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Waste to Energy
A Tunisian-Japanese initiative for a clean city

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General Framework

Waste

- The production of waste per inhabitant per day is on average between 0.85 and 1 kg/hab/day
- Waste recycling is estimated at only 4% of the recyclable potential
- Energy recovery from waste is almost non-existent
- Biogas released from landfills is a lethal source of energy! And polluting.

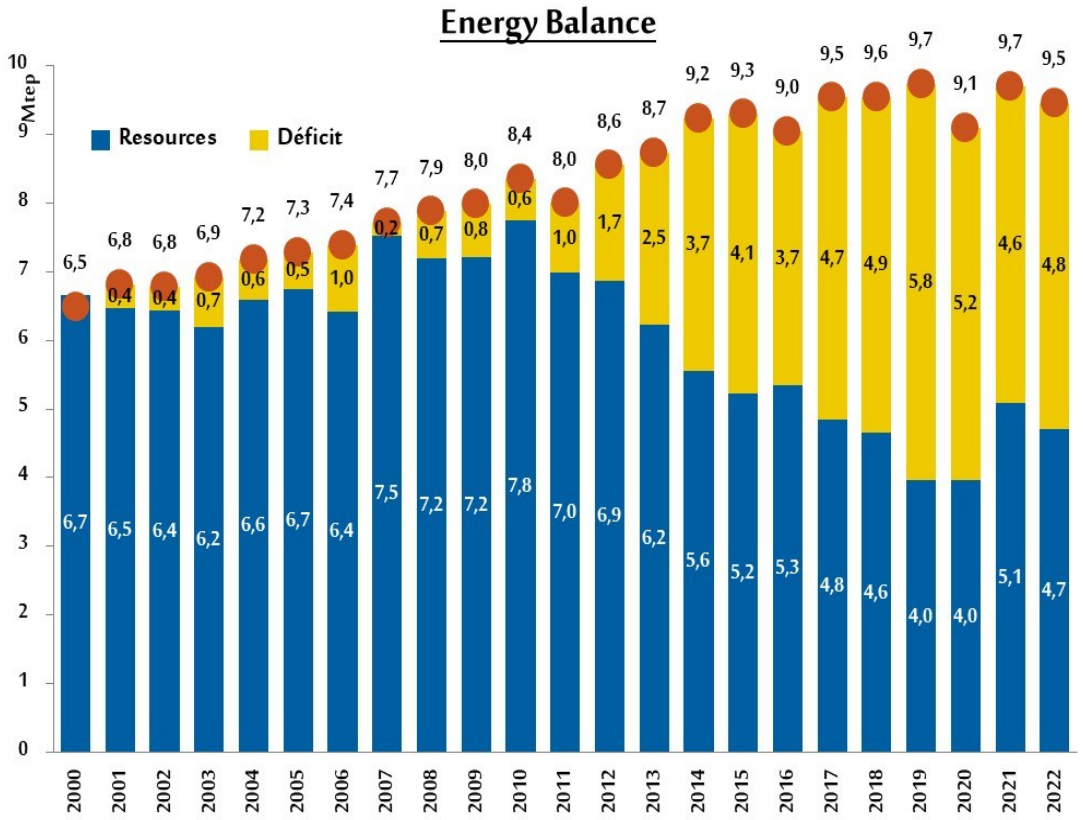
Energy

- The problem is compounded by rising energy prices worldwide.
- Tunisia therefore, has an interest in engaging in an energy transition policy.

Tunisian Energy Context

Continuous deficit since 2001, reaching a maximum of 5.8 Mtoe, equivalent to 60% in 2019.

In 2023, the energy deficit reached 4.7 Mtoe, representing a 48% deficit.



Tunisian energy context

- 96% of electricity generated from natural gas
- 50% of natural gas is imported.
- Natural gas is imported from a single country, Algeria.

Objectives of the Tunisian government

1

45% GHG

Reduction in carbon intensity in 2030 compared to 2010 (Organic Law No. 72 of 2016).

2

35% Renewable 2030

Renewable contribution to the energy balance

50% Renewables 2035

3

30% Energy efficiency

Compared to the BAU scenario

Biogas potential in Tunisia

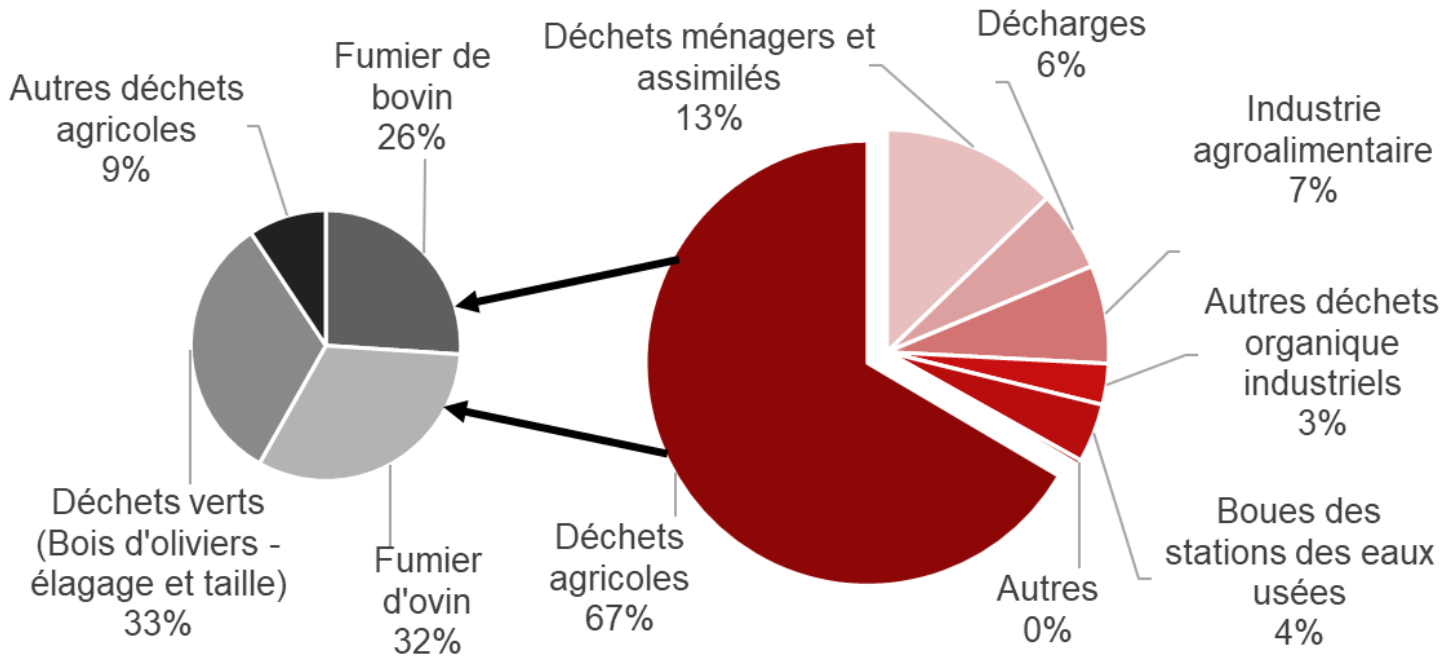
Vue globale du potentiel énergétique des déchets

Potentiel total			
Catégorie	**Potentiel net (GWH)**	**Capacité (MW)**	**%**
Déchets ménagers et assimilés	1.422	190	12,8%
Décharges	651	87	5,9%
Déchets organiques industriels	1.123	150	10,1%
Déchets agricoles	7.379	984	66,5%
Boues des stations des eaux usées	476	9	4,3%
Autres	40	5	0,4%
Total déchets	**11.092**	**1.424**	**100,0%**

56 % Méthanisation
44 % Incinération

Biogas Potential in Tunisia

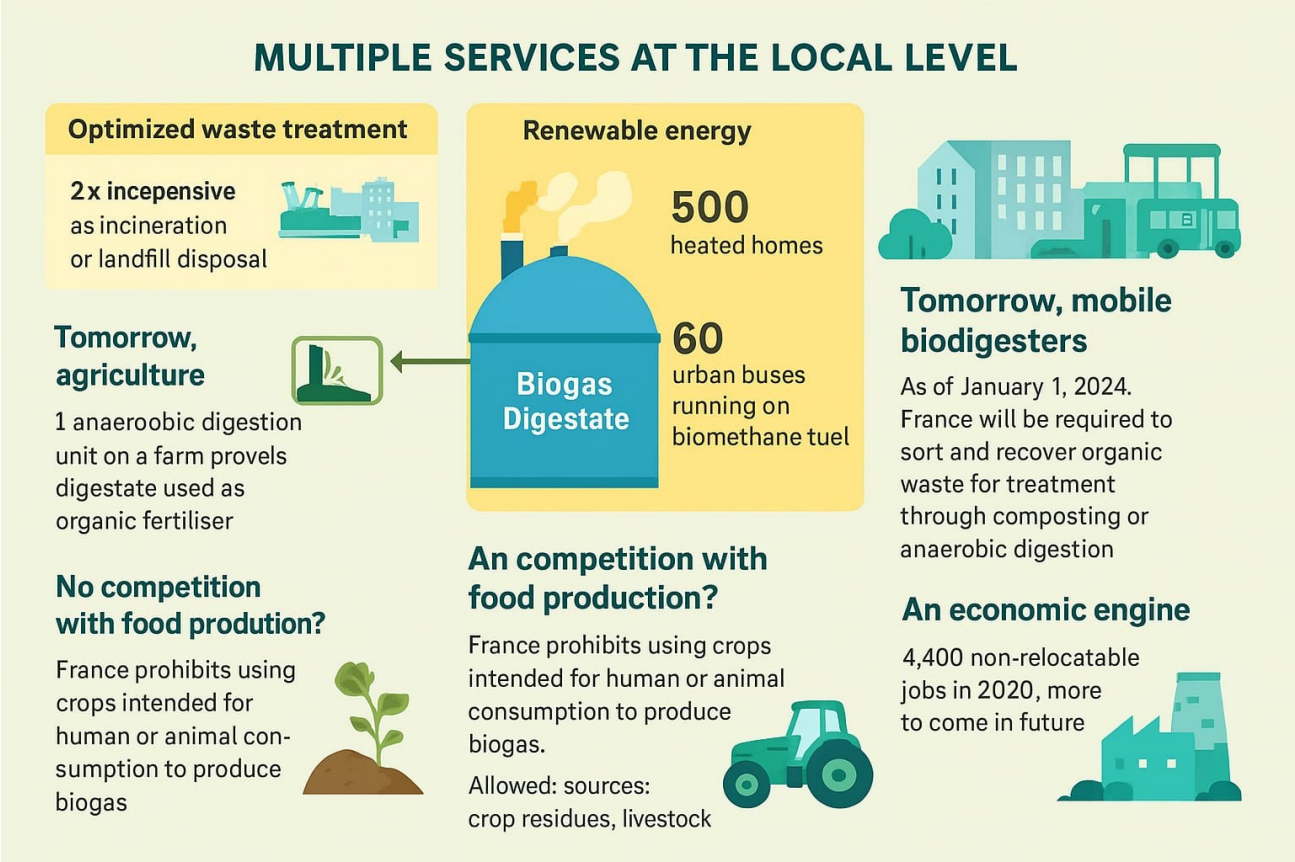
Potentiel énergétique total (potentiel net (GWH))



Powering Tunisia’s Future From Biomethane to Energy Solutions

Methane production has a role to play in Tunisia's renewable energy mix

- A renewable energy source, although its potential in Tunisia remains limited compared to solar and wind power.
- Biogas, the only renewable gas, can replace fossil gas in industrial boilers and as fuel for vehicles.
- The injection of biomethane into the national gas network should be authorised.
- In the absence of a gas network, electricity production could be optimised by using heat to produce cooling.



Recommendations for the development of anaerobic digestion in Tunisia

International benchmarking brimming with ideas

2) A regulatory framework proportionate to the characteristics of the methanisation sector:

- with the amortisation periods of the required investments
- with requirements defined according to proven risks
- consistent with purchase prices, due to its financial impact on projects

3) A favourable ecosystem:

- training officers trained in methanisation
- bankers and insurers invited to support methanisation, and who themselves have a good knowledge of methanisation
- training courses in methanisation included in university curricula (technicians and engineers)
- public bodies acting as points of reference for methanisation
- standardisation of the methanisation process to improve the quality and safety of projects
- involvement of PPIs and citizens in decision-making

Biomethane injection:

The need to comply with commercial natural gas interchangeability requirements for biomethane injectable into the STEG gas network.

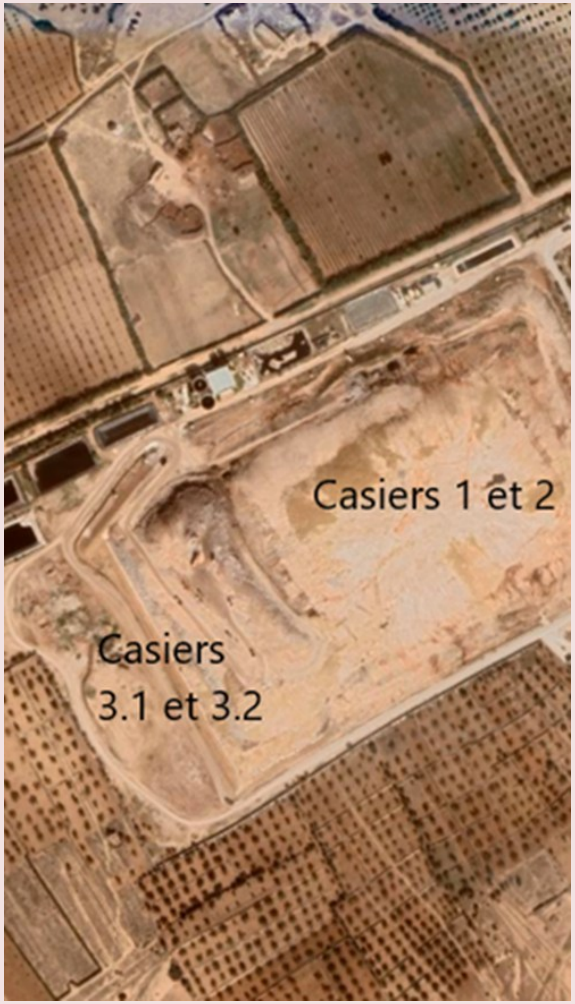
The pricing framework for biomethane injectable into the STEG network should be based on Decree No. 2000-1027 of 15/05/2000 setting the price of commercial gas sold on the local market by hydrocarbon concession holders.

The tariff resulting from the application of this framework, for commercial gas delivered to the entry point of the STEG main gas transmission network, is calculated according to the following formula:
Price of injected biogas (DT/TEP): 80% X (price of low-sulphur fuel oil in DT/TEP)The application of this price is conditional on injection into the main gas transmission network and the delivery of commercial gas whose characteristics comply with STEG's technical requirements.
In the event of the sale of gas at a delivery point upstream of the main network, the sale price shall be adjusted accordingly.

Cogeneration:

1. For electricity generated from biogas, retain the authorisation system with the tariff based on avoided fuel costs, based on STEG data setting 307 mill/kWh according to the overall cost of electricity (rounded to 307 mil/kWh).
2. It seems that the proposed tariff is not attractive for certain categories of installations, so the Government could decide to grant:
   - ❑ A substantial investment bonus on the FTE-FODEP or other to improve the project's economics and reduce the return on investment (ROI)
   - ❑ An additional bonus on the price per kWh sold to STEG over a fixed period of operation of the recovery system

Tunisian-Japanese Initiative : Improvement of Oued Laya Waste Site Management by Using Biomethane Gas for Renewable Uses



Project background

- The Oued Laya-Sousse controlled landfill has been in operation since July 2008. It receives on average around 600 tonnes/day
- The landfill site is demarcated by a fence. Its surface area is 47 hectares, of which only 20 hectares are currently developed.
- landfill cell 1 and 2 have reached the final level, while landfill cell 3 is currently being exploited.
- In total, approximately 2,657,361 tonnes of waste were received and buried at the Oued Laya controlled landfill from July 1, 2008 to July 31, 2022.


Évacuation des eaux pluviales
Casier en cours de remplissage
Casier fermé
Déchets
Entrée du site et contrôle des déchets
Torchère
Valorisation biogaz (production chaleur ou électricité, réseau gaz de ville)
Captage du biogaz
Bassin de contrôle avant rejet
Bassin étanche de récupération des lixiviats
Lixiviats
Récupération du jus des déchets (lixiviats)
Station de dépolllution des lixiviats
Lixiviats nettoyés
Bassin de contrôle des rejets après traitement

- In cumulative terms over the period 2021-2030, emission reductions compared to the trajectory BaU will total 87.5 MtCO2. These emission reductions would come mainly from the energy sector (72%), followed by AFOLU (13%), and processes (9%). The remaining mitigation results (6%) stem from the low-carbon policy of the waste sector (Source CDN 2021).

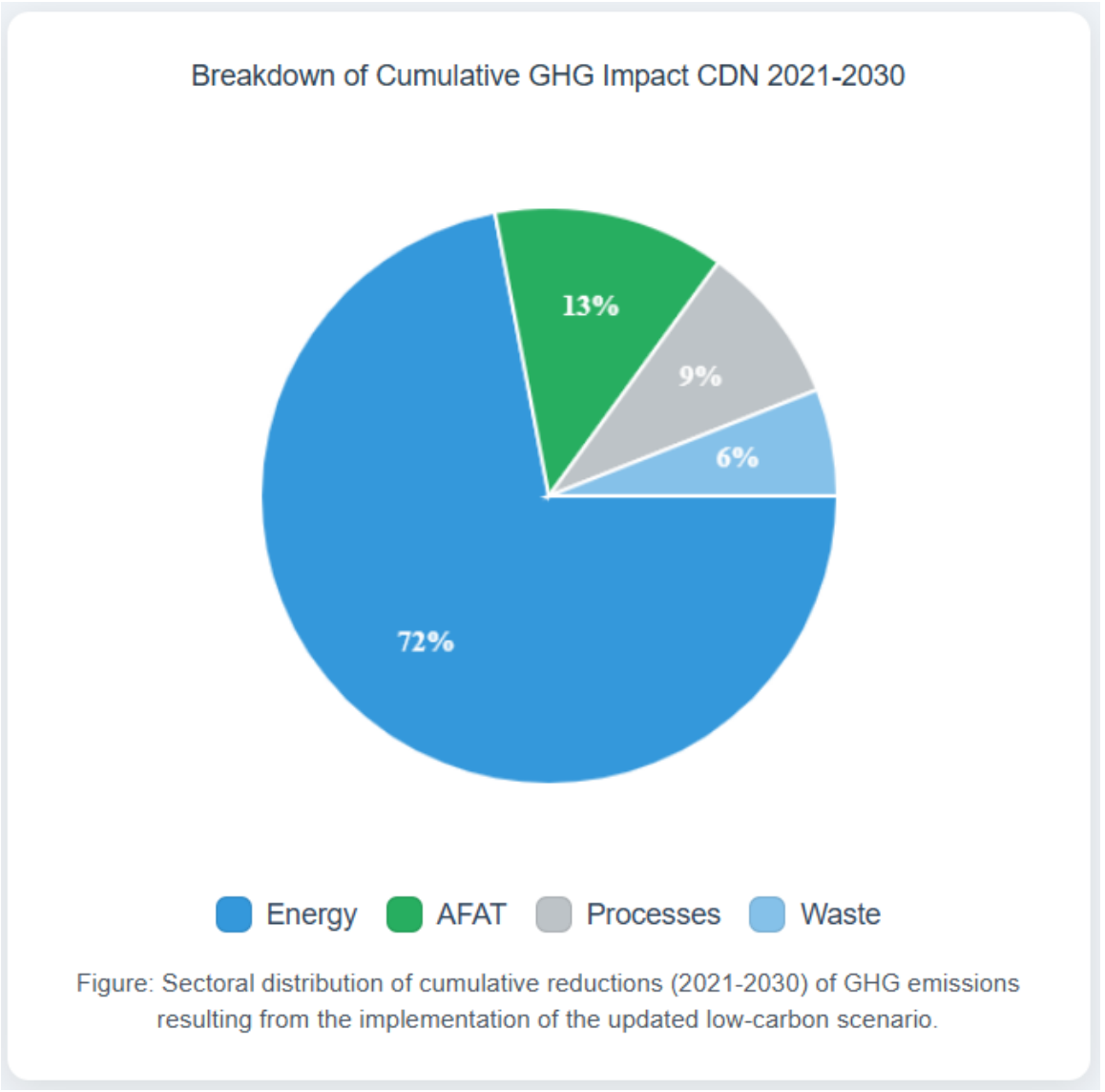
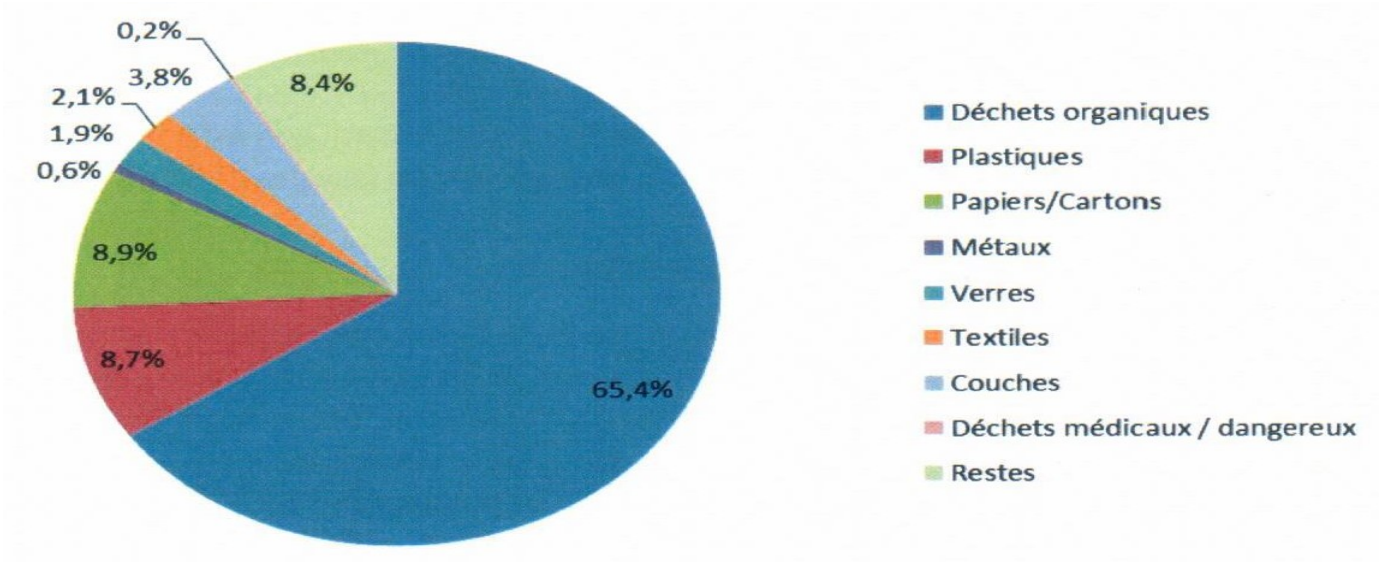


Figure: Sectoral distribution of cumulative reductions (2021-2030) of GHG emissions resulting from the implementation of the updated low-carbon scenario.

“Stored wealth being lost through spending”

Composition and quantities of buried waste and leachatesretained

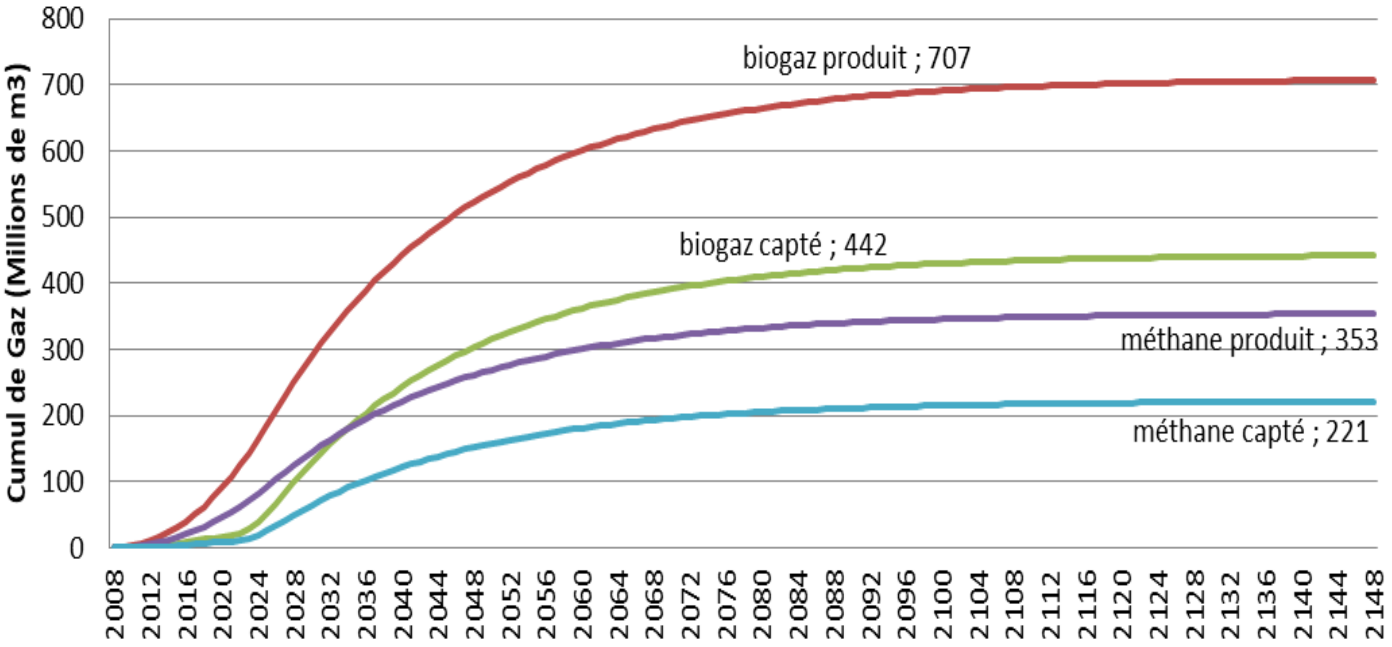
In summer, the average percentages of the different waste fractions change slightly compared to winter with the arrival of tourists. The seasonal difference, however, remains small and the composition remains close to the composition of waste on a national scale, despite an organic fraction of more than 65%. The higher this latter fraction, the greater the quantities of leachate will be produced after landfill. A possible integration of mechanical-biological treatment (MBT) into the waste management process before landfill will reduce the quantities of leachates produced later.



Results of the characterization of waste from the governorate of Sousse during the summer period (ANGed)

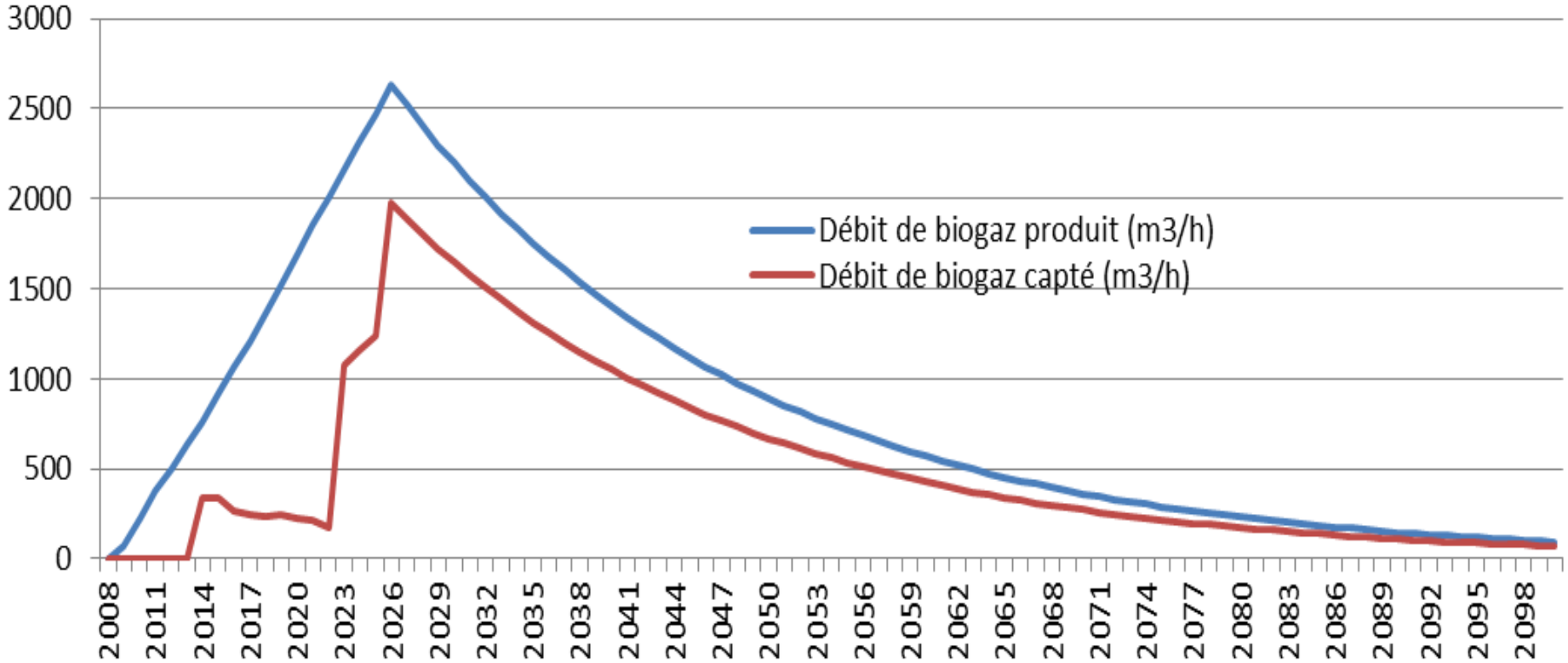
Scenario A

- The production of biogas in this scenario takes into account the burial of waste in existing compartments 1, 2 and 3 in the Oued Laya controlled landfill, therefore until the year 2025. The actual and planned productions and captures have been modeled and are summarized in Figure 5 which presents the cumulative volumes of biogas and biomethane. In Figure 6, the flows already measured in previous years are reported directly on the curve and the flows for future years are modeled using the software LandGEM according to the data of scenario A.



Simulation of biogas accumulations and biomethane produced and captured according to scenario A in the Oued Laya landfill – Sousse (millions of m3).

The cumulative biogas that will be produced in the Oued Laya-Sousse landfill according to scenario A will exceed 700 million m3, including approximately 440 million m3 that will be captured and will be subject to energy recovery, always according to the same scenario. Half of these volumes will correspond only to biomethane.

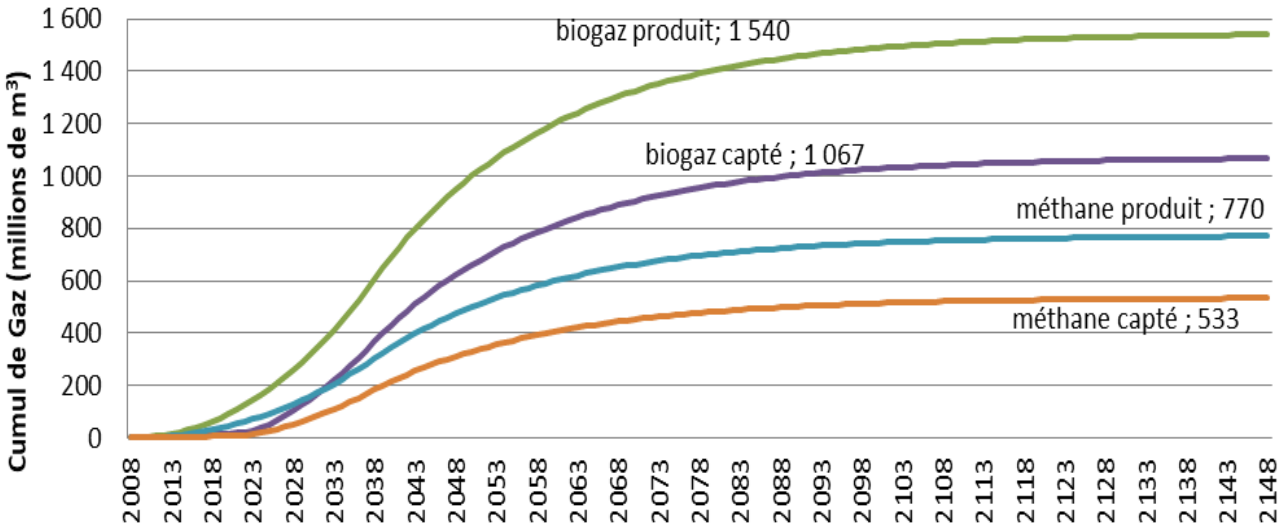


Simulation of biogas production and capture flow rate (m3/h) depending on the years at the Oued Laya controlled landfill – Sousse according to scenario A.

The planned installation of new biogas capture wells will increase the biogas flow rate from its current level of around 200 m3/h to 1000 m3/h after one year and then 1200 m3/h two years later. The closure of compartment 3 will further increase the biogas production rate, which will reach a peak of around 2000 m3/h in this scenario A and then gradually decrease while maintaining biogas production for decades. The simulation shows that even in 80 years the capture network at the landfill will continue to provide approximately 100 m3 of biogas which will be recoverable.

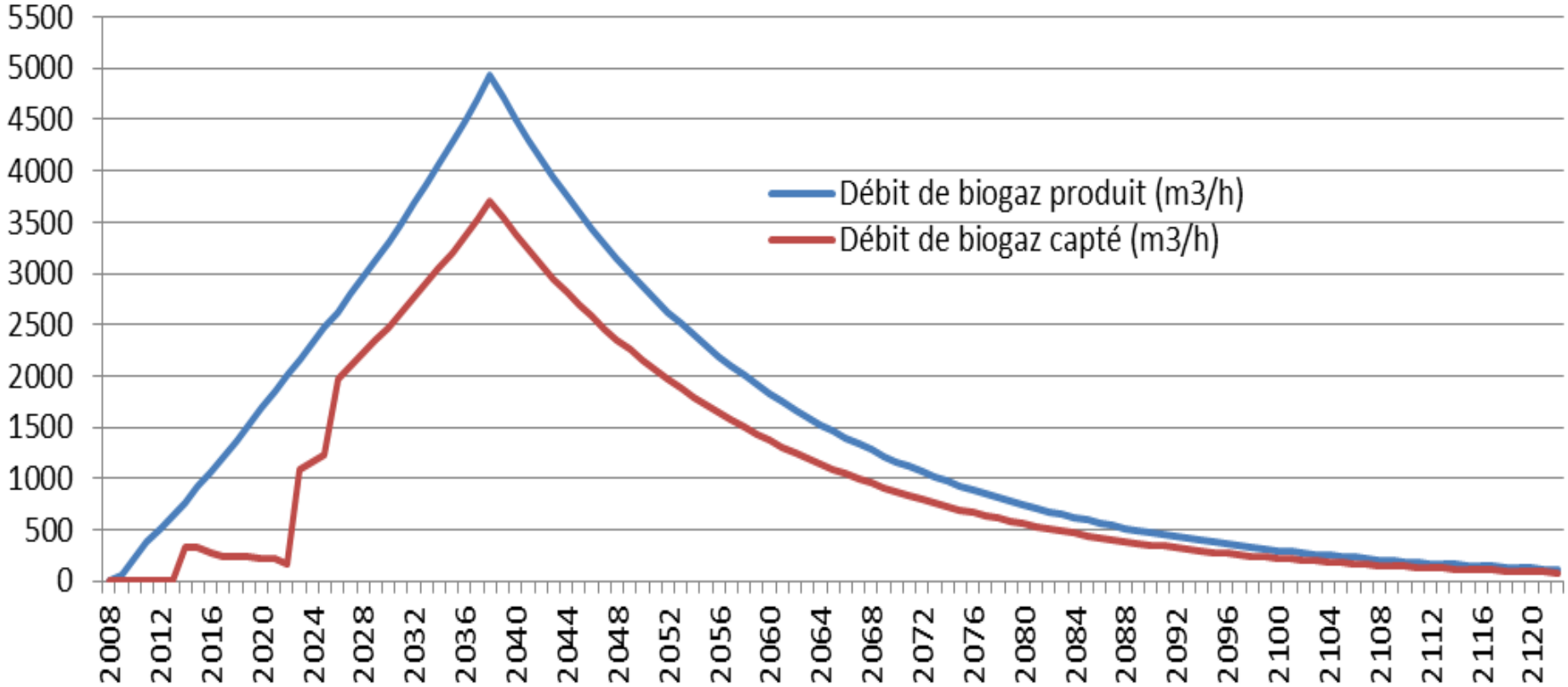
Scenario B

- The production of biogas in this scenario takes into account the burial of waste in existing and planned bins 1, 2, 3, 4 and 5 in the Oued Laya controlled landfill, therefore, until the year 2037. The quantities of biogas and biomethane that will be produced and captured in the landfill have been estimated as a function of years (Figure 7). Figure 8 shows the modeling results in terms of biogas flow rates produced and captured. The flow rates already measured in previous years are reported directly on the curve and the flow rates for future years are modeled using the software LandGEM according to the data of scenario B.



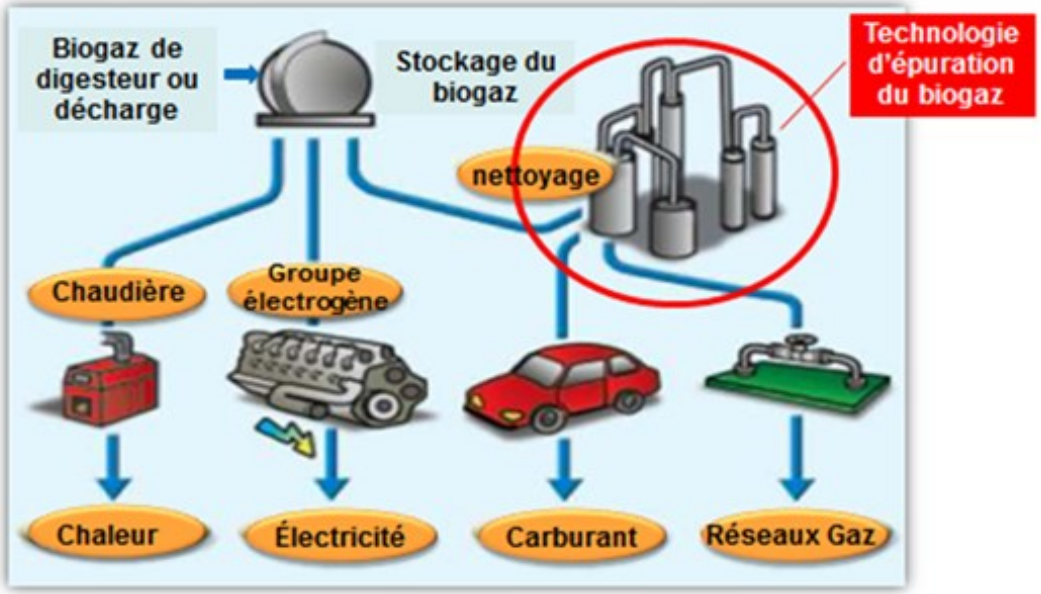
Simulation of biogas accumulations and biomethane produced and captured according to scenario B in the Oued Laya landfill – Sousse (millions of m^3).

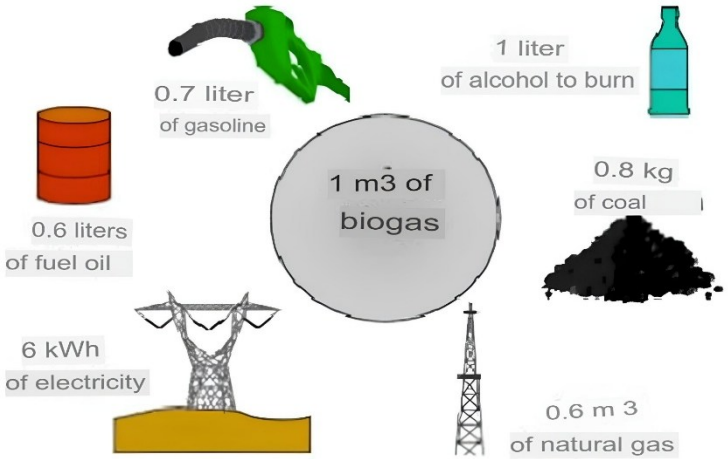
Modeling according to scenario B predicts biogas production in the Oued Laya – Sousse landfill which will exceed 1500 million m^3 cumulative including more than one million m^3will be captured for recovery. Half of these volumes will correspond to the biomethane.



Simulation of the biogas production and capture flow rate (m3/h) as a function of years at the Oued Laya controlled landfill – Sousse according to scenario B.

According to scenario B, the operation of all current and planned lockers, namely 1, 2, 3, 4 and 5 and their closure and equipment with a capture system will make it possible to gradually increase the flow rate of captured biogas from its current level of around 200 m3/h to more than 3500 m^3/h. The peaks of biogas produced and collected will be reached after the closure of the last compartment, i.e. in 2038 in this scenario B. A gradual decrease in gas flow rates will then be observed while maintaining production and capture of around 100 m3 of biogas that can be recovered after a century.





Biogas, like natural gas, can be used in different ways.

In this section, scenarios for the recovery of biogas produced in the Oued Laya landfill are presented, detailed and compared based on:

- Technical feasibility,
- No contradiction with the laws in force,
- Sustainable use,
- Legal framework,
- Required level of technicality,
- Number of interested parties and complexity of procedures,
- Investment and economic viability.

Best Scenario Achieved

- The **biogas theoretically contains an energy of around 6kWh eq/m3.**
- **Cogeneration, since it converts part of this energy into heat and another part is lost, gives about 2kWh electricity/m3 of biogas**.
- This means that an average biogas flow rate of 200 m3 can produce approximately 400 kWh of electricity.
- Even with the least optimistic scenario, there is a certain energy potential of the biogas produced in the Oued Laya landfill – Sousse.

Sce-nario	Technology	Legislative framework	Terms	Cost: Investment and Exploitation	Current feasibility	Dura-bility	Multipl-icityparts
1	CoG– self-production – municipalities	Decree2002-3232 / Law 2015-12		+/-	+	+	-
2	CoG– self-production – concession	Decree2002-3232 / Law 2015-12		+/-	+	+	+
3	CoG– self-production - ANGed	Decree2002-3232 / Law 2015-12	Conventio n	+/-	+/-	+	+ / -
4	CoG– R authorization - ANGed	Law 2015-12	Conventio n	+/-	+/-	+	-
5	GN network injection	Absent		+ / -	-	+/-	-
6	BioNGV	Decree2002-2017	Conventio n	-	+/-	+/-	-
7	BioGNCcylinder	Order 1956	Conventio n	-	+/-	+/-	-
8	Boiler			+	+ / -	+/-	-

+ Favorable ; - binding

Constitution of July 25, 2022 *Chapter II, Article 47 "...It is the responsibility of the State to provide the means necessary for the elimination of environmental pollution »*

Kyoto Protocol... *Use of ER...Limitation and /or reduction of methane emissions through recovery and use in the waste management sector...*

Principles and Commitments

A. from Paris–CDN *Reduction of carbon intensity by 45%... Partly through the production of electricity from biogas*

Law No. 96-27 *STEG + IPP* Energy recovery

Decree No. 2002-3232 ↔ **Decree No. 2009-3377** *CoGenergy efficient: thermal and electricity from primary energy or biomass. Right of Transmission and Sale to STEG up to 2/3 for power < 3 MW or 1/2 if > 3 MW* → **Order of 24 dec2007** *CCh CoGon the electrical network*

Law No. 2004-72 ↔ **Law No. 2009-7** ↓

Decree No. 2009-2773 *Right to transport electricity from RE and sale < 30% to STEG. May be exceededto.p. biomass*

↓

Decisionof June 2, 2014 *Transport rates 7mill/kWh and purchase by STEG of the surplusto.p. ICoGand ER* ↔ **Decree-law No. 2022-12** → **Order of November 17, 2022** *Self-productionto.p. ER > 1 MW requires authorization from the Ministry of Energy*

Biogas Project - Energy

Law No. 2015-12 → **Decree No. 2016-1123**

Orders of February 9, 2017 and August 30, 2018 *CONTRACT -type of transport and 3 sales contracts* ↔ **Law No. 2019-47** *Relaxation of proceduresadmin.*

Orders of August 8, 2019 and October 6, 2020 *Flammable gas tanks*

Law 2008-23 *Concessions system*-**Decree-law 2022-68** *Authorization of ER projects in the public domain*

Law No. 96-41 *Local authorities and groups of municipalities can entrust operations or installations collection, disposal and treatment household waste to businesses*

Decree No. 2005-2317 *L'ANGedmay enter into concessions with public or private companies in the event that a local authority subcontracts it with the management of household waste*

Waste management

Order of January 17 2007 *CChrecycling and recovery of waste non-dangerous*

Achieved Scenario : Cogeneration – Authorisation regime – ANGed – Agreement

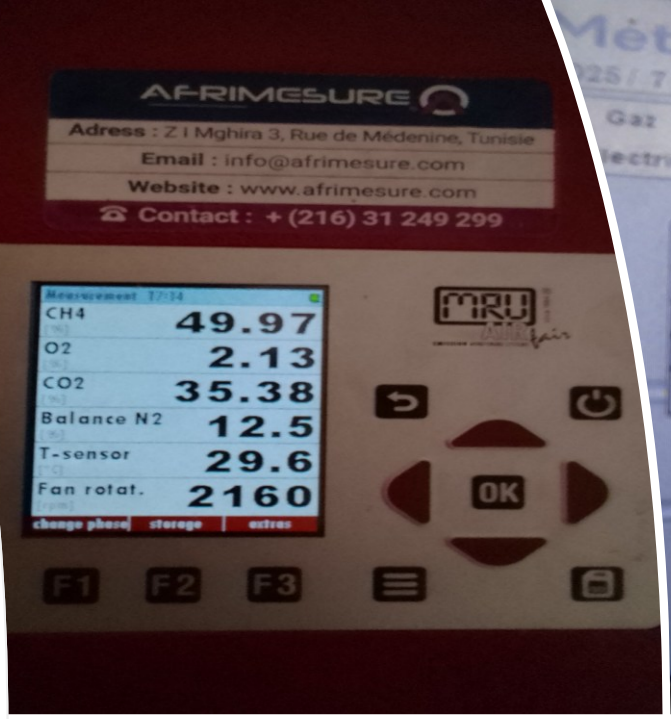
- ANGed will generate electricity through cogeneration using biogas, which is considered a renewable energy source, and will sell its entire production to STEG under an agreement.

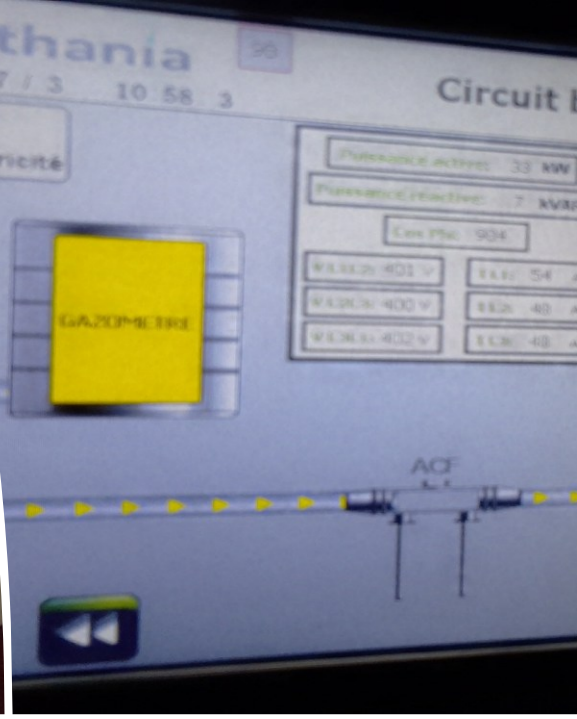
- Considering the current average production of the biogas network at the Oued Laya-Sousse landfill site, which is around 200 Nm3/h of biogas, capable of producing more than 400 kWh of electricity through cogeneration, this energy could meet the average consumption of around 2,000 households in one year. The average annual consumption per household is estimated at 1,760 kWh by STEG.

Best Scenario Achieved: First Pilot cogeneration unit in Tunisia

Recording the working hours of the cogeneration station at the Oued Laya Controlled Landfill

STEG COUNTER INDEX WITH ENGINE OPERATION





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