Tuto Brightway – Partie 1

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DEHT/STB/L2PS

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Programme

1. Principes théoriques

- L'approche matricielle de BW
- Architecture
- Activités & échanges
- Réaliser une ACV en BW

2. Pratique

- Setup son projet
- Import des base de données
- ACV : simple, comparatives, multicatégories
- Data visualization (simple)
- Analayse de contribution
- Incertitudes

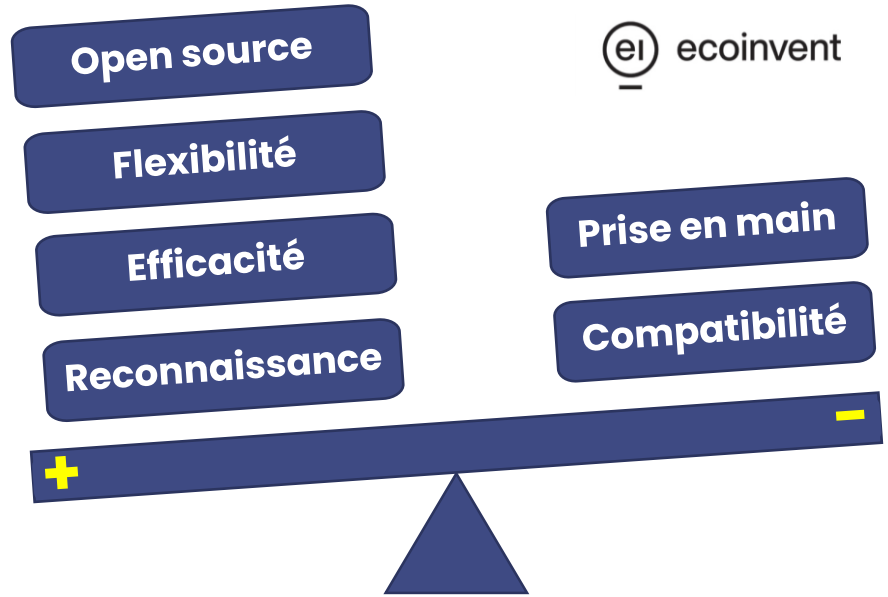
Bright what ?

Les institutions :

Brightway

DÉPART DE SENTIER

PAUL SCHERRER INSTITUT PSI



Les boss :

Chris Mutel (Ecoinvent, ex-PSI)

Tomas Navarrete Gutiérrez (LIST)

Romain Sacchi (PSI)

Bernhard Steubing (Leiden)

Adrian Haas (VSHN)

Les refs :

- **Société** → Départ de Sentier https://www.d-d-s.ch/
- **Publi** → Mutel, Chris. (2017) https://doi.org/10.21105/joss.00236
- **Documentation** officielle → https://docs.brightway.dev/en/latest/ *et le blog de développement de Cmutel* : https://chris.mutel.org/
- **Code** → https://github.com/brightway-lca
- **Tutos** en Notebook, selection :
  - https://github.com/brightway-lca/brightway2/blob/master/notebooks/Getting%20Started%20with%20Brightway2.ipynb
  - https://github.com/maximikos/Brightway2_Intro/blob/master/BW2_tutorial.ipynb
  - https://github.com/PoutineAndRosti/Brightway-Seminar-2017/blob/master/Day%201%20AM/2%20-%20BW%20structure%20and%20first%20LCAs.ipynb
  - *Si questions insolvables* → https://stackoverflow.com/ *avec label 'Brightway" (réponse ne moins d'un jour)*

Formations et évènements brightway

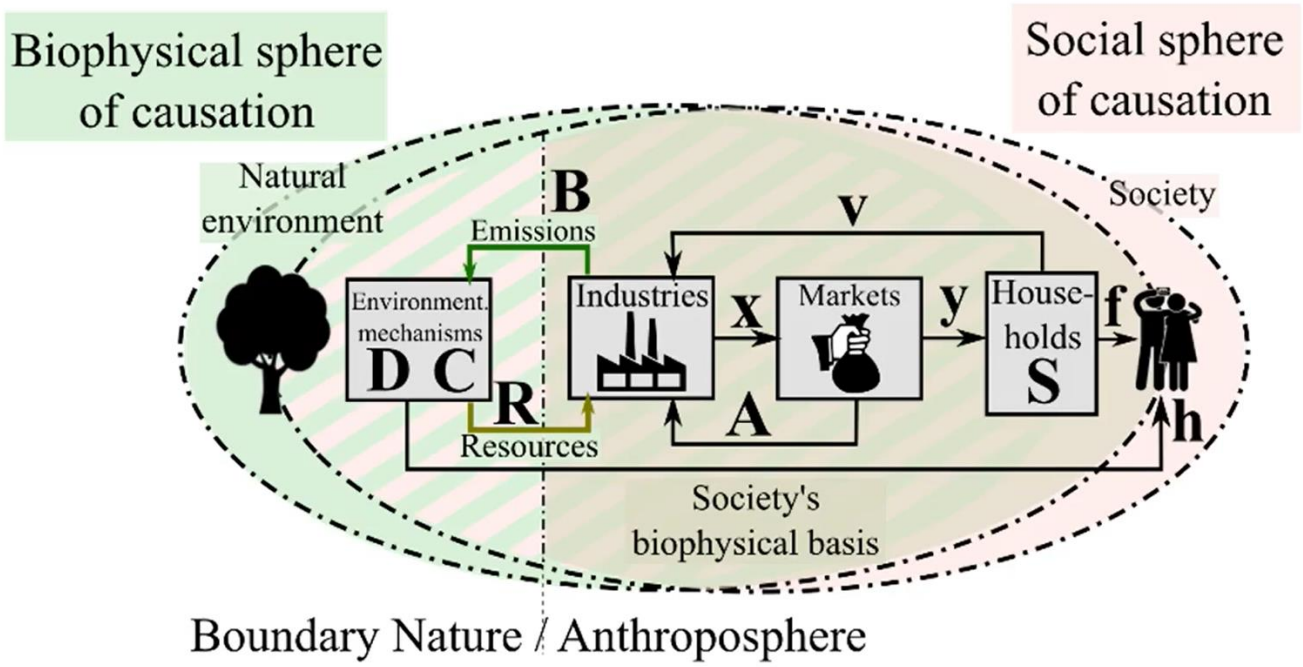
- **Autumn school 2024** : **Inventory modelling at scale**, October 6-11, Switzerland
  - Advanced BW topics but **very instructive**
  - **Meet the community !**
  - **Location amazing**
  - **1325€ (tout compris)**
- Brightcon :
  - conference sur les nouveaux développement
  - Hackathon !
  - Au LIST, Luxemburg, mi-septembre
- MOOC CIRAIG

1. Principes généraux

Brightway & principes théoriques

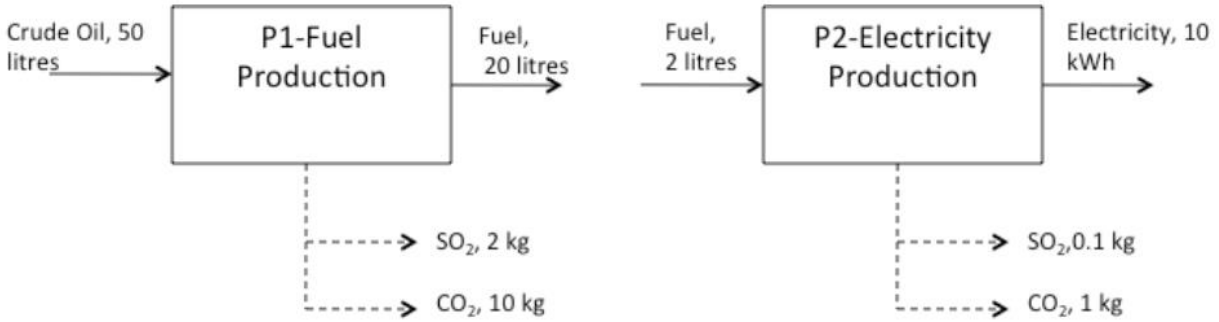
L'ACV dans BW se résume à cette équation (vision matricielle) :

$$\boldsymbol{h = D \cdot C \cdot B \cdot (I - A)^{-1} \cdot S \cdot f} \quad \sim \quad \boldsymbol{h = C \cdot B \cdot A^{-1} \cdot f}$$



Pour aller plus loin : Scott Matthews et al. « LCA Book ». In Life Cycle Assessment: Quantitative Approaches for Decisions That Matter. Carnegie Mellon University, 2014.
EcoSD, Advanced LCA Methodologies & Tools : Uncertainties & Impact Assessment, 2020
http://www.teaching.industrialecology.uni-freiburg.de/

Brightway & principes théoriques



Let's assume $Y = \begin{pmatrix} Y_1 \\ Y_2 \end{pmatrix}$ with Y_1 the final fuel production and Y_2 electricity production, and $X = \begin{pmatrix} X_1 \\ X_2 \end{pmatrix}$ is a scaling factor that represents the production capacity. We can write :

Equation can be rewrite with matrix :

$$\begin{cases} 20X_1 - 2X_2 = Y_1 \\ 0X_1 + 10X_2 = Y_2 \end{cases}$$

$$\boldsymbol{A \cdot X = Y \Leftrightarrow X = A^{-1} \cdot Y}$$

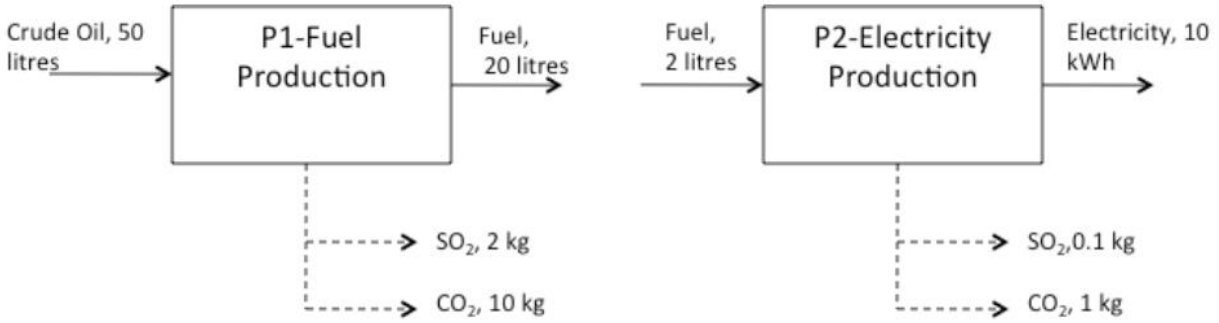
P1 P2

$$A = \begin{bmatrix} 20 & -2 \\ 0 & 10 \end{bmatrix}$$ ← Fuel ← Electricity

A is the **technosphere matrix**
→ *Rows = flows ; Columns = Activities*

$$A^{-1} = \begin{bmatrix} 0.05 & 0.01 \\ 0 & 0.1 \end{bmatrix}$$

Brightway & principes théoriques



Exercise : If we want to produce 1000 kWh, how much fuel do I need ?

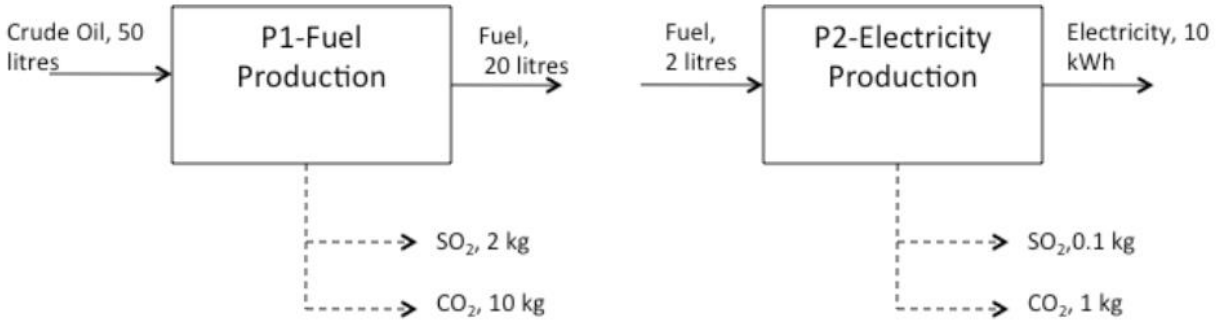
$$Reminder : \begin{cases} 20X_1 - 2X_2 = Y_1 \\ 0X_1 + 10X_2 = Y_2 \end{cases} (2)$$

Answer :

Produce 1000 kWh $\rightarrow \mathrm{Y} = \begin{bmatrix} 0 \\ 1000 \end{bmatrix} \Longrightarrow \mathrm{X} = \begin{bmatrix} 10 \\ 100 \end{bmatrix}$

*Which means I need to do **10× the P1-process** to do 100× the P2-process (to get 1000 kWh),*

Brightway & principes théoriques



If we add the **biosphere matrix B**, which represents the emissions for each process, we get **b, the life cycle inventory** (i.e. all elementary flows to meet the demand f)

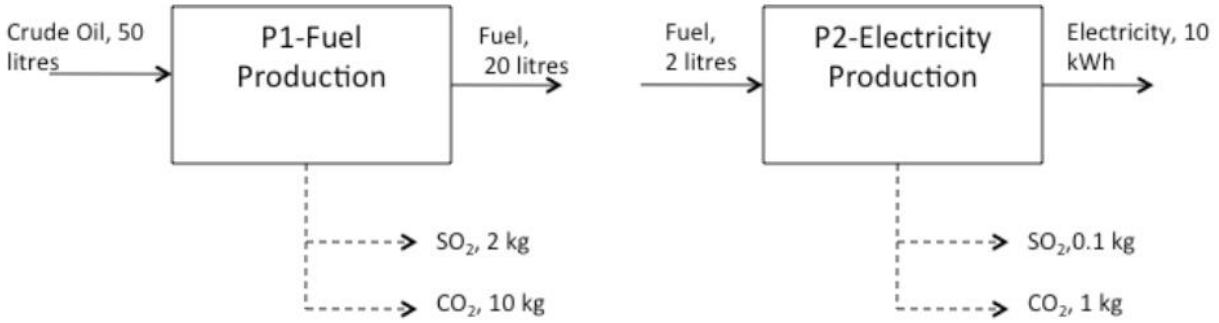
$$\mathbf{b} = \boldsymbol{B} \cdot \boldsymbol{X} = \boldsymbol{B} \cdot \boldsymbol{A}^{-1} \cdot \boldsymbol{Y} \qquad (4)$$

$$\text{with} : B = \begin{bmatrix} -50 & 0 \\ 2 & 0.1 \\ 10 & 1 \end{bmatrix}$$

$$A = \begin{bmatrix} 20 & -2 \\ 0 & 10 \end{bmatrix}$$

columns → **activities** (ie. the process)
rows → **intermediary flows** (for A) or **elementary flows** (for B).

Brightway & principes théoriques



Exercise : What are the emissions that result from the production of 1000 kWh ?

Reminder :

$$B = \begin{bmatrix} -50 & 0 \\ 2 & 0.1 \\ 10 & 1 \end{bmatrix}$$

Answer :

Produce 1000 kWh $\rightarrow \mathrm{Y} = \begin{bmatrix} 0 \\ 1000 \end{bmatrix} \Longrightarrow \mathrm{X} = \begin{bmatrix} 10 \\ 100 \end{bmatrix} \Longrightarrow \mathrm{b} = B \cdot X = B \cdot A^{-1} \cdot Y$

Numerical application : $b = \begin{bmatrix} -500 \\ 30 \\ 200 \end{bmatrix}$ *which means we will extract 500L of crude oil and emits 30kg* SO_2 *and 200kg* CO_2

Brightway & principes théoriques

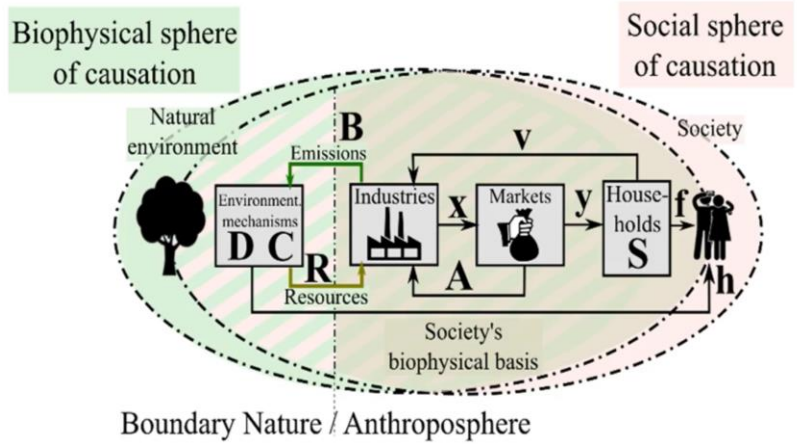
Go back to our main equation :

s = supply array, what is needed to supply my functional unit

$$h = C \cdot B \cdot A^{-1} \cdot f$$

b = life cycle inventory, all the elementary flows to meet my demand

h represents the characterized impacts for one impact category



Nomenclature:

f = final demand vector *[p×1]*

A = technosphere matrix *[p×q]*

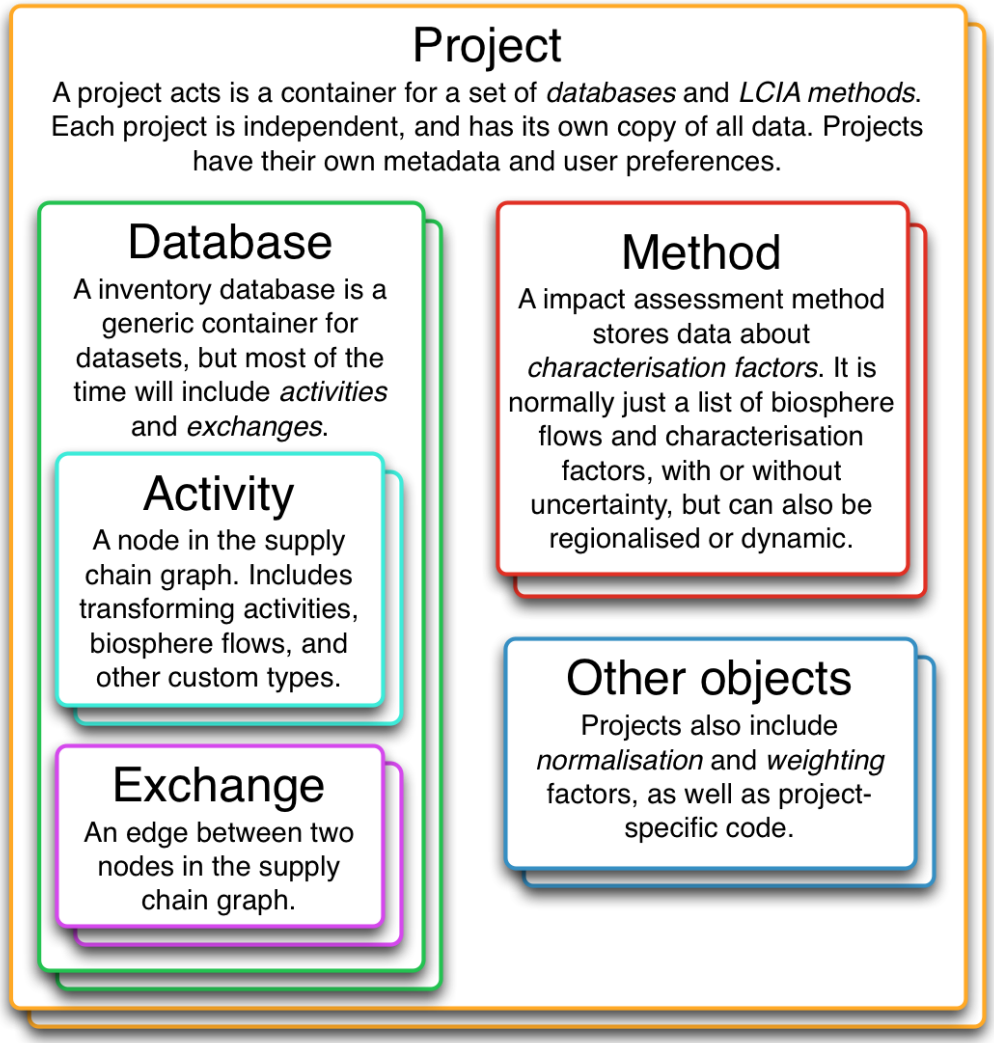
B= biosphere matrix *[r×q]*

C = characterization matrix *[p×q]*

h = characterised inventory matrix *[1]*

columns → **activities/**process *[q]*
rows → **intermediary flows** for A *[p]* or **elementary flows** for B *[r]*

Architecture



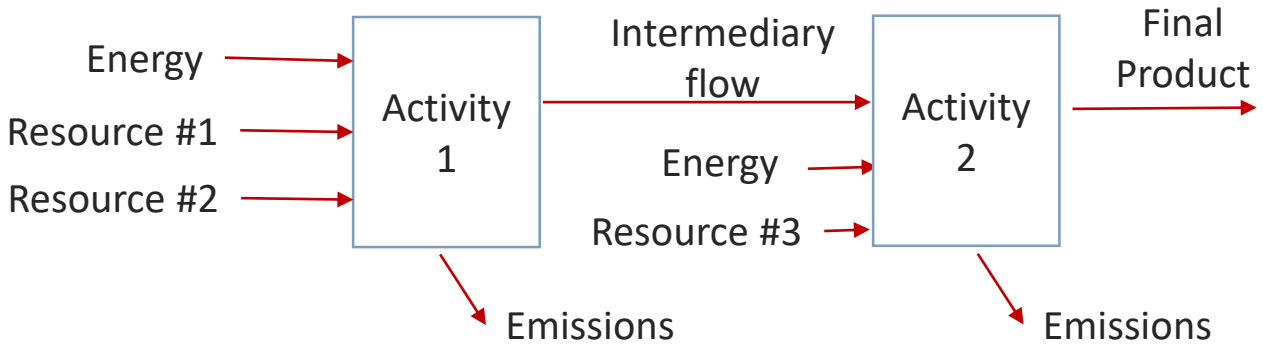
- Data in Brightway2 is structured in a hierarchy.
- At the top level, we have **projects**.
  → contains **database** and LCIA **methods**
  → totally independent of other projects
  → saved as subdirectories in the file system
- The database contain the activities connected with exchanges

NB : BW and Activity Browser share the same projects/databases

Activities & exchanges

Activities = **nodes** in the database
- → include transforming and **market/product activities** (technoshere or intermediary flows)
- → but also **biosphere flows** (biosphere flows)

Exchanges = **edges between two nodes** → inputs or outputs of several types :
- **biosphere** : consumption of resource or emissions,
- **technosphere** process,
- **production** : output amount



Linking activity datasets within and between databases requires a **unique identifier or a code** = a string of numbers and letters

```
In [7]: activity[0], activity[1]
Out[7]: ('ecoinvent 3.2 cutoff', 'ab2f7a551a06a59de9191065128233e4')

In [8]: activity == ('ecoinvent 3.2 cutoff', 'ab2f7a551a06a59de9191065128233e4')
Out[8]: True
```

LCA in BW

1. Translate the functional unit into a demand array
2. Find the right parameter arrays, and ask matrix builder for matrices
3. Solve the linear system As=F
4. Multiply the result by the LCIA CFs, if a LCIA method is present

FU → {activity : amount}

Select a characterization method

Produce A and B matrices and solves As=f

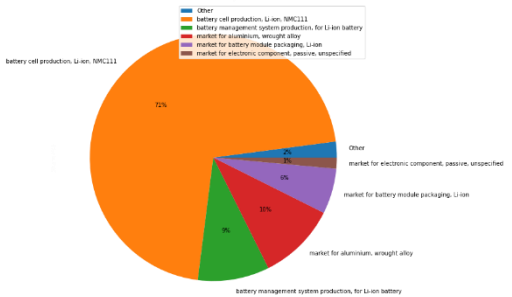
Compute the impacts .lcia

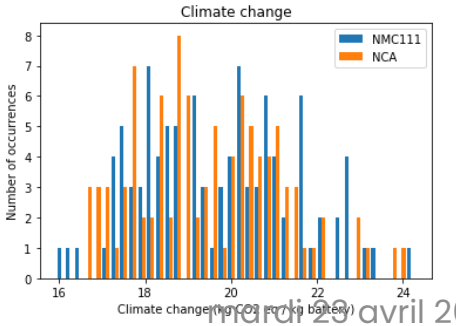
Analysis : contribution, MC, sensitivity…

```
[11]: NMC111_pack=[NMC111_pack for NMC111_pack in eidb if
                   'market for battery, Li-ion, NMC111, rechargeable, prismatic' in str(NMC111_pack)][0]
      fu_NMC={NMC111_pack.key:1}
      fu_NMC

[11]: {('ecoinvent 3.8_cutoff_ecoSpold02', 'bb7113838446330b7ffd1d91f72a1201'): 1}
```

```
[14]: list_methods = [method for method in bw.methods if "CML v4.8 2016"
                      in str(method) and not "no LT" in str(method)]
      list_methods[1]

[14]: ('CML v4.8 2016', 'climate change', 'GWP 100a')
```

```
[16]: lca = bw.LCA(fu_NMC, list_methods[1])
      lca.lci()
      lca.lcia()
      print("La fabrication d'1kg de pack NMC111 émet {:f}{}"
            .format(lca.score,bw.Method(list_methods[1]).metadata['unit']))

      La fabrication d'1kg de pack NMC111 émet 16.739185kg CO2-Eq
```





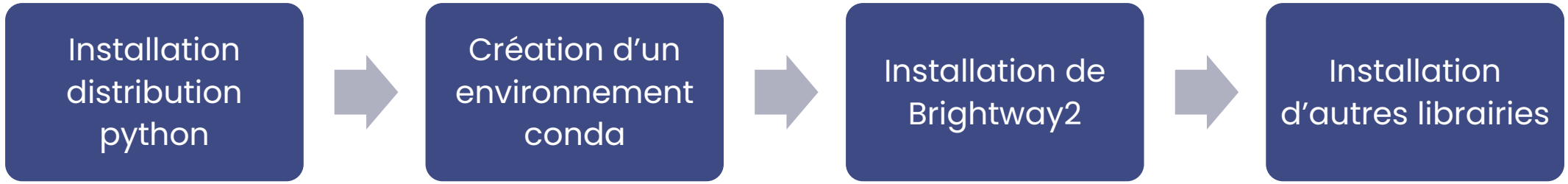
2. Partie pratique

Installation

Toutes les **ressources et la documentation sont en libre accès**, et mis à disposition par les développeurs sur Github et sur le site officiel :

- Outil **collaboratif** dont l'évolution et l'amélioration sont ouverts à tous
- Guide **d'installation**
- **Tutoriel**
- **Exemples** pratiques
- **Code** en open-access

Procédure d'installation un peu difficile, dans les grandes lignes :



- *Procédure détaillée sur https://docs.brightway.dev/en/latest/content/installation/index.html*
- *Pour le CEA, micromamba à la place de anaconda. Procédure détaillé S:\370-Energie\370.25-BATTERIES\370.25.228-ACV BATTERIES ET PEM\Logiciels\Brightway\Install Brightway*
- *Une installation simplifiée peut être aussi réalisée avec le fichier yaml tuto-env.yml qui créé un environnement tuto et installe toutes les librairies d'un coup, en version stable et compatibles (voir le README.md pour la procedure exacte)*

Partie pratique

Setup :

- ✓ Create a working directory on your computer (*/Documents/tuto_bw/* for instance)
- ✓ Clone the repository or copy/Paste *BW2_tutorial_perso_ecoinvent.ipynb* in your working directory

Open Jupyter :

- ✓ Open a anaconda/miniconde console
- ✓ Run *conda activate bw2* (replace bw2 with the envt name where bw is installed)
- ✓ Open a Jupyter interface: run *jupyter lab*
- ✓ A web (localhost) window open with Jupyter interface
- ✓ Dig into your folder to reach your working directory
- ✓ Open up the Notebook *BW2_tutorial_perso_ecoinvent.ipynb*
- ✓ Best practice: when over, go in *File/Shut down* to properly turn off the server. (or you can also *Ctrl + C* in the console to force it to stop)

Thank you for your attention

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