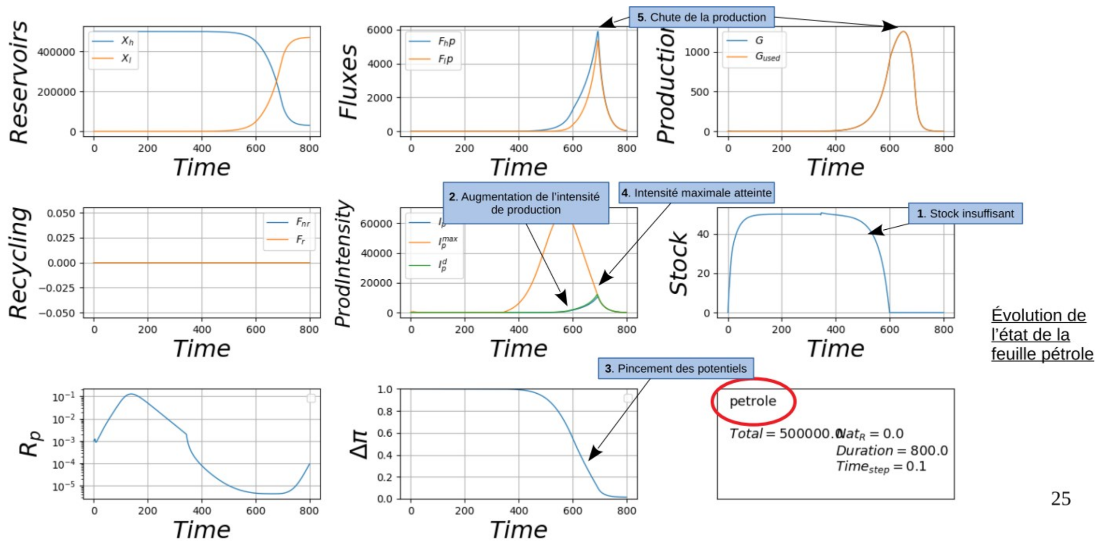


Figure 9: text

References

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