RÉPUBLIQUE
FRANÇAISE
Liberté
Égalité
Fraternité

ADEME
AGENCE DE LA TRANSITION ÉCOLOGIQUE

Will there be enough biogenic CO_2 for projected e-fuels demand in France?

Which need of electricity and biogenic CO2 by 2050?
What are the main limitations?

Aicha El Khamlichi, Department of Bioeconomy and Renewable Energy- ADEME

Workshop “Bioenergy in a Net Zero Future”- 19th October 2023

Overall framework

- Background: recent adoption at European level of minimum targets for the decarbonisation of fuels in the aviation (ReFuel EU aviation) and maritime (FuelEU maritime) sectors.
- Objective of this work: estimate the needs for electricity and biogenic CO_2 necessary for the domestic production of e-fuels (without importations).
- E-fuels scope :
  - Aviation : e-jetfuel;
  - Maritime: e-methanol, e-ammonia and e-methane
- 4 contrasting scenarios in France by 2050 :
  - **Demand assumptions** for e-fuels by 2050: low and high (see slide 3)
  - **Technical assumptions for** the processes (yields, selectivity, etc.): two conservative and optimistic variants (see slide 4)

4 modelised scenarios	**Low demand**	**High demand**
Optimistic technical assumptions	Low optimistic	High optimistic
Conservative technical assumptions	Low conservative	High conservative

Assessement of the demand of e-fuels by 2050

Aviation sector

Current demand: the energy consumption of air traffic in France in 2019 amounted to **56.4 TWh** (including 20.9 TWh for domestic flights and 50% of international bunkers)

Prospective demand by 2050 for aviation:

	« Low demand » scenario	« High demand» scenario
Reference scenario	S2 Transition(s) 2050	SA I-Care & ADEME
Total demand	29,3 TWh	69,8 TWh
Share of e-jetfuel	35%	
Demand of e-jetfuel	**10,3 TWh**	**24,4 TWh**

Minimum of incorporation of e-fuels imposed by the «ReFuel EU aviation» regulation (on a total minimum of incorporation of 70% of sustainable fuels, integrating both e-fuels and biofuels)

Maritime sector

Current demand: **12,2 TWh** of energy consumption in the maritime and river sector in 2019 (including 2.3 TWh for national transport and 50% of international bunkers)

Prospective demand by 2050 for maritime :

	« low demand » scenario	« high demand » scenario
Reference scenario	S3 Transition(s) 2050	Roadmap of the sector
Total demand	15,5 TWh	46,4 TWh
Share of « alternative » fuels	92%	
Share of e-fuels	70%	
Demand of e-fuels	**10,5 TWh**	**30,1 TWh**
e-CH4 (36%)	5,52 TWh	16,5 TWh
e-MeOH (28%)	4,42 TWh	13,2 TWh
e-NH3 (6%)	0,98 TWh	2,92 TWh

Scenarios « low demand » : based on ADEME scenarios of Transition(s) 2050 (S2- reduced demand et S3- « green » technology)
Scenarios « high demand » : based on roadmap of the sectors
Share of e-fuels by 2050: based on « ReFuel EU aviation » et « Fuel EU maritime » regulations

Assumptions on energy consumption of the production of e-fuels

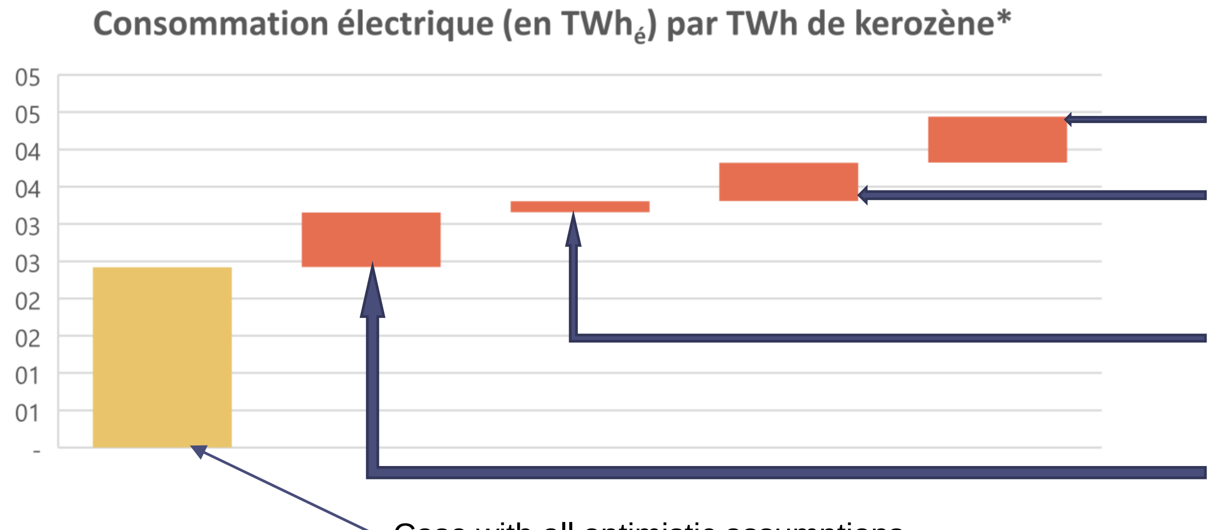
Fuel efficiency sorted by processes :

		Optimistic assumptions	Conservative assumptions
e-jetfuel (Fischer-Tropsch reaction)	Consumption of H_2 (TWh_{H2}/TWh)	1,7	2,7
	Consumption of electricity ($TWh_{é}$/TWh)	2,4 (η = 42%)	4,4 (η = 23%)
e-methane (methanation reaction)	Consumption of H_2 (TWh_{H2}/TWh)	1,4	1,4
	Consumption of electricity ($TWh_{é}$/TWh)	1,9 (η = 53%)	2,3 (η = 43%)
e-ammoniac (Haber-Bosch process)	Consumption of H_2 (TWh_{H2}/TWh)	1,2	1,2
	Consommation d’électricité ($TWh_{é}$/TWh)	1,7 (η = 59%)	1,9 (η = 53%)
e-methanol (methanolisation process)	Consumption of H_2 (TWh_{H2}/TWh)	1,1	1,1
	Consumption of electricity ($TWh_{é}$/TWh)	1,5 (η = 67%)	1,8 (η = 56%)

From less efficient (e-jetfuel) to most efficient(e-methanol) in term of yield of the processes

High variability in process efficiency between min (23%) and max (67%)

Focus on Fischer-Tropsch reaction (e-jetfuel) : almost twice the energy consumption between optimistic and conservative scenario



Consommation électrique (en $TWh_{é}$) par TWh de kerozène*

Conservative assumption on the electrolysis yield (70% $_{PCI}$ → 60% $_{PCI}$)

Conservative assumption on the selectivity of the Fischer-Tropsch reaction (70%→60%)

Conservative assumption on consumption of H2 for the hydrotreatment (2%→6%)

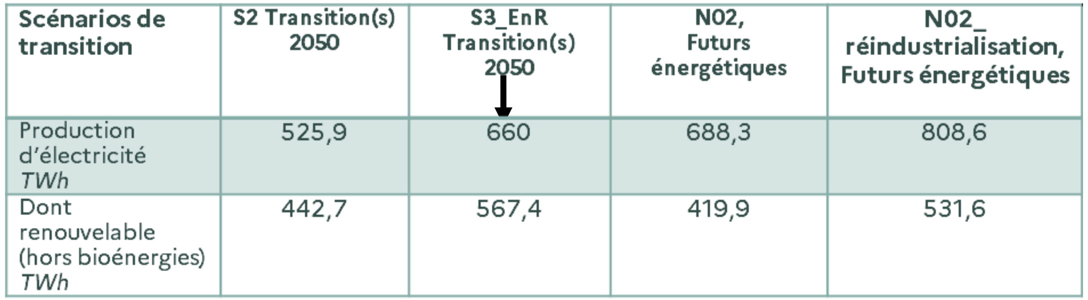
Conservative assumption on consumption of H2/CO2 for Fischer-Tropsch reaction

Case with all optimistic assumptions

Electricity requirements for e-fuels production by 2050

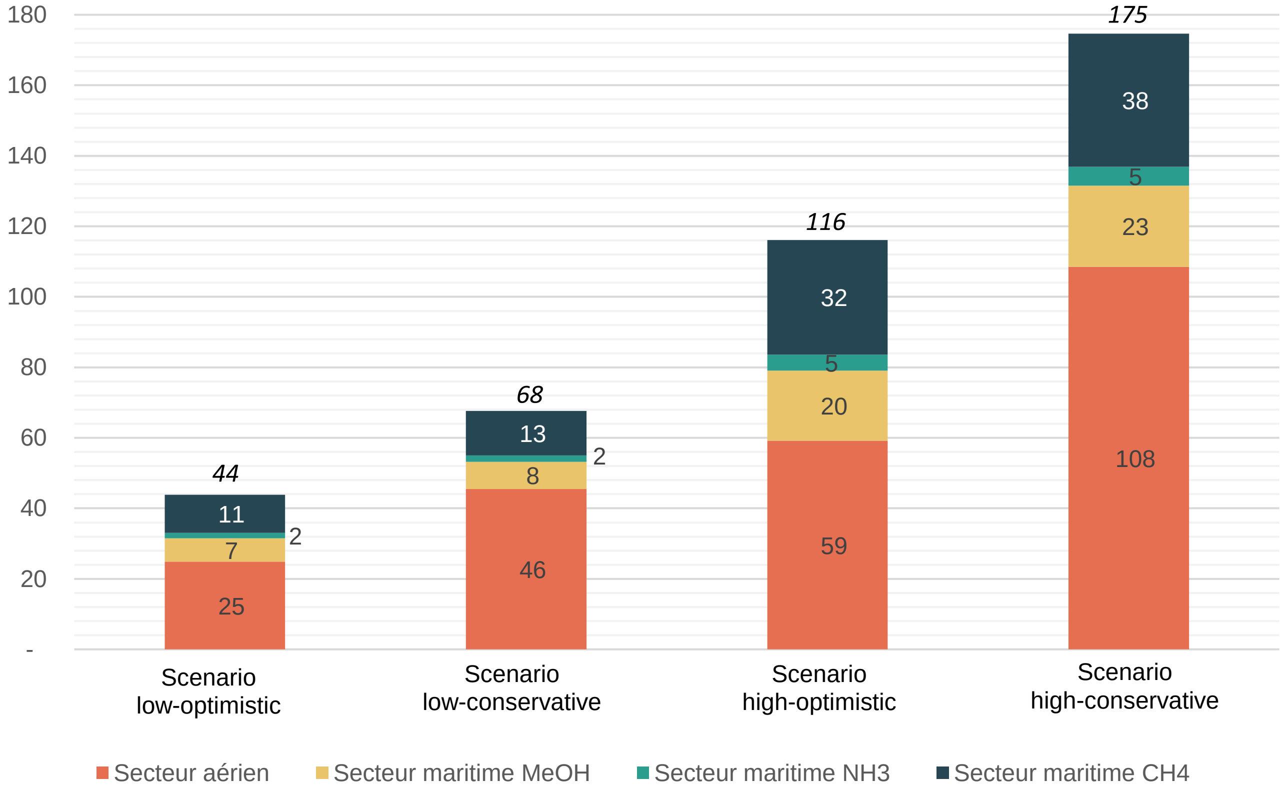
- **New electricity requirements for e-fuels estimated at 44 to 175 TWhe/year**
- **Scenario with the higher electricity demand : 175 TWhe, equivalent to 13 EPR reactors (1,65 GW per reactor)**
- Compared to electricity need for e-fuels from several prospective works:
  - SFEC (on going) (50% e-fuels) : 110 TWhe
  - ADEME / Transition(s) 2050 (S2) : 18 TWhe
  - RTE / Future energy system (Ref et H_2+) : 6,7 et 68 TWhe

Electricity requirements for e-fuels is too high in the «high» scenarios compared to the total electricity production estimated in 2050:



Scénarios de transition	S2 Transition(s) 2050	S3_EnR Transition(s) 2050	N02, Futurs énergétiques	N02_ réindustrialisation, Futurs énergétiques
Production d'électricité *TWh*	525,9	660	688,3	808,6
Dont renouvelable (hors bioénergies) *TWh*	442,7	567,4	419,9	531,6

Electricity consumption for the synthesis of e-fuels in 2050 ($TWh_é$)



Biogenic CO_2 requirements for e-fuels production by 2050

RED III directive : 3 « kind » of CO_2 are eligible for the production of low carbon fuels (RFNBO) :

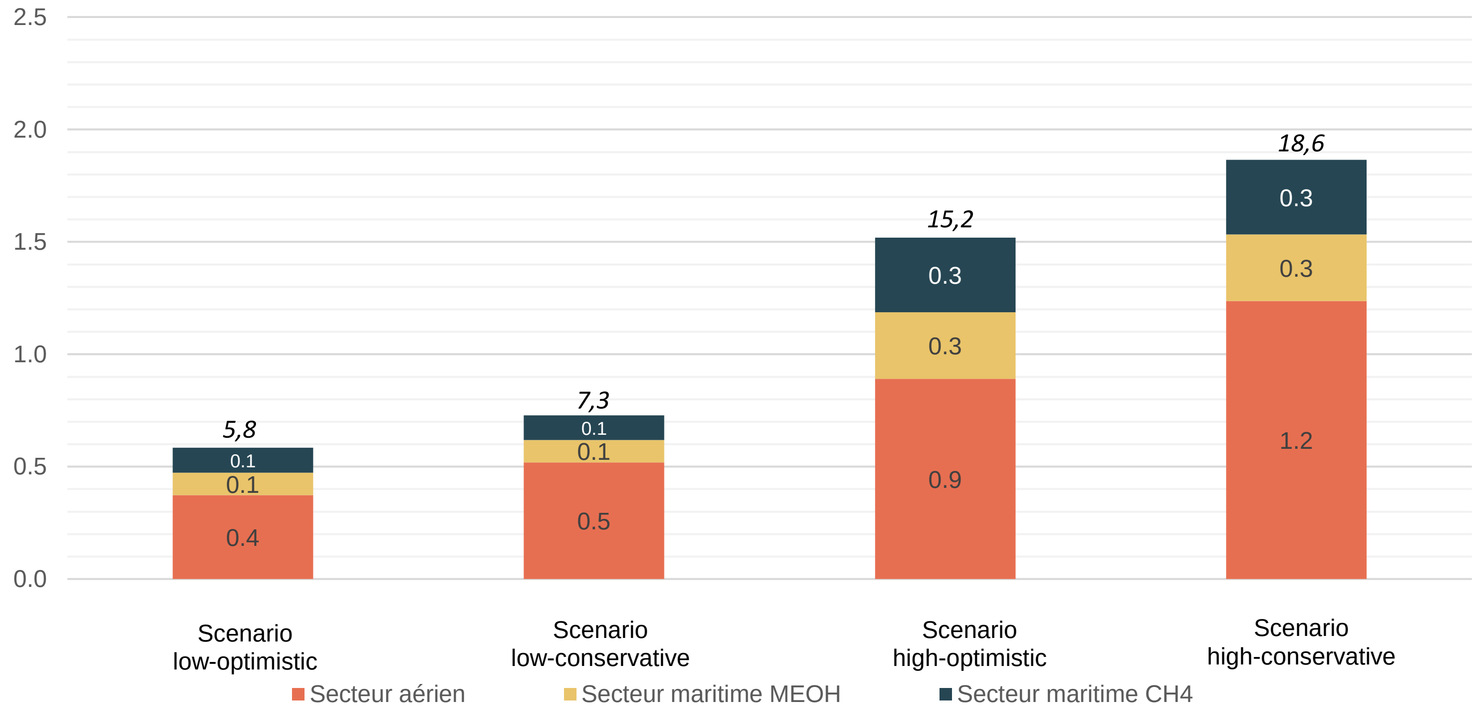
- Biogenic CO_2
- CO_2 from direct air capture (DAC) (discarded because too energy intensive)
- Fossil CO_2 from industries, but only until 2041 (so discarded in this work because modelisation for 2050)

Estimated requirements for the production of e-fuels : **5,8 à 18,6 Mt of biogenic CO_2 per year**

Comparison with « available » sources of biogenic CO_2 :

- ~11-16MtCO_2biogenic by 2050 that could be captured on high emitters (>200ktCO_2/an)
- ~32MtCO_2biogenic by 2050 that could be captured if CO_2 transport network (pipeline) is developed in France (emitters >30ktCO_2/an)

CO_2 consumption for the synthesis of e-fuels by 2050 (Mt)



What means « available » sources of biogenic CO_2?

- Biogenic CO_2 requirement (post 2041) for e-fuels certification under the European REDIII Directive
- Scale effect on the e-fuels production unit → profitability from 200ktCO_2/year
  - Currently, this threshold represents 17 units in France for a total of 6,5Mt$CO_{2\text{biogenic}}$
- In case of shared network from several emitters, a dedicated CO_2 pipeline network will be required → profitability in this case was estimated at a threshold of 30ktCO_2/year
- Estimation of a « theoretical » maximum volume of biogenic CO_2, without considering the localisation of the emitters

Quantification from ADEME's prospective work -Transition(s) 2050

CO_2b captable (Mt/an)	S2 gisement >200kt	S2 gisement >30kt	S3 gisement >200kt	S3 gisement >30kt
Industrie	6,85	17,43	4,80	12,23
UVE	2,02	2,02	6,48	6,48
Bioraffineries	2,62	2,62	4,90	4,90
Réseaux de chaleur urbains	0	10,06	0	9,69
Total	**11,49**	**32,13**	**16,18**	**33,30**

⚠ **This estimated volume of biogenic CO_2 for e-fuels production is directly in conflict with the use in BECCS**

Conclusions

The low demand scenarios (mobilizing levers of sobriety) could reach the European decarbonization targets on the aviation and maritime sectors, while mobilizing reasonably the electricity resources and biogenic CO_2.

It will require to:

- ➢ **Prioritize uses by doing planification in order to avoid conflicts of use (electricity and biogenic CO_2)** by a rapid deployment of e-fuels production units that would prevent decarbonization of other sectors, and so to prevent the closing of the energy and climate gap by 2050.
  - ⇨ **Define a threshold for resource allocation (electricity, CO_{2b} for 2030 and 2050) for the production of e-fuels within the next main energy-climate policies and within sectoral strategies** (H_2, CCUS, mobility, bio-based products and sustainable fuels, etc.).
  - ⇨ **Maintain a share of biogenic CO_2 for geological storage (BECCS), which requires a low demand scenario.**

- ➢ **Plan the reduction of demand,** which is the first sensitivity factor through the implementation of various measures :
  - ⇨ **Implement policies to reduce traffic in the medium and long term, notably through modal shift for certain uses** (e.g.: short and medium-haul rail-oriented).
  - ⇨ **Directly pass on the production costs of e-fuels to the final consumers (transport of people or goods)** (ex: impact on the price of the air ticket), **the price signal being of first order to rationalize the demand for transport**
  - ⇨ **Properly articulate public policy mechanisms in a way of rationalization of public money** (measure for the transport sector, hydrogen production support mechanism for industry, AAP France 2030, etc.**)**

Main limitations

This work focused only on a technical approach; further work is still needed: :

- **An environmental assessement (LCA)** will be necessary to complete this energy-ressources approach (electricity/ biogenic CO_2 biogenic).

  ⚠ **E-fuels are not carbon neutral**: 1 tCO_2eq to 2.75 tCO_2eq/ t of e-jetfuel produced in France, depending on the carbon footprint of the electricity supply, compared to 3.82 tCO_2eq/ t for conventional jetfuel (source: IAC-Partners study).

- **Integration of a constrain on the location of e-fuels production units because of several factors** (nearby of a biogenic CO_2 source, coupling with an electrolyzer and issues of connection to the electricity grid, transportation of fuels to ports/airports, access to available land, etc.) at the territorial level

- Investigate the impact of the different co-production scenarios of «e-naphtha» (as co-product of Fischer-Tropsh process) on the decarbonization roadmaps of the olefin sector, naphta being one of the main inputs of current olefin steam crackers.

- A geopolitical and economic analysis need to be assessed to take in account the impact of EU ETS Aviation or the risk of importation of e-fuels vs French offer and comparative advantages with other countries, etc.

RÉPUBLIQUE
FRANÇAISE
Liberté
Égalité
Fraternité

ADEME
AGENCE DE LA
TRANSITION
ÉCOLOGIQUE

If you want to know more …

TRANSITION(S)
2050
CHOISIR MAINTENANT
AGIR POUR LE CLIMAT

https://transitions2050.ademe.fr/documents

- Reports, synthesis, abstract, infographics...
- But also thematic reports:
- Protein sectors
- Adaptation to climate change
- Soils…


RÉPUBLIQUE
FRANÇAISE

ADEME

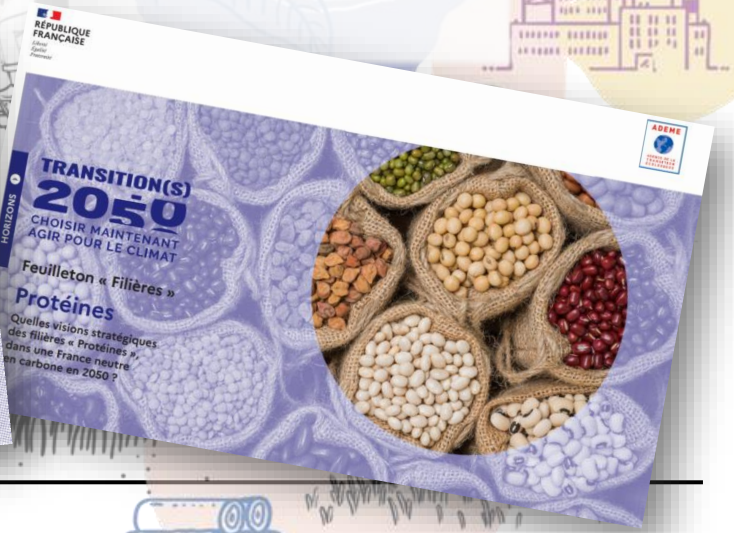
HORIZONS

TRANSITION(S)
2050
CHOISIR MAINTENANT
AGIR POUR LE CLIMAT

Feuilleton

Sols

Quels enjeux pour une gestion durable
des sols à l'horizon 2050 ?


RÉPUBLIQUE
FRANÇAISE

ADEME

HORIZONS

TRANSITION(S)
2050
CHOISIR MAINTENANT
AGIR POUR LE CLIMAT

Feuilleton « Filières »

Protéines

Quelles visions stratégiques
des filières « Protéines »,
dans une France neutre
en carbone en 2050 ?

RÉPUBLIQUE
FRANÇAISE

Liberté
Égalité
Fraternité

ADEME

AGENCE DE LA
TRANSITION
ÉCOLOGIQUE

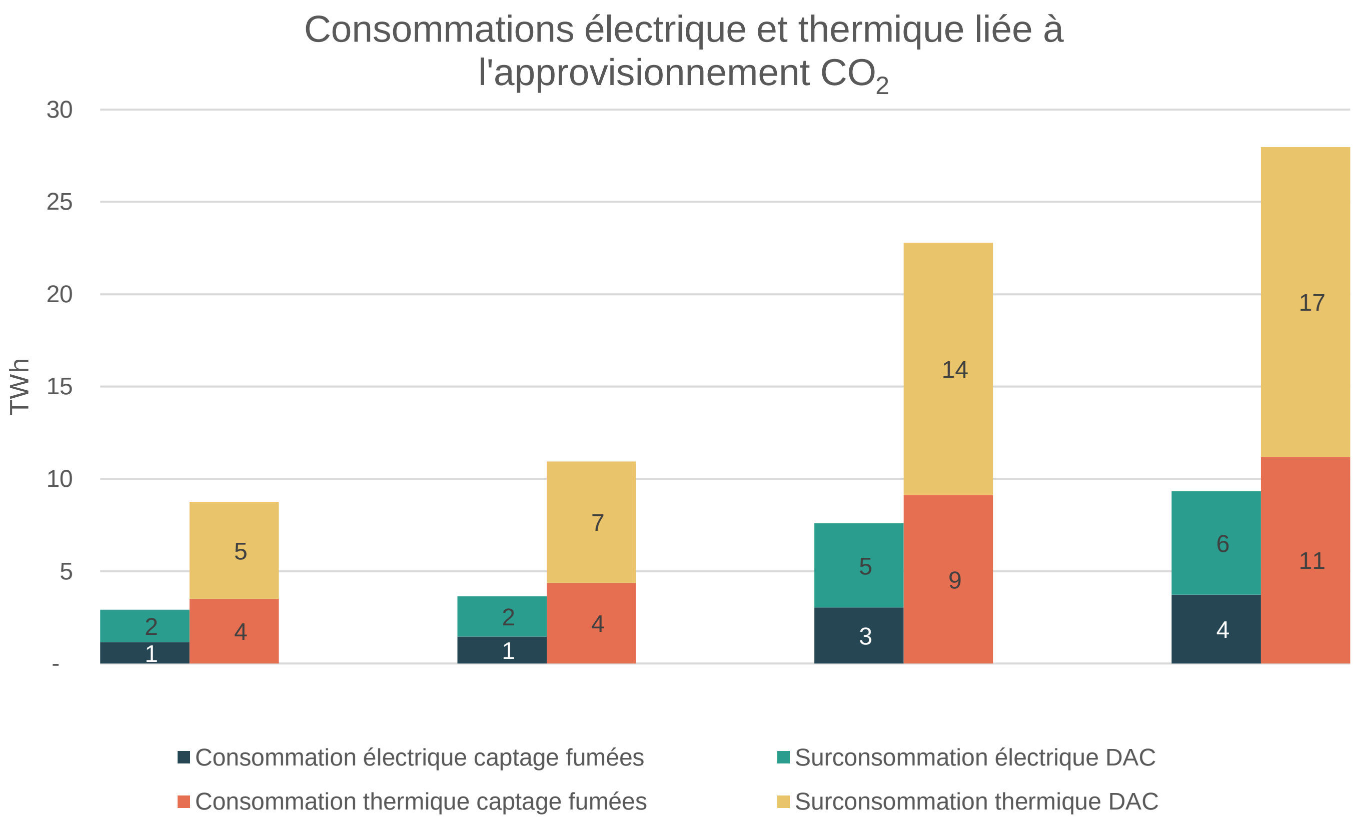
Thank you for your attention

Aicha El Khamlichi, Department of Bioeconomy and Renewable Energy- ADEME

aicha.elkhamlichi@ademe.fr

Supplementary material

Annex
High energy consumption (thermal and electrical) of Direct Air Capture


Consommations électrique et thermique liée à l'approvisionnement CO_2

RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

ADEME
AGENCE DE LA TRANSITION ÉCOLOGIQUE

Téléchargez/Download sur
transitions2050.ademe.fr

Le rapport

La synthèse

Le résumé exécutif


TRANSITION(S) 2050
CHOISIR MAINTENANT AGIR POUR LE CLIMAT
Rapport

TRANSITION(S) 2050
CHOISIR MAINTENANT AGIR POUR LE CLIMAT
Synthèse

TRANSITION(S) 2050
CHOISIR MAINTENANT AGIR POUR LE CLIMAT
Résumé exécutif

Téléchargez les jeux de données
data-transitions2050.ademe.fr

La vidéo en motion capture

Festival Atmosphere

Article sur la sobriété


THE CONVERSATION

La sobriété, au-delà du progrès technique et des changements de comportement individuels

Les feuilletons :

- Mix Electrique
- Matériaux de la transition énergétique
- Les effets macro-économiques
- Adaptation au Changement Climatique
- Sols
- Mode de vie
- Protéines
- Construction Neuve
- Logistique des derniers kilomètres
- Gaz et Carburants liquides
- Territoires


TRANSITION(S) 2050
CHOISIR MAINTENANT AGIR POUR LE CLIMAT
Feuilleton
Mix électrique
Quelles alternatives et quels points communs ?


TRANSITION(S) 2050
CHOISIR MAINTENANT AGIR POUR LE CLIMAT
Feuilleton
Les matériaux pour la transition énergétique, un sujet critique


TRANSITION(S) 2050
CHOISIR MAINTENANT AGIR POUR LE CLIMAT
Feuilleton
Les effets macroéconomiques


TRANSITION(S) 2050
CHOISIR MAINTENANT AGIR POUR LE CLIMAT
Feuilleton
Adaptation au changement climatique : transports, agriculture, forêts, industries, bâtiments


TRANSITION(S) 2050
CHOISIR MAINTENANT AGIR POUR LE CLIMAT
Feuilleton
Sols


TRANSITION(S) 2050
CHOISIR MAINTENANT AGIR POUR LE CLIMAT
Feuilleton
Modes de vie


TRANSITION(S) 2050
CHOISIR MAINTENANT AGIR POUR LE CLIMAT
Protéines


TRANSITION(S) 2050
CHOISIR MAINTENANT AGIR POUR LE CLIMAT
Logistique des derniers kilomètres


TRANSITION(S) 2050
CHOISIR MAINTENANT AGIR POUR LE CLIMAT
Gaz et carburants liquides


TRANSITION(S) 2050
CHOISIR MAINTENANT AGIR POUR LE CLIMAT
Territoires

… et prochainement :
- Qualité de l'Air
- Numérique
- Empreinte matière et CO_2
- Adaptation du système électrique
- Effets redistributifs
- Chocs et vulnérabilités