

Using LCA data to inform the decision making of the Belgium energy future.



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Brief presentation of the energy model

Importance of using of prospective data



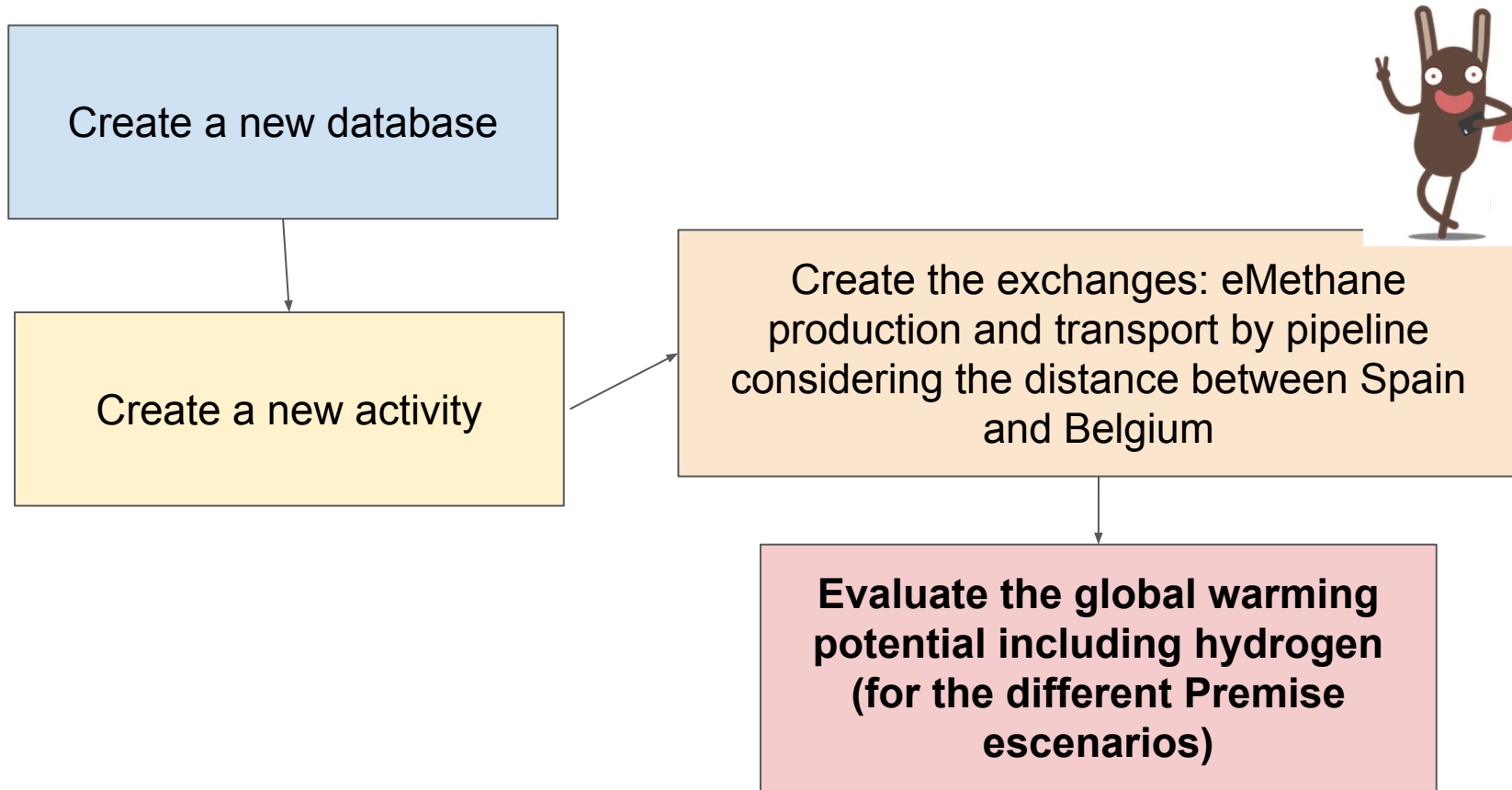
Premise scenarios: year-2050

```
list_scenario = list(bd.databases)
list_scenario = [db for db in list_scenario if 'ecoinvent_' in db]
list_scenario
```

```
['ecoinvent_image_SSP2-RCP19_2050',
 'ecoinvent_remind_SSP2-PkBudg500_2050',
 'ecoinvent_image_SSP2-Base_2050',
 'ecoinvent_image_SSP2-RCP26_2050',
 'ecoinvent_remind_SSP2-Base_2050',
 'ecoinvent_remind_SSP2-NDC_2050',
 'ecoinvent_remind_SSP2-PkBudg1150_2050']
```

I-SSP2-RCP19	compliant with the hard targets of the Paris Agreement (increase of 1.5 C ₉)
R-SSP2-PkBud 500	CO ₂ emissions peak at 500 Gt. Scenario compliant with the hard targets of the Paris Agreement
I-SSP2-Base	worst-case scenario
I-SSP2-RCP26	compliant with the soft targets of the Paris Agreement (1.8-2 C)
R-SSP2-Base	worst-case scenario
R-SSP2-NDC	Current Nationally-determined Contributions implemented by the parties of the Paris Agreement
R-SSP2-PkBudg1 150	CO ₂ emissions peak at 1150 Gt. Scenario compliant with the soft targets of the Paris Agreement

Add the transportation stage to the eMethane activity



Add the transportation stage to the eMethane activity

#Function that creates new activities (eMethane transp to BE from ES) with scenarios as inputs

```
def create_activity(db_scenario):  
  
    name_scenario = db_scenario.name  
  
    new_act = mydb.new_activity(code = 'eMethane transported to Belgium from Spain by pipelines, ' + name_scenario,  
                                name = 'eMethane transported to Belgium from Spain by pipelines, ' + name_scenario,  
                                unit = 'kg',  
                                amount = 1,  
                                type = 'process',  
                                comment = '',  
                                location = "BE",  
                                authors = 'our amazing group',  
                                scenario = name_scenario)  
  
    new_act.save()
```

Create activities and exchanges

#output_1

```
new_act.new_exchange(type = 'production',
                      name = new_act['name'],
                      unit = new_act['unit'],
                      amount = new_act['amount'],
                      input = new_act.key,
                      output = new_act.key,
                      ).save()
```

#input_1

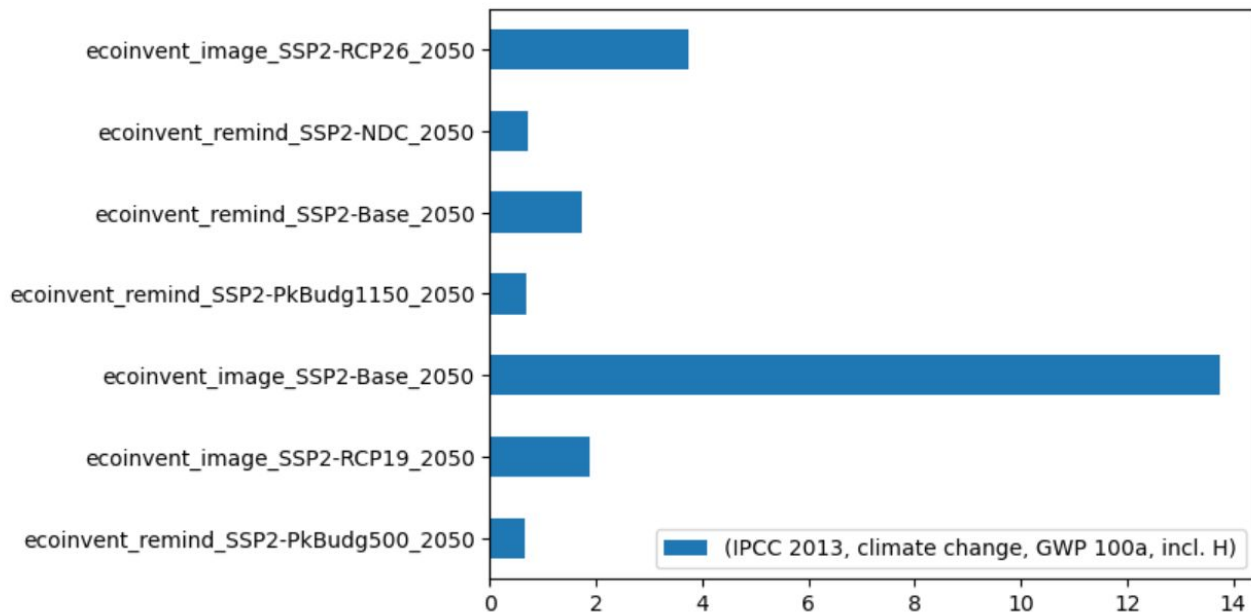
```
act_input = [act for act in db_scenario if "transport, pipeline, onshore" in act["name"]
                                                    and "natural gas" in act["name"]
                                                    and "RER" in act["location"]][0]
```

```
new_exc = new_act.new_exchange(type = 'technosphere',
                                name = act_input["name"],
                                amount = 2,
                                input = act_input.key,
                                output = new_act.key,
                                )
```

```
new_exc.save()
```

Add the transportation stage to the eMethane activity

```
# setting up my new MultiLCA for all the different databases with the 2 different methods
list_functional_units = [{act:1} for act in list_act]
list_methods = [pr_gwp]
bd.calculation_setups['ech4_prospective'] = {'inv':list_functional_units, 'ia':list_methods}
myMultiLCA = bc.MultiLCA('ech4_prospective')
df = pd.DataFrame(myMultiLCA.results, columns = list_method)
```



Regionalization

```
bwa.print_recursive_calculation(act, method_ipcc, cutoff= 0.01, max_level= 8)
```

Fraction of score	Absolute score	Amount	Activity
0001	1.972	1	'eMethane transported to Belgium from Spain by pipelines, ecoinvent_im
0.0594	0.1172	2	'market for transport, pipeline, onshore, long distance, natural gas'
0.0594	0.1172	2	'transport, pipeline, onshore, long distance, natural gas' (ton kilome
0.05	0.09871	0.145	'natural gas, burned in gas turbine, for compressor station' (kilowatt
0.941	1.855	1	'methane, from electrochemical methanation, with carbon from atmospher
0.941	1.855	1	'methane, from electrochemical methanation, with carbon from atmospher
0.13	0.257	2.768	'carbon dioxide, captured from atmosphere, with heat pump heat, and gr
0.0176	0.0348	2.768	'carbon dioxide capture system' (unit, RER, None)
0.0139	0.0274	3.032e-07	'adsorption and desorption unit, carbon dioxide capture process' (unit
0.0135	0.02656	0.003942	'aluminium production, primary, ingot' (kilogram, IAI Area, EU27 & EFT
0.0122	0.02412	0.003724	'aluminium production, primary, liquid, prebake' (kilogram, IAI Area,
0.0139	0.02748	0.3936	'market group for electricity, low voltage' (kilowatt hour, WEU, None)
0.013	0.02567	0.3742	'market group for electricity, medium voltage' (kilowatt hour, WEU, No
0.0126	0.02489	0.3763	'market group for electricity, high voltage' (kilowatt hour, WEU, None
0.0567	0.1117	1.6	'market group for electricity, low voltage' (kilowatt hour, WEU, None)
0.0529	0.1044	1.521	'market group for electricity, medium voltage' (kilowatt hour, WEU, No
0.0513	0.1012	1.53	'market group for electricity, high voltage' (kilowatt hour, WEU, None
0.806	1.59	0.5078	'hydrogen production, gaseous, 25 bar, from electrolysis' (kilogram, W
0.799	1.576	22.56	'market group for electricity, low voltage' (kilowatt hour, WEU, None)
0.0127	0.0251	1.972e-06	'distribution network construction, electricity, low voltage' (kilomet
0.746	1.472	21.46	'market group for electricity, medium voltage' (kilowatt hour, WEU, No

REGIONALISATION

Goal

Change the electricity mix used for the electrolyzer from RER to ES using user-defined scenarios in Premise

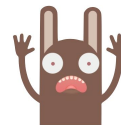


- A new configuration file has been created
- A new scenario_data.csv file is created to estimate the future electricity mix in Spain assuming that it will be based on PV.
- Some errors related to the configuration file occurred when creating a new database including user-defined scenarios.









We tried good habits, but it didn't last long...

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ee1aebc 13 hours ago ⌚ 4 commits

 .gitignore	Update .gitignore	2 days ago
 LICENSE	Beerware license	2 days ago
 README.md	Initial commit	2 days ago
 Test.ipynb	test	13 hours ago

Try to use another external data source... the E3 database

A very old tool containing a lot of data related to bioenergy pathways...

Process Description

Process Name: FC / MCFC / MTU / Syngas-bio vs
Project Name: [dropdown]
Process Type: **Energy Conversion**

Main Output: Electricity
Main Input: Syngas-bio

id_group: LBST
id_timestamp: 18.05.2004 16:25:18

BASICS (2)

Time Horizon	Process Scale	kWh/h	Data Range
2000	300	Average	

General Data | Economic Data | Emissions | N2O, CH4 | Reference

Investment: 383469 €
Labour: 0 €/yr
Dismantling (of plant): 0 €

Maintenance coefficient: 0 % of Inv./yr
Overhead coefficient: 0 % of Inv./yr
Annual Full Load hours: 7500 h/yr

Total Variable Costs (VC): 0 €/kWh
Cost Calculation with VC: ☐

IN / OUT (3)

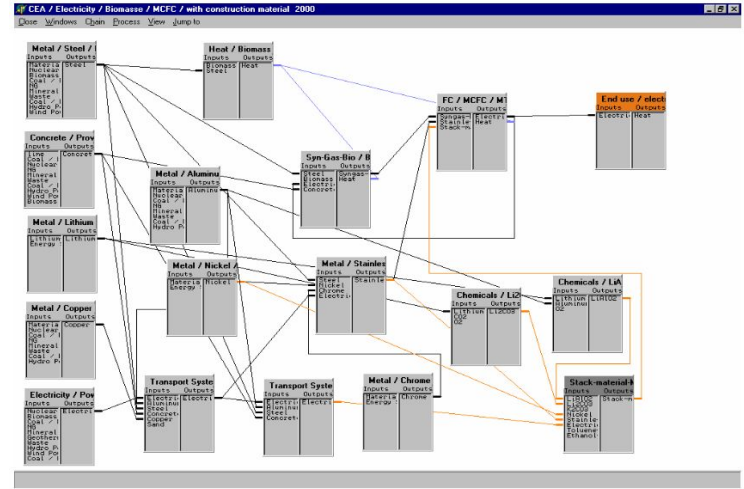
Material: Syngas-bio
ID_Type: Input
Amount: 2.381 kWh/kWh

Distribution: ☒ Param1 Param2 Param3

Notes: The efficiency of the Hot Module is indicated with 42% for syngas as fuel. It is not clear whether the auxiliaries are completely included.

Chosen I/Os:

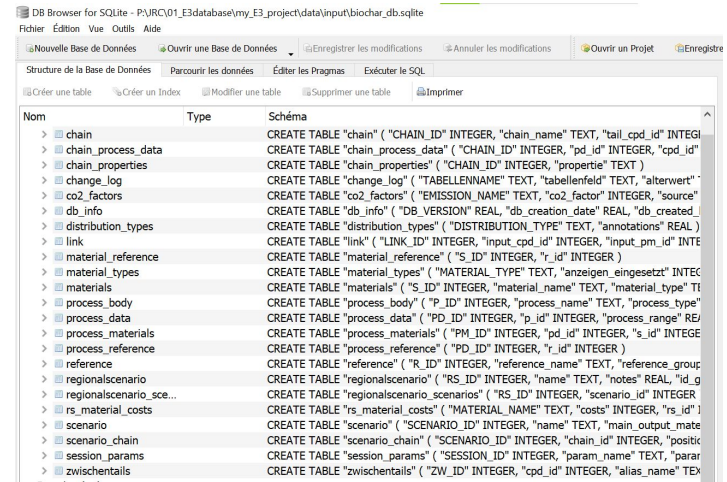
MATERIAL_NAME	ID_TYPE	AMOUNT
Syngas-bio	Input	2.381
Electricity	Output	1
Heat	Output	0.8095



But unfortunately not open source, making it difficult to check and analyze the contained data...

We've won some battles, but not the war (yet)...

- We manage to import the database and manipulate the SQL database with peewee.
- Successful creation of 435 nodes for “material”
- Successful creation of >6000 nodes for “process” and 55311 edges with the “material” and biosphere flows (took 90 minutes)
- Many duplicated data... Only after deleting duplicated: 1343 nodes remained and 9215 edges.
- Next step is to substitute edge with material to edge with the right “process”.
- We've been able to analyze the inventories, and calculate direct impact only as processes are not chain connected yet...



DB Browser for SQLite - P:\RC\01_E3database\my_E3_project\data\input\bioschar_db.sqlite

Fichier Édition Vue Outils Aide

Nouvelle Base de Données Ouvrir une Base de Données Enregistrer les modifications Annuler les modifications Ouvrir un Projet Enregistrer

Structure de la Base de Données Parcourir les données Écarter les Pragmas Exécuter le SQL

Créer une table Créer un Index Modifier une table Supprimer une table Imprimer

Nom	Type	Schéma
chain		CREATE TABLE "chain" ("CHAIN_ID" INTEGER, "chain_name" TEXT, "tail_cpd_id" INTE
chain_process_data		CREATE TABLE "chain_process_data" ("CHAIN_ID" INTEGER, "pd_id" INTEGER, "cpd_id"
chain_properties		CREATE TABLE "chain_properties" ("CHAIN_ID" INTEGER, "propriete" TEXT)
change_log		CREATE TABLE "change_log" ("TABELLENNAME" TEXT, "tabellenfeld" TEXT, "alterwert"
co2_factors		CREATE TABLE "co2_factors" ("EMISSION_NAME" TEXT, "co2_factor" INTEGER, "source"
db_info		CREATE TABLE "db_info" ("DB_VERSION" REAL, "db_creation_date" REAL, "db_created"
distribution_types		CREATE TABLE "distribution_types" ("DISTRIBUTION_TYPE" TEXT, "annotations" REAL)
link		CREATE TABLE "link" ("LINK_ID" INTEGER, "input_cpd_id" INTEGER, "input_pm_id" INTE
material_reference		CREATE TABLE "material_reference" ("S_ID" INTEGER, "r_id" INTEGER)
material_types		CREATE TABLE "material_types" ("MATERIAL_TYPE" TEXT, "anzeigen_eingesetzt" INTEC
materials		CREATE TABLE "materials" ("S_ID" INTEGER, "material_name" TEXT, "material_type" TI
process_body		CREATE TABLE "process_body" ("P_ID" INTEGER, "process_name" TEXT, "process_type"
process_data		CREATE TABLE "process_data" ("PD_ID" INTEGER, "p_id" INTEGER, "process_range" RE
process_materials		CREATE TABLE "process_materials" ("PM_ID" INTEGER, "pd_id" INTEGER, "s_id" INTEGE
process_reference		CREATE TABLE "process_reference" ("PD_ID" INTEGER, "r_id" INTEGER)
reference		CREATE TABLE "reference" ("R_ID" INTEGER, "reference_name" TEXT, "reference_group
regionalscenario		CREATE TABLE "regionalscenario" ("RS_ID" INTEGER, "name" TEXT, "notes" REAL, "id_g
regionalscenario_sce...		CREATE TABLE "regionalscenario_scenarios" ("RS_ID" INTEGER, "scenario_id" INTEGE
rs_material_costs		CREATE TABLE "rs_material_costs" ("MATERIAL_NAME" TEXT, "costs" INTEGER, "rs_id" I
scenario		CREATE TABLE "scenario" ("SCENARIO_ID" INTEGER, "name" TEXT, "main_output_mate
scenario_chain		CREATE TABLE "scenario_chain" ("SCENARIO_ID" INTEGER, "chain_id" INTEGER, "positi
session_params		CREATE TABLE "session_params" ("SESSION_ID" INTEGER, "param_name" TEXT, "parai
zweiscentails		CREATE TABLE "zweiscentails" ("ZW_ID" INTEGER, "cpd_id" INTEGER, "alias_name" TEX

Biomethane from microalgae

Inventories in Excel file

Inventories of the system in Excel file

FU: 1GWh of biomethane		For one kg biomethane	
Miroalgae culture infrastucture			
Activities	ecoinvent_act	Amount	Unit
LDPE	"market for packaging film, low density polyethylene", "GLO"	3,30095E-06	kg
water_pipeline	"market for water supply network", "GLO"	2,19454E-12	km
Glass_fibre_paddle_wheel	"market for glass fibre", "GLO"	1,55903E-06	kg
steel_paddle_wheel	"market for steel, low-alloyed", "GLO"	3,04949E-07	kg
steel pump paddle wheel	"market for steel, low-alloyed", "GLO"	1,22071E-07	kg
CO2 pipeline	"market for pipeline, natural gas, low pressure distribution network", "GLO"	8,00091E-12	km
Culture operation			
N-fertilizer	"market for inorganic nitrogen fertiliser, as N, "FR"	3,31881E-09	kg
P2O5-fertilizer	"nutrient supply from triple superphosphate, "RER"	7,06402E-10	kg
seawater	"Water, salt, ocean"	-5,05365E-08	m3
electricity co2 injection	"market for electricity, medium voltage, "FR"	1,32129E-09	kWh
electricity water supply	"market for electricity, medium voltage, "FR"	6,99508E-09	kWh
electricity cultivation	"market for electricity, medium voltage, "FR"	9,1439E-09	kWh
Culture emissions			
water evaporation	'air', 'low population density, long-term'	1,68146E-08	m3
CO2 leak	'air', 'low population density, long-term'	1,61215E-08	kg
ammonia emissions	'air', 'low population density, long-term'	3,98257E-10	kg
N2O leak emissions	'air', 'low population density, long-term'	5,3101E-12	kg

Biomethane from microalgae

Use of Excel template to be imported in Brightway2

cutoff		14					
database	Microalgal biomethane						
Activity	Biomethane						
reference product	Biomethane						
code	biomethane_production						
location	SP						
amount		1					
unit	kg						
Exchanges							
name	reference product	location	amount	unit	database	type	categories
Biomethane	Biomethane	SP	1	kilogram	Microalgal biomethane	production	
Microalgae infrastucture	Microalgae infrastucture	SP	1	unit	Microalgal biomethane	technosphere	
Culture operation	Culture operation	SP	1	unit	Microalgal biomethane	technosphere	
Harvesting microalgae	Harvesting microalgae	SP	1	unit	Microalgal biomethane	technosphere	
Microalgae anaerobic digestion	Microalgae anaerobic digestion	SP	1	unit	Microalgal biomethane	technosphere	

Biomethane from microalgae

Import of the Excel file into Brightway2



```
del bd.databases['Microalgal biomethane']
```

```
# # == Import foreground databases ==
# # == Water database ==
if "Microalgal biomethane" in bd.databases:
    print("Microalgal biomethane database already exists")
else:
    # # 1. Specify filepath to your foreground inventories.
    biomethane_path = "biomethane.xlsx"
    # # 2. Create an instance of a class that contains basic methods for importing a database from an excel file.
    biomethane = bi.ExcelImporter(biomethane_path)
    # # 3. `apply_strategies` is one of such basic methods, it makes sure units, locations, etc are in correct format.
    biomethane.apply_strategies()
    # # 4. Next step is to link your foreground exchanges to existing databases by matching relevant exchanges fields.
    biomethane.match_database("biosphere3", fields=("name", "unit", "categories"))
    biomethane.match_database("ei 3.8 cutoff", fields=("name", "location", "unit"))
    biomethane.metadata.pop(None) # Remove metadata None entry. TODO
    # # 5. If everything is linked, write database so that it is saved in your project.
    if len(list(biomethane.unlinked)) == 0 :
        biomethane.write_database()
```

cutoff		14					
database	Microalgal biomethane						
Activity	Biomethane						
reference product	Biomethane						
code	biomethane_production						
location	SP						
amount		1					
unit	kg						
Exchanges							
name	reference product	location	amount	unit	database	type	categories
Biomethane	Biomethane	SP	1	kilogram	Microalgal biomethane	production	
Microalgae infrastructure	Microalgae infrastructure	SP	1	unit	Microalgal biomethane	technosphere	
Culture operation	Culture operation	SP	1	unit	Microalgal biomethane	technosphere	
Harvesting microalgae	Harvesting microalgae	SP	1	unit	Microalgal biomethane	technosphere	
Microalgae anaerobic digestion	Microalgae anaerobic digestion	SP	1	unit	Microalgal biomethane	technosphere	

Biomethane from microalgae

Success import but...UNREALISTIC score of GWP

```
bd.databases
```

```
Databases dictionary with 12 object(s):
```

```
Microalgal biomethane  
basic_premise  
biosphere3  
ecoinvent_image_SSP2-Base_2050  
ecoinvent_image_SSP2-RCP19_2050  
ecoinvent_image_SSP2-RCP26_2050  
ecoinvent_remind_SSP2-Base_2050  
ecoinvent_remind_SSP2-NDC_2050  
ecoinvent_remind_SSP2-PkBudg1150_2050  
ecoinvent_remind_SSP2-PkBudg500_2050  
ei 3.8 cutoff  
our own database
```

```
biomethane_act = [act for act in mdb if "Biomethane" in act["name"]][0]  
biomethane_act
```

```
'Biomethane' (kilogram, SP, None)
```

```
myFirstLCA = bc.LCA({biomethane_act:1}, pr_gwp)  
myFirstLCA.lci()  
myFirstLCA.lcia()  
myFirstLCA.score
```

```
503.21199168790935
```

Biomethane from microalgae

Looking for activities with the bigger share to the impact

```
ba.print_recursive_calculation(biomethane_act, pr_gwp, cutoff=0.025)
```

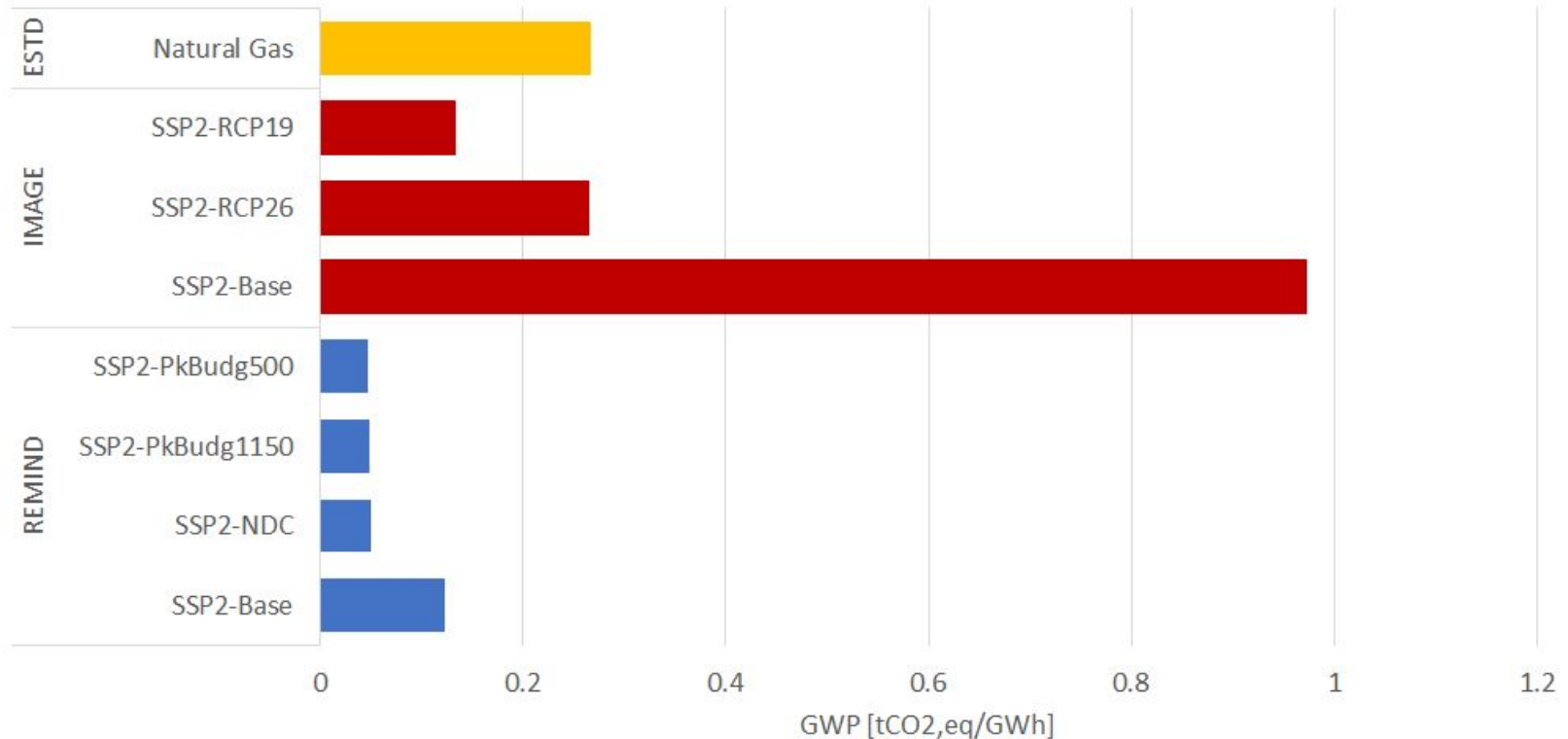
Fraction of score	Absolute score	Amount	Activity
0001	503.2	1	'Biomethane' (kilogram, SP, None)
0.999	502.5	1	'Microalgae infrastructure' (unit, SP, None)
0.644	323.9	104.3	'market for packaging film, low density polyethylene' (kilogram, GLO, None)
00.2	100.8	34.48	'packaging film production, low density polyethylene' (kilogram, RER, None)
0.427	214.9	69.82	'packaging film production, low density polyethylene' (kilogram, RoW, None)
0.237	119.3	49.26	'market for glass fibre' (kilogram, GLO, None)
0.0667	33.55	16.29	'glass fibre production' (kilogram, RER, None)
0.163	82.02	32.98	'glass fibre production' (kilogram, RoW, None)
0.0385	19.36	9.636	'market for steel, low-alloyed' (kilogram, GLO, None)
0.0253	12.73	5.687	'steel production, converter, low-alloyed' (kilogram, RoW, None)
0.0403	20.3	0.0002528	'market for pipeline, natural gas, low pressure distribution network' (kilogram, GLO, None)
0.0402	20.25	0.0002521	'pipeline construction, natural gas, low pressure distribution network' (kilogram, RoW, None)

Soft-coupling with an Energy System Optimisation Model

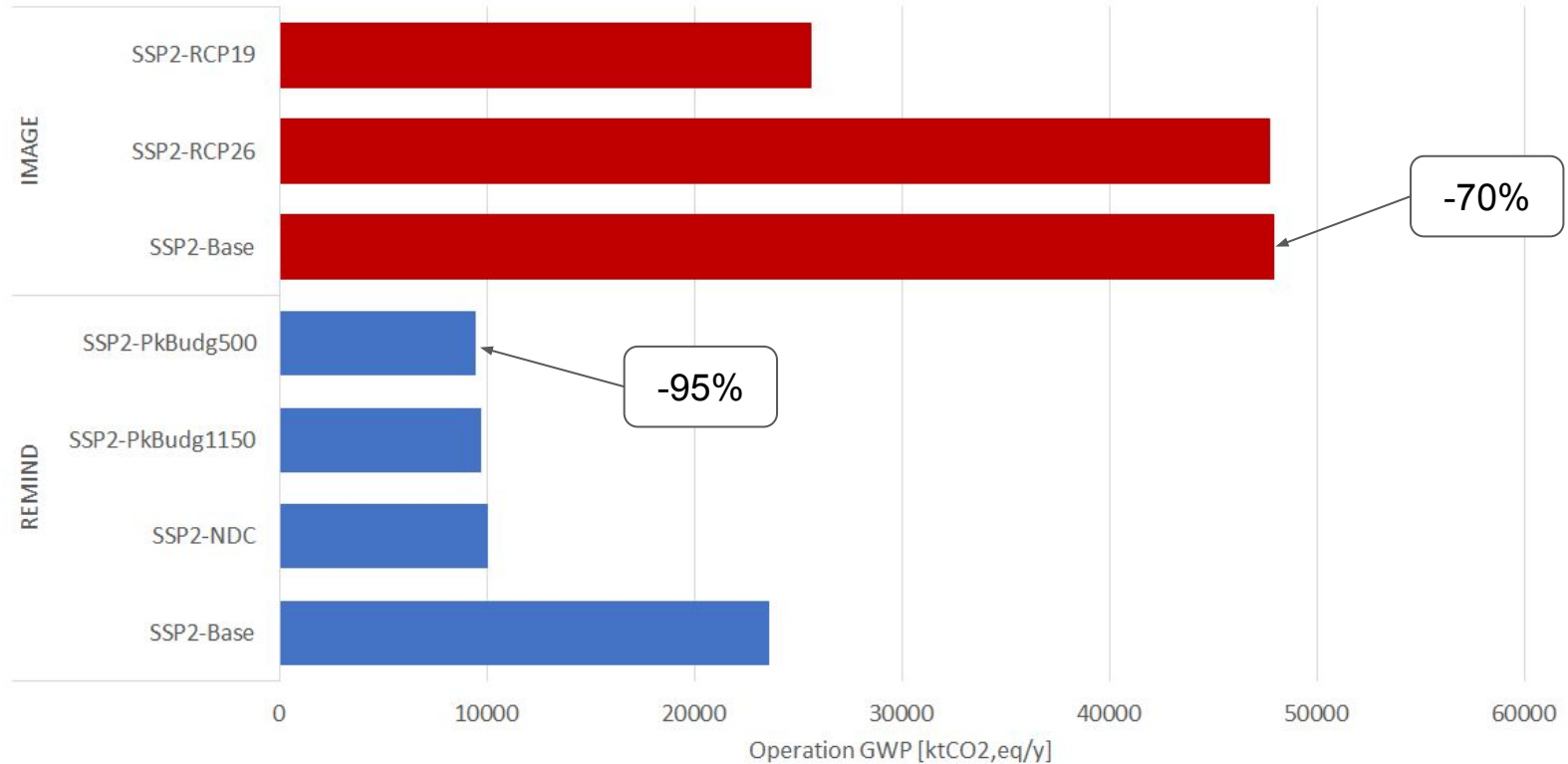
Soft-coupling with EnergyScope TD

- EnergyScope TD is a regional whole-energy system optimisation model
 - Applied to 2050 Belgium energy system
 - Optimize the design and operation of the system to have minimal operational emissions
 - Upper bound on cost increase: 20%
 - The embodied emissions of the e-methane are given as an input to the energy model
- Results
 - Reachable reduction objectives
 - Energy (and technology) mixes

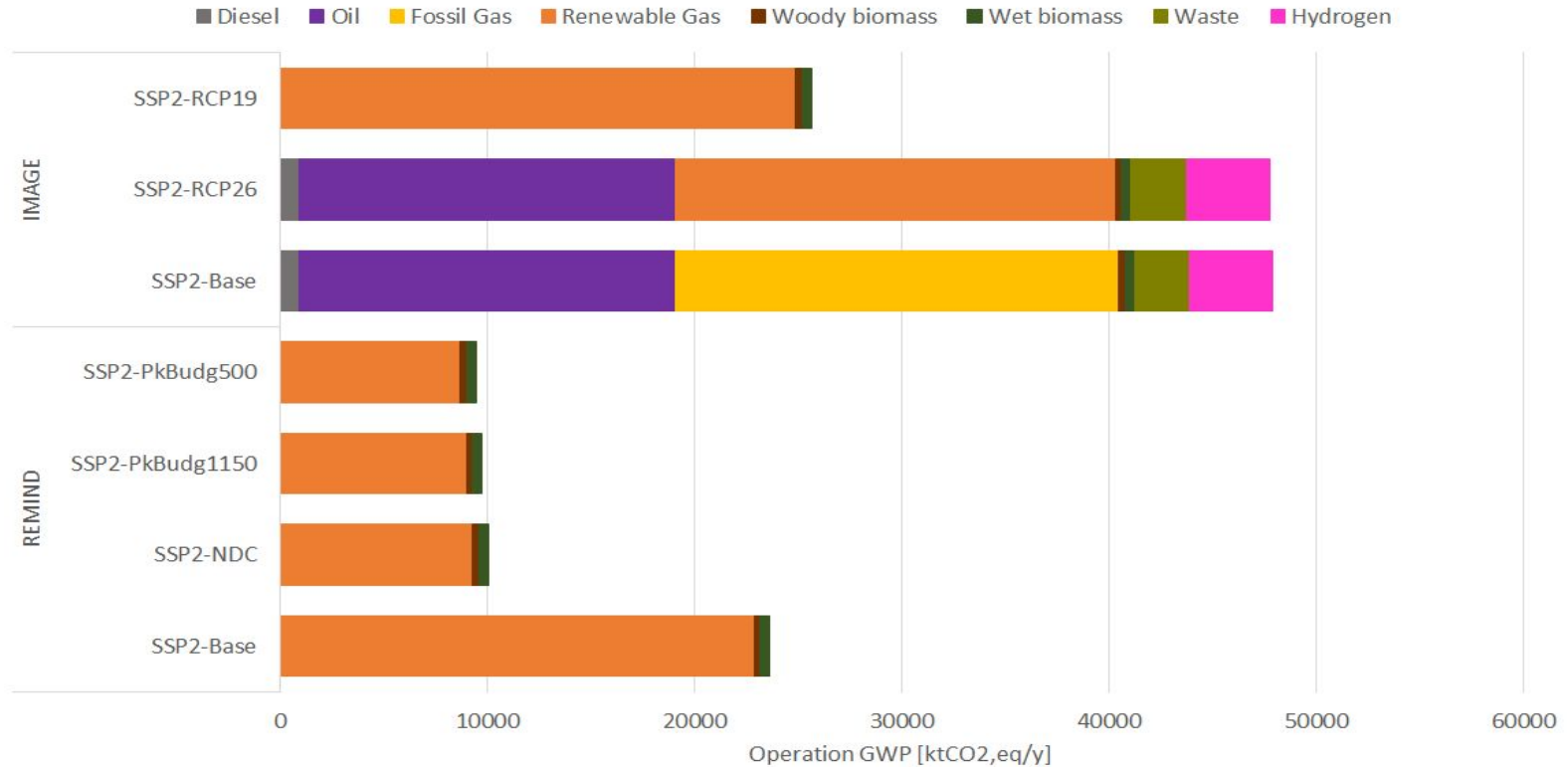
Input : embodied emissions of the e-methane



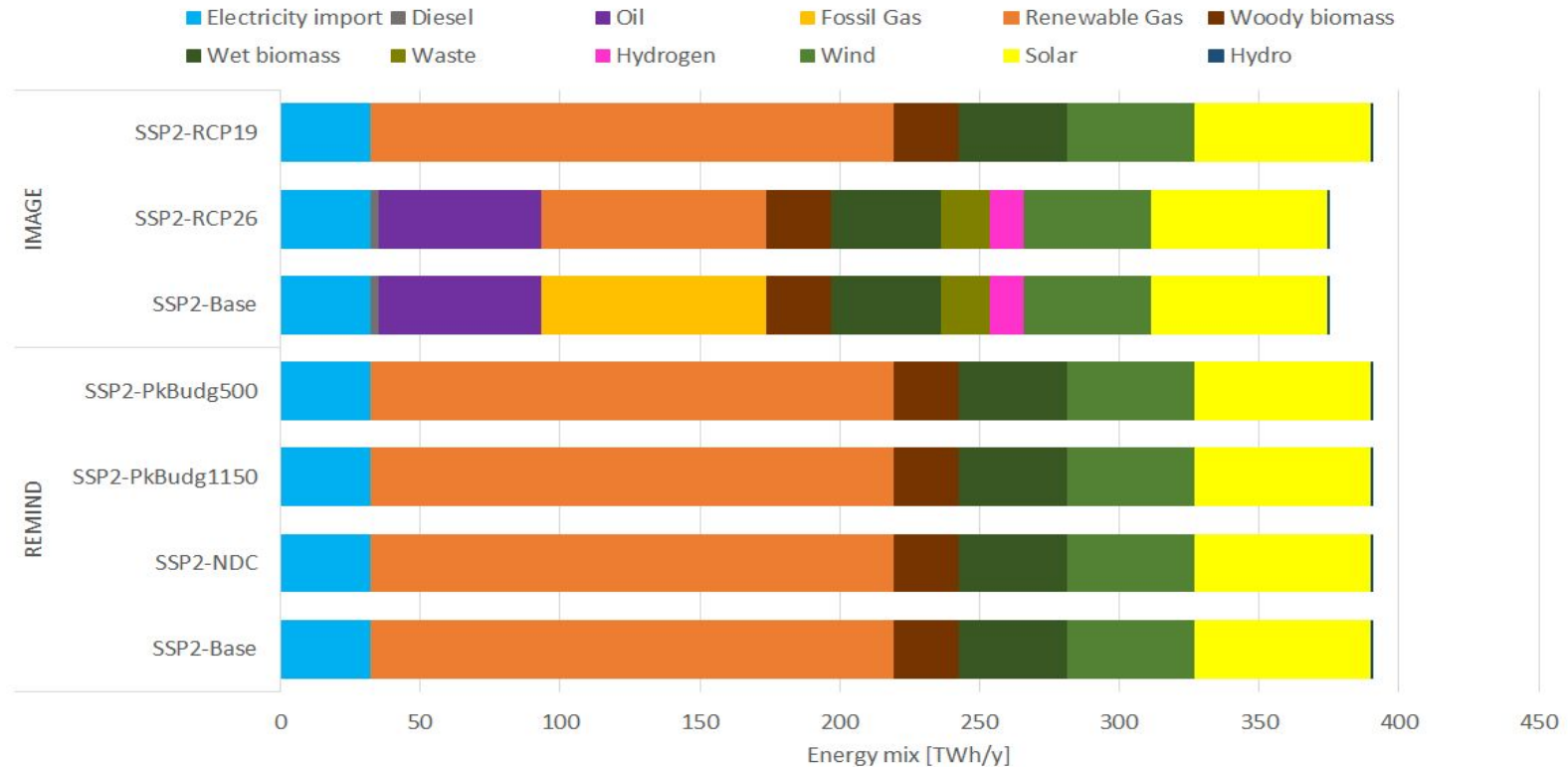
Optimal system emissions



Emission mix



Energy mix of the optimal energy system



Perspectives of the coupling

- Computing emissions of other renewable fuels
- Computing emissions of energy system infrastructures and assets
- Application on European energy system and feedback loop to regionalize :
 - Electricity mix in European countries
 - Heat mix
 - Vehicles fleets
 - ...