

Waste-to-Energy

Opportunities, Challenges & Research

Case of Morocco



Saida TAYIBI
UM6P-Morocco

November 6-8, 2023



University
Mohammed VI
Polytechnic

A photograph of four diverse students (three men and one woman) laughing and looking upwards in a sunny outdoor setting. The image is partially covered by a large orange semi-transparent rectangle on the left and bottom. A white 3D cube graphic is positioned at the intersection of the white background and the orange rectangle.

Empowering Minds.

THEMATIC SITES TO RESPOND TO TERRITORIAL CHALLENGES



BENGUERIR

The UM6P Central Campus dedicated to applied research and the teaching of exact sciences.



RABAT

Rabat hosts UM6P of Governance, Economics, Social Sciences Faculty, in addition to Ai Rearch Center and Africa Business School.



CASABLANCA

In order to ensure proximity to the business world, UM6P will soon settle a platform of innovation and a Startup ecosystem in Casablanca.



LAÂYOUNE

In Laâyoune,, ASARI "African Sustainable Agriculture Research Institute" is the first component of UM6P Campus, to tackle the agricultural challenges of Morocco and Africa.



MAZAGAN

A new urban and university hub to host a research center in the fields of chemistry, and a start-up incubation platform.



KHOURIBGA / TETOUANE / YOUSSEUFIA / SAFI

The 1337 and YouCode schools specialized in computer coding have opened in several cities. In Tetouane, in collaboration with the F.TMSA.



UM6P France

UM6P is opening its first international Branch in Paris, focusing on Research activities, Executive Education and Entrepreneurship ecosystem.

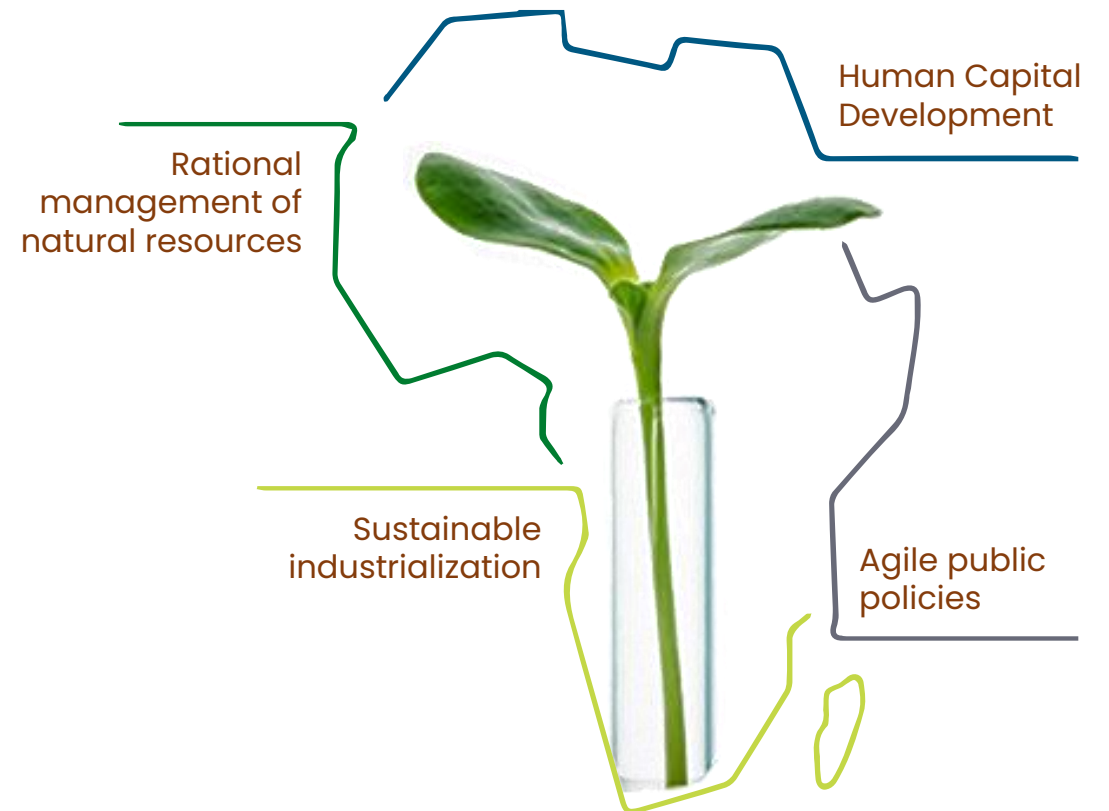
RESEARCH AND INNOVATION FOR AFRICA'S SUSTAINABLE DEVELOPMENT

Research topics

- 
-  Water, Agriculture & Environment
 -  Natural Resources & Food Security
 -  Renewable Energy
 -  Industrial & Chemical Engineering
 -  Biotechnology & Biomedical Engineering
 -  Architecture, Urban Planning & Land Use
 -  Geology and Sustainable mining
 -  Agricultural Economics & Development
 -  Chemical and Bio-chemical / Green Process Engineering
 -  Complex system engineering and Human Sciences
 -  Behavioral Sciences
 -  Modélisation, Data Sciences & Intelligence Artificielle
 -  Medical Application Interface
 -  Industrial Economy and emerging Africa



African challenges



LIVING LABS

REAL-SCALE EXPERIMENTATION PLATFORMS

EXPERIMENTAL
FARMS



EXPERIMENTAL
MINES



URBAN
POLE OF
MAZAGAN



CHEMICAL HUB
OF SAFI



GREEN ENERGY
PARK



FAB LAB



DATA CENTER



DIGITAL
LEARNING LAB

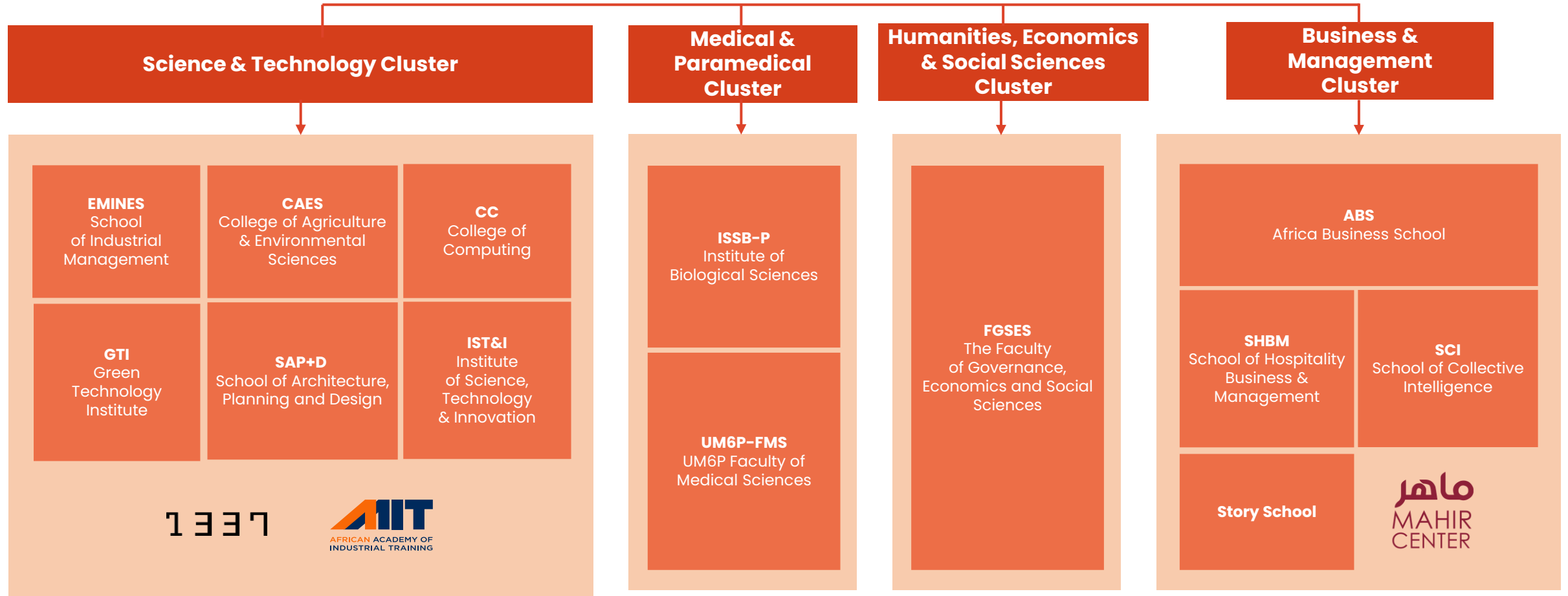


FOUM EL OUED
TECHNOPOLE



CLUSTERS & SCHOOLS

UNIVERSITY MOHAMMED VI POLYTECHNIC

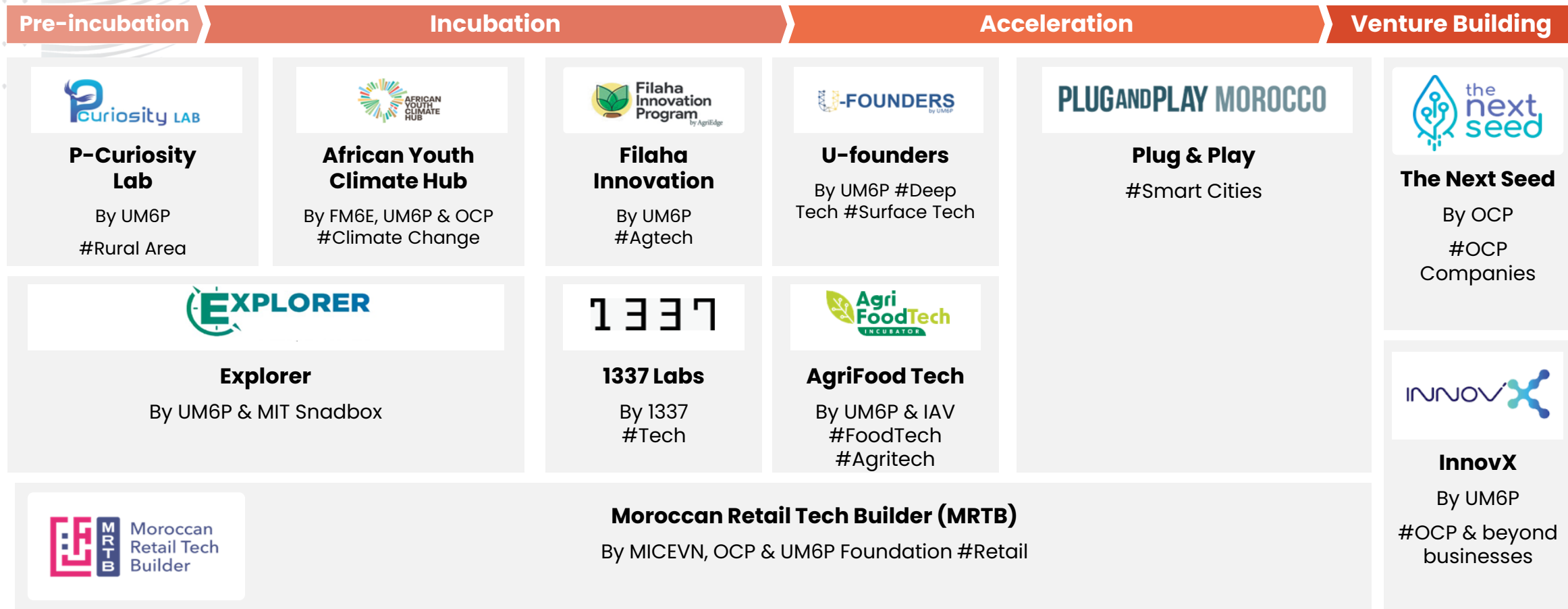


CEDOC – Center for Doctoral Studies

EXECUTIVE EDUCATION

MBA | Exécutive Masters | Short courses | Sur mesure

UM6P ENTREPRENEURSHIP AND VENTURING EXISTING PROGRAMS



A Corporate Venture Capital Company launched by UM6P and the OCP Group



VENTURES

The UM6P investment fund



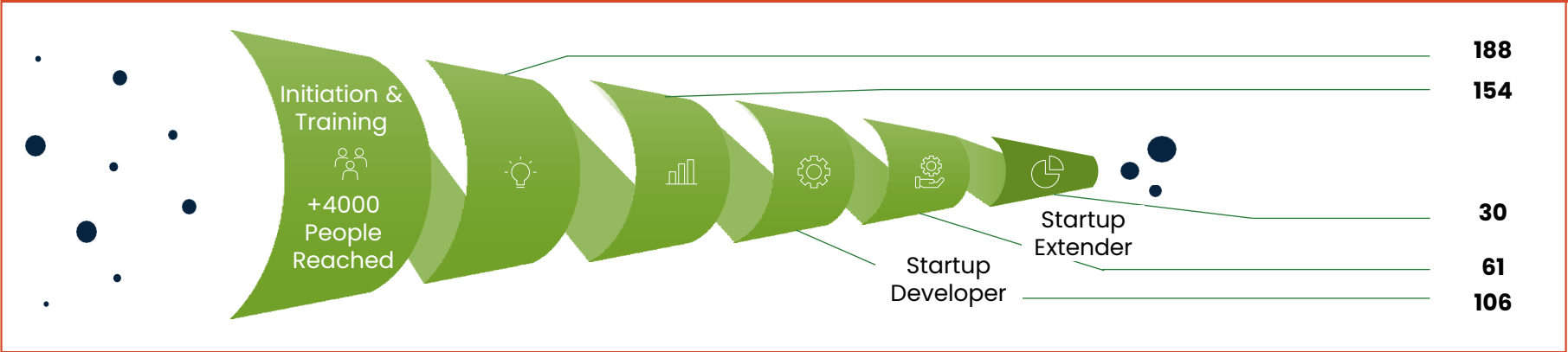
Fondation MaSciR Investment and Incubation Company

ZOOM ON UM6P ENTREPRENEURSHIP AND VENTURING : KEY METRICS

Key Performance Indicators



Over 530 project founders and startups supported



\$20.6M+
Funds raised by our
top 25 startups
(since 2020)

bidra \ vc **\$10.5M** invested in 4 startups and 2 funds

UM6P VENTURES **\$5.6M** invested in 23 startups



College of Agriculture
& Environmental
Sciences



CULTIVATING TODAY,
A GREENER
TOMORROW

CAES Research

Disciplinary research:

Soil Science, Soil microbiome and bio-fertilizers, plant sciences, biomass valorization, water research, remote sensing, digital and precision agriculture, decision support and agricultural extension

Transdisciplinary research:

Climate change, food and nutritional security, poverty reduction, resilience and sustainability, bio-saline agriculture, agriculture in marginal environments, sustainable intensification of African Agriculture

College of Agriculture and Environmental Sciences (CAES)

Poste	Number
Professors (all ranks)	41
Adjunct Professors	45
Technical and administrative staff	135
Postdoctoral fellows	18
PhD Students	112
Extension Services	95
Total	446

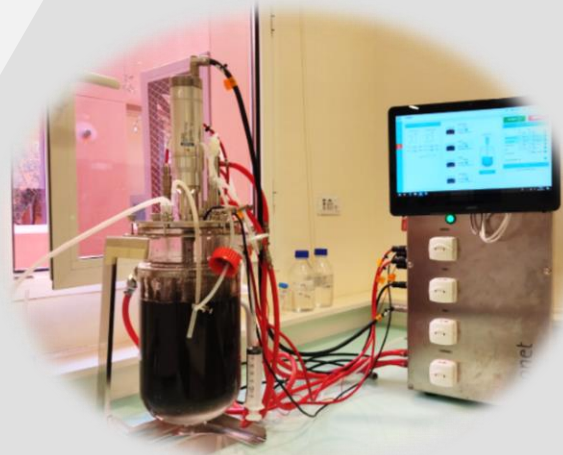


11 Entities	Staffing
AgriTech-AgriEdge	22
Agrobiosciences (AGBS)	74
Agricultural Innovation and Technology Transfer Center (AITTC)	60
Al Moutmir	96
African Sustainable Agriculture Research Insitute (ASARI)	42
Center of Excellence in Soil and Fertilizer Research in Africa (CESFRA)	32
Chair Soil Science	6
College	6
Center for Remote Sensing Application (CRSA)	30
School of Agricultural Sciences Fertilization and Environment (ESAFE)	17
International Water Research Institute (IWRI)	61

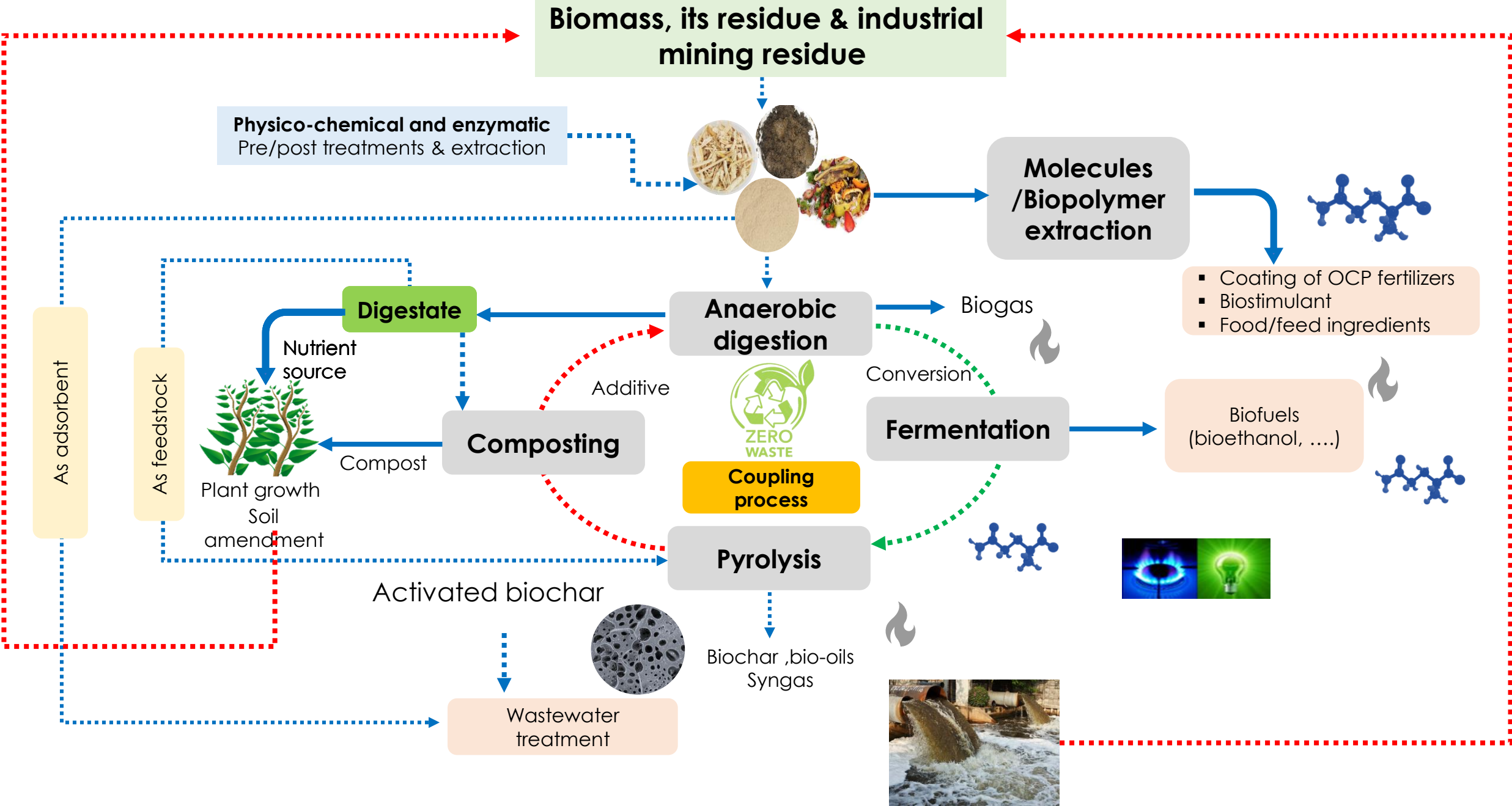
Research on waste valorization



**AgroBioScience
Program**



Research approach & strategy



Main Research Topics and Applications

- Biological processes (aerobic/anaerobic digestion; fermentation, composting)
- Pretreatments to enhance organic matter solubilization and degradation (physical: mechanical; ultrasonic, chemical, thermal and enzymatic) before the processes.
- Biological treatment of OCP by-product
 - Soil fertilizing/amendment with digestate;
 - Production of biogas, bioethanol,.
 - Production of compost
 - Metals recovery from OCP by-products



Reactor for anaerobic/aerobic digestion

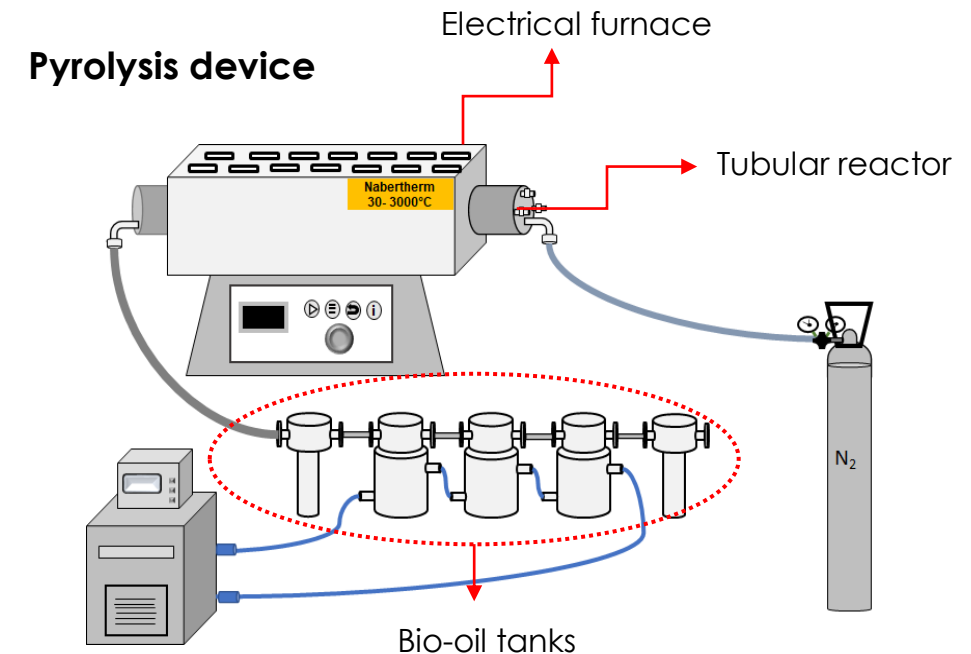
Main Research Topics and Applications

- Thermochemical processes to valorize biomasses and biomass residues to produce biochar, bio-oil and syngas
 - Production of biochar for soil amendment/conditioner.
 - Production of activated biochar for toxic compounds adsorption
 - Biofuels as bio-oil and syngas
 - Development of new adsorbent based on mining

Pyrolysis device composed on:

- Electrical furnace
- Tubular reactor
- Bio-oil tanks
- Cooling system

Semi-Pilot scale Pyrolysis Tubular reactor



Energy Demand : Case Of Morocco

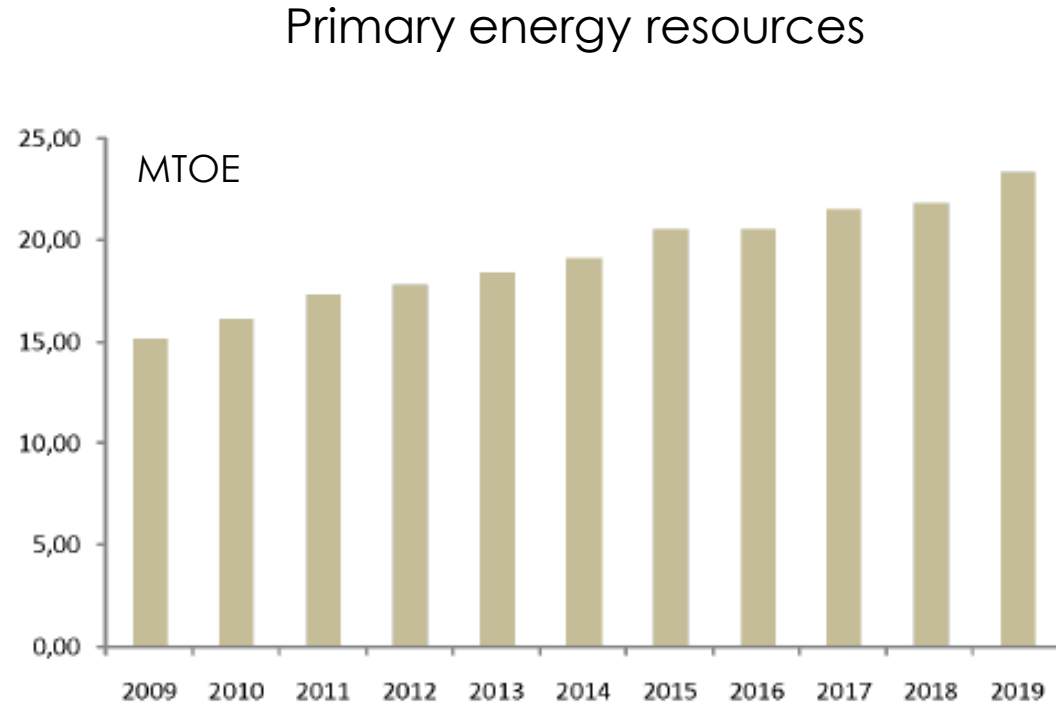


Fig.1. Evolution of primary energy demand (2009-2019)

1 TOE= 11628 kWh

TOP: tone of oil equivalent

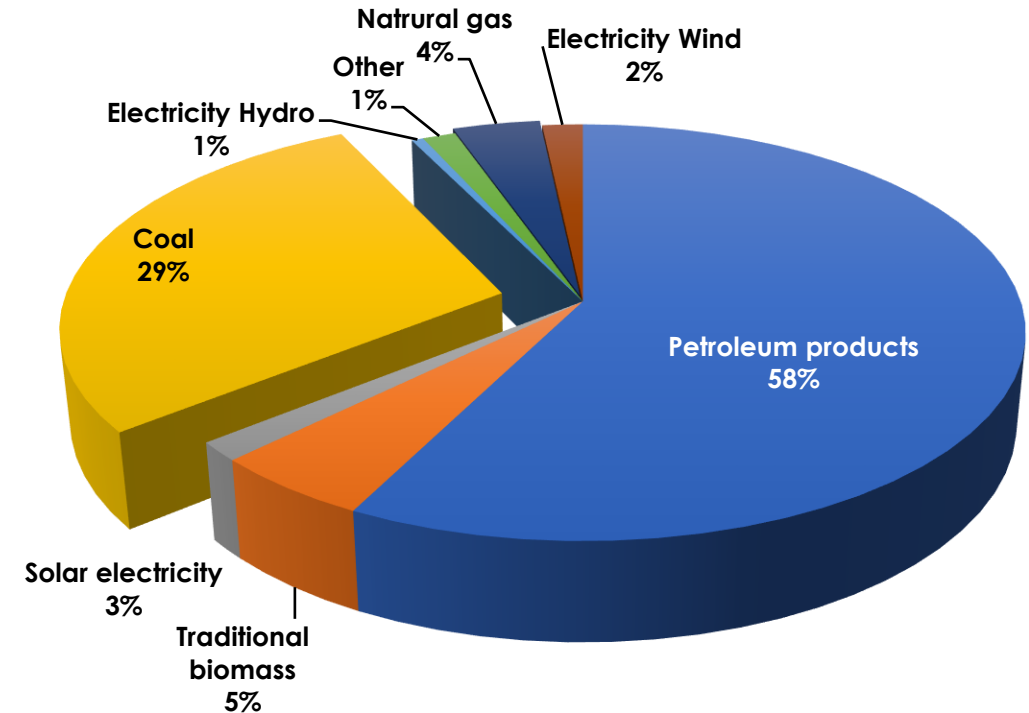
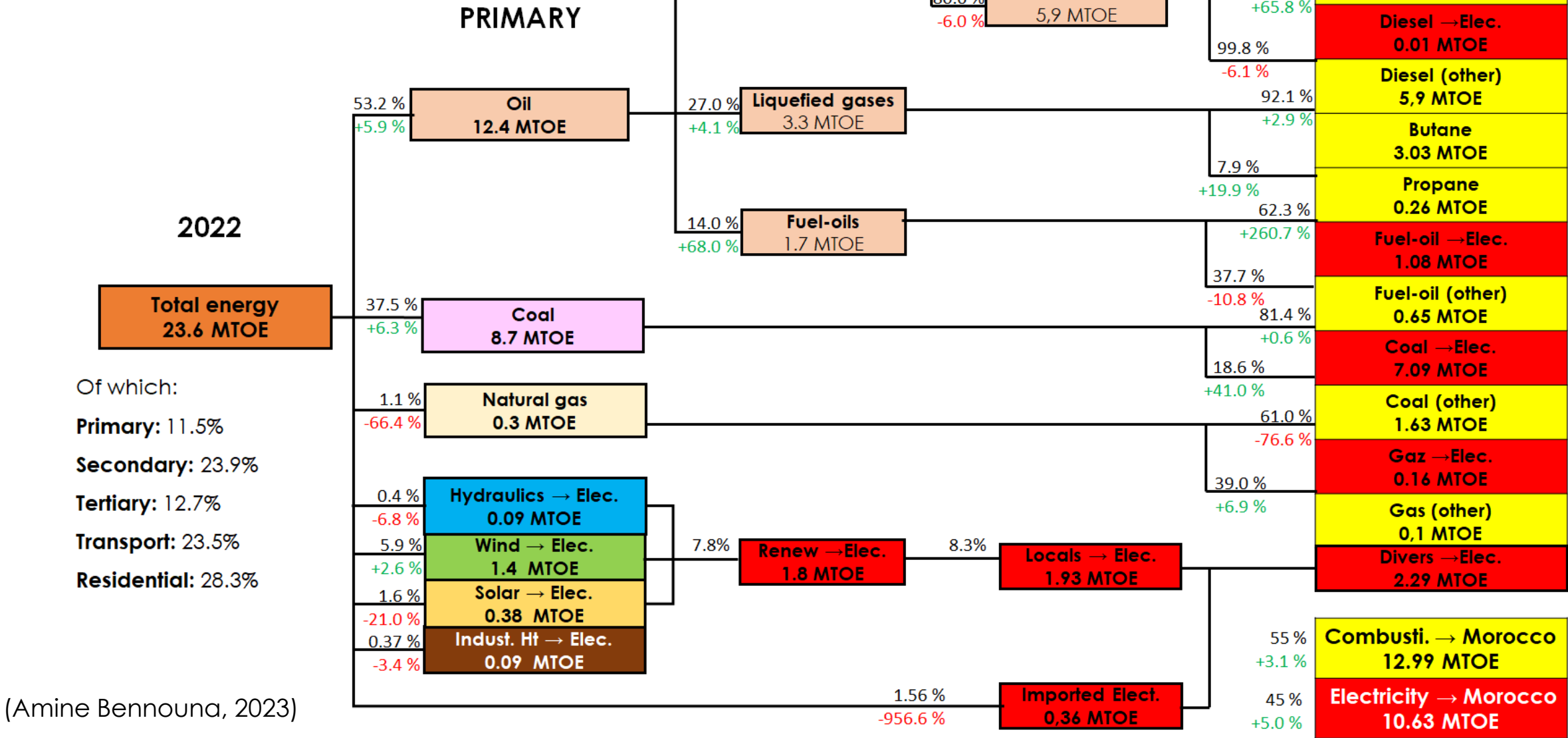


Fig.2. Breakdown of primary energy demand by source in 2019

Energy Flow Diagram

Case of Morocco (2022)

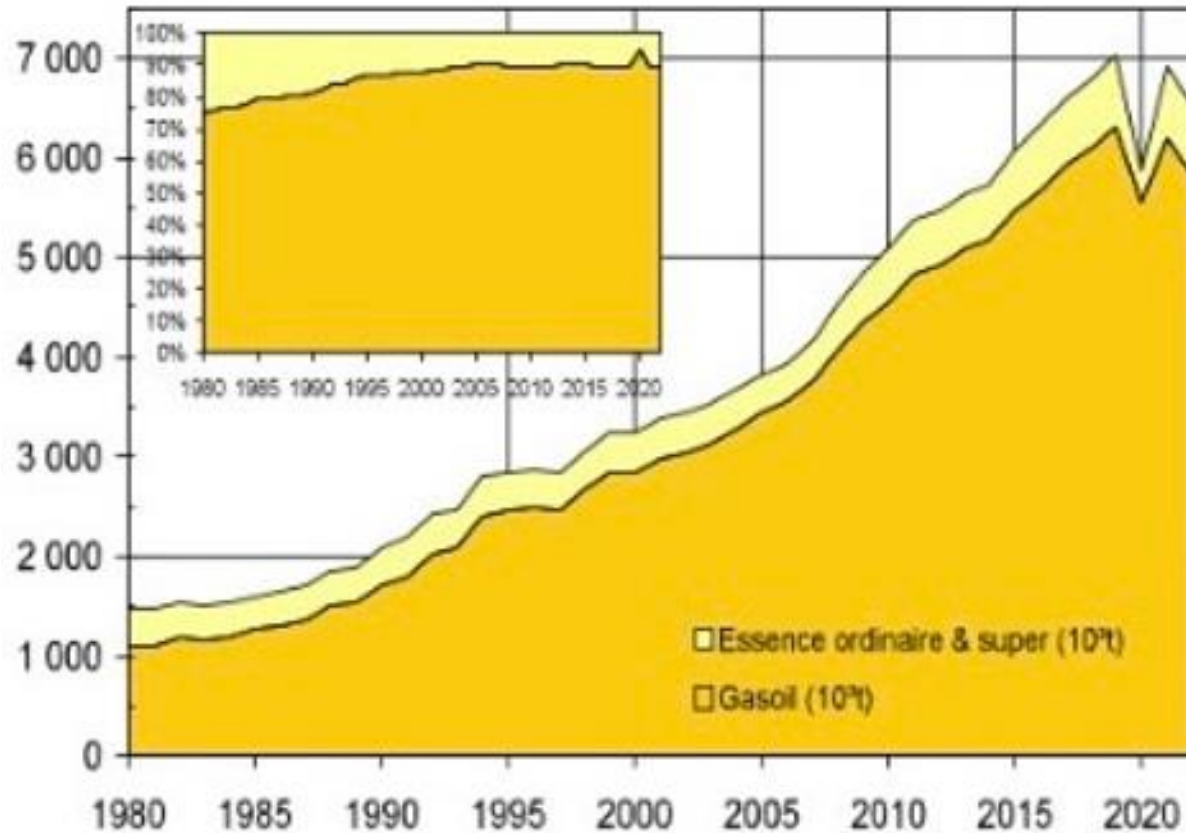


(Amine Bennouna, 2023)

White Fuel And Liquefied Petroleum Gas Markets

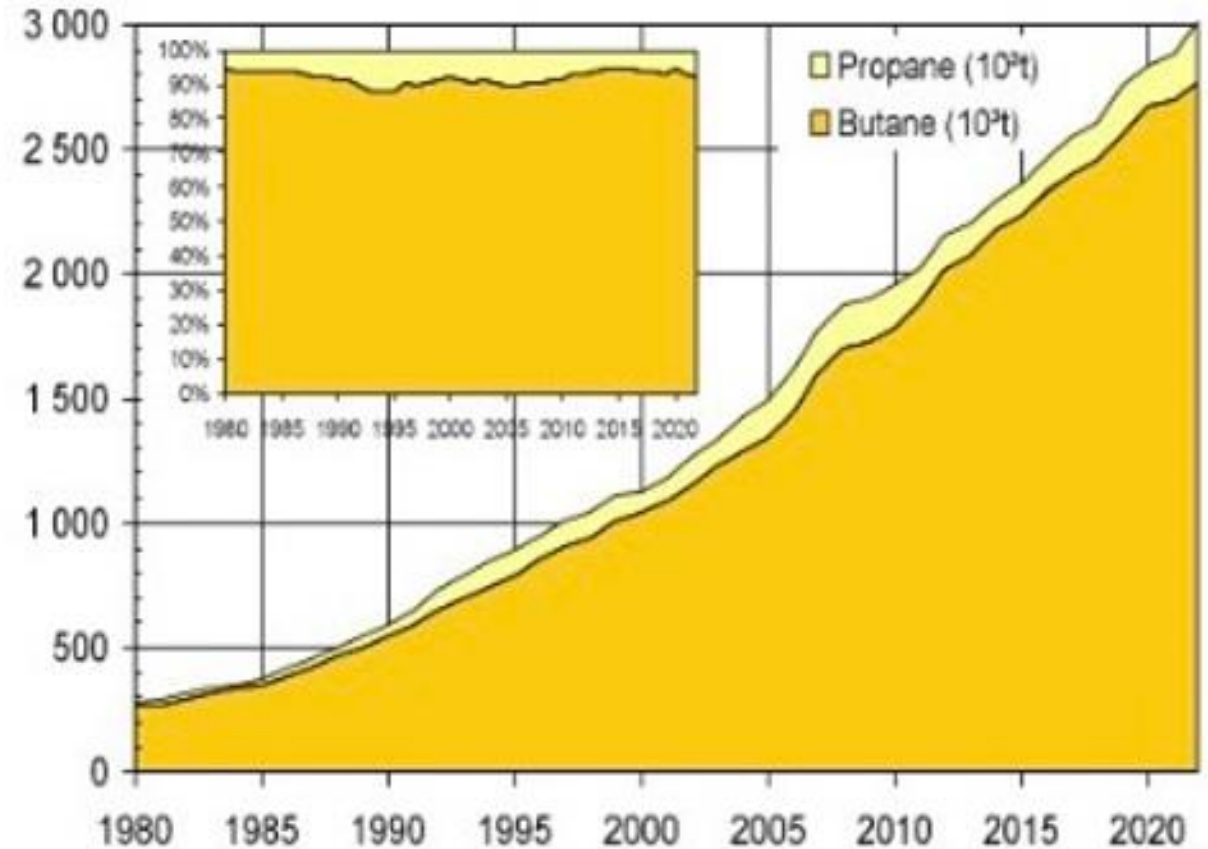
Case of Morocco (1980 -2022)

(Amine Bennouna, 2023)



Fuels market:

- **1980:** 1.5 millions tones
- **2012:** 7 millions tones



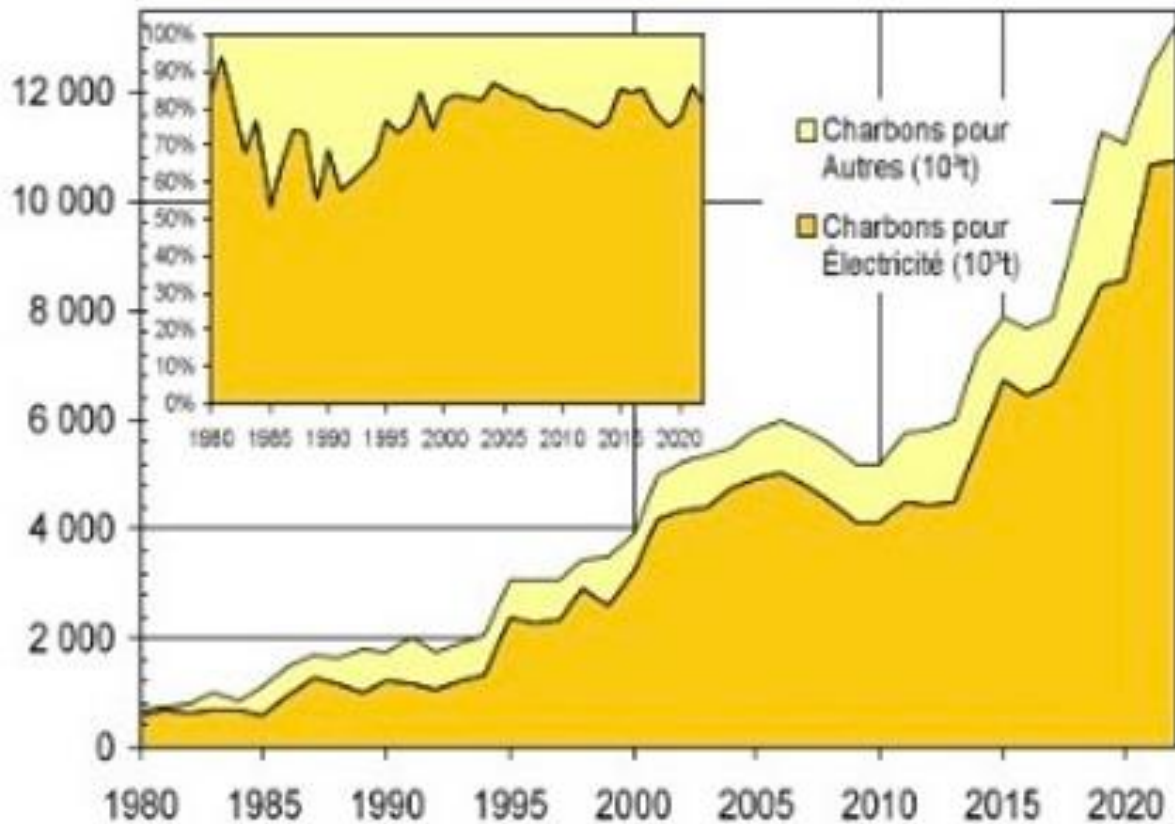
LPG market

- **1980:** 350 000 tones
- **2012:** 3 millions tones

Coal And Natural Gas Markets

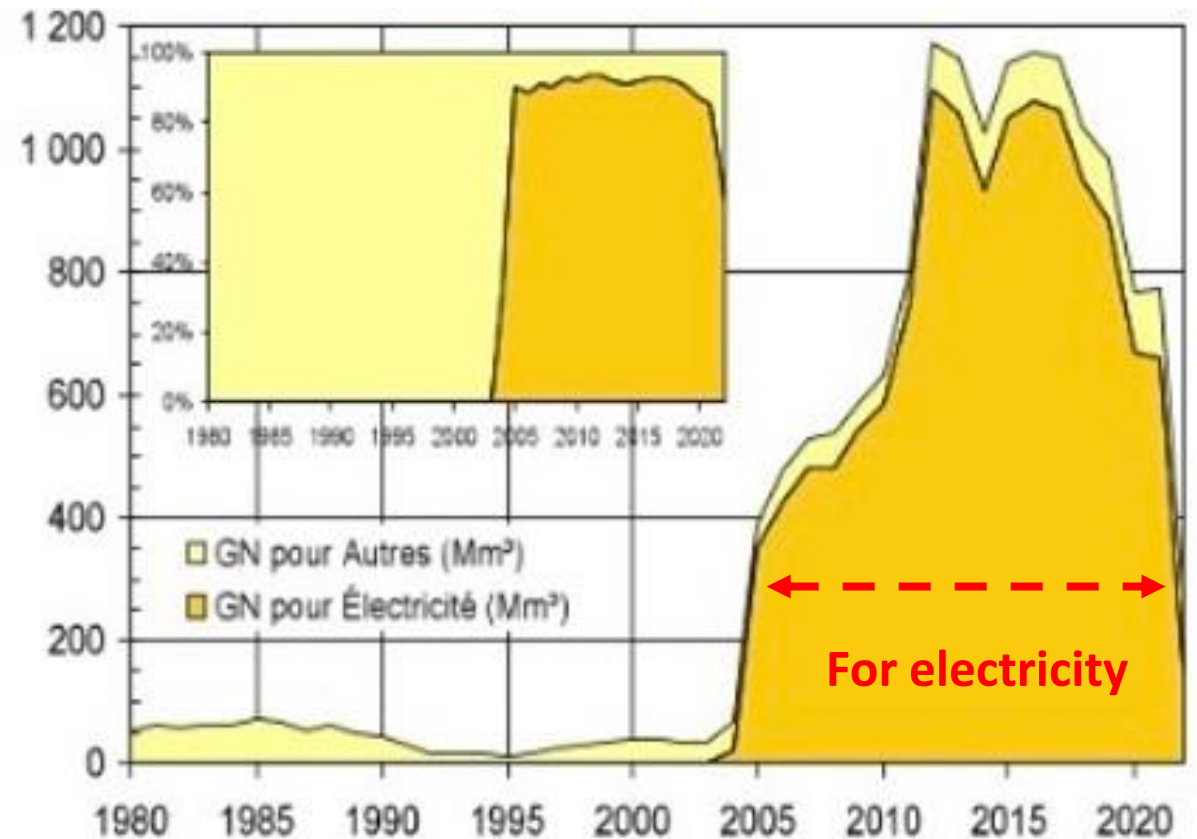
Case of Morocco (1980 -2022)

(Amine Bennouna, 2023)



Coal market (mainly for electricity):

- **1980:** 600 000 tons
- **2022:** ~13 millions tons



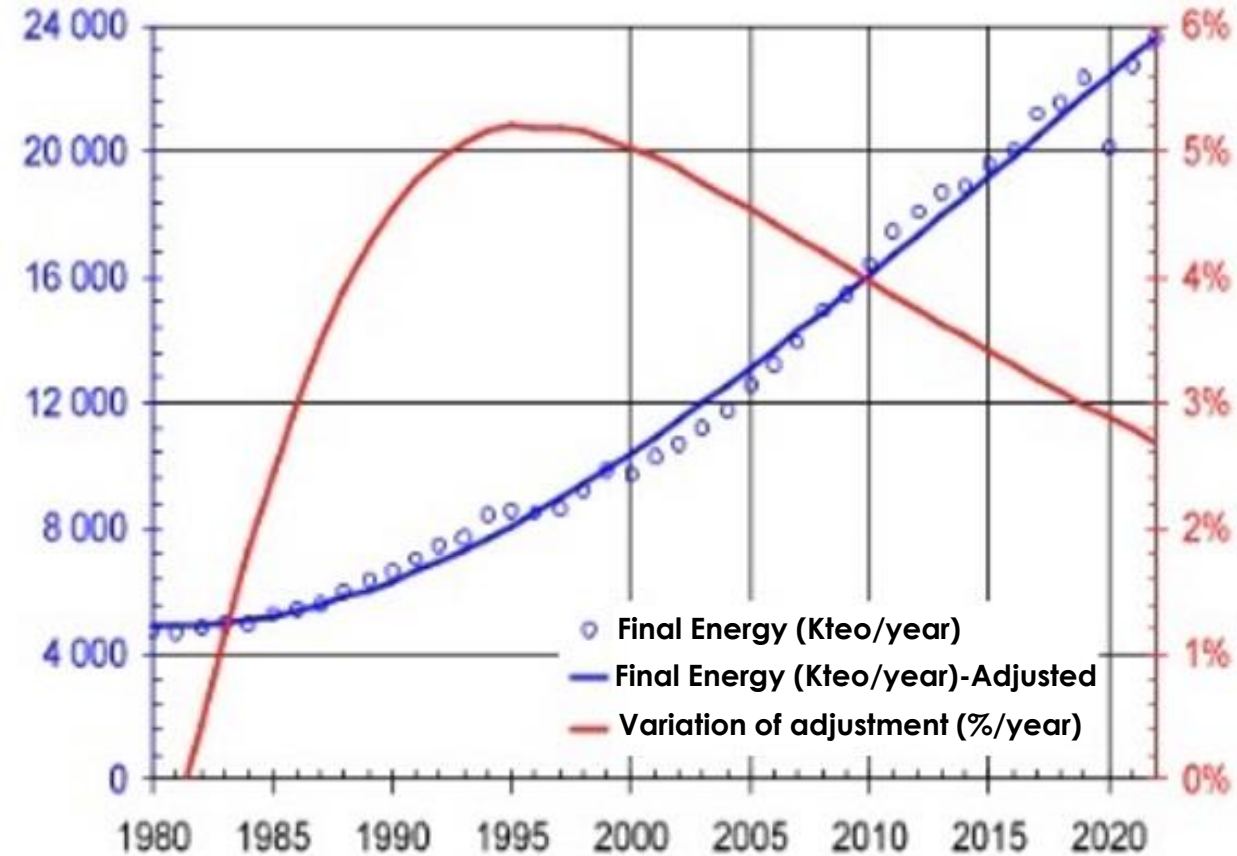
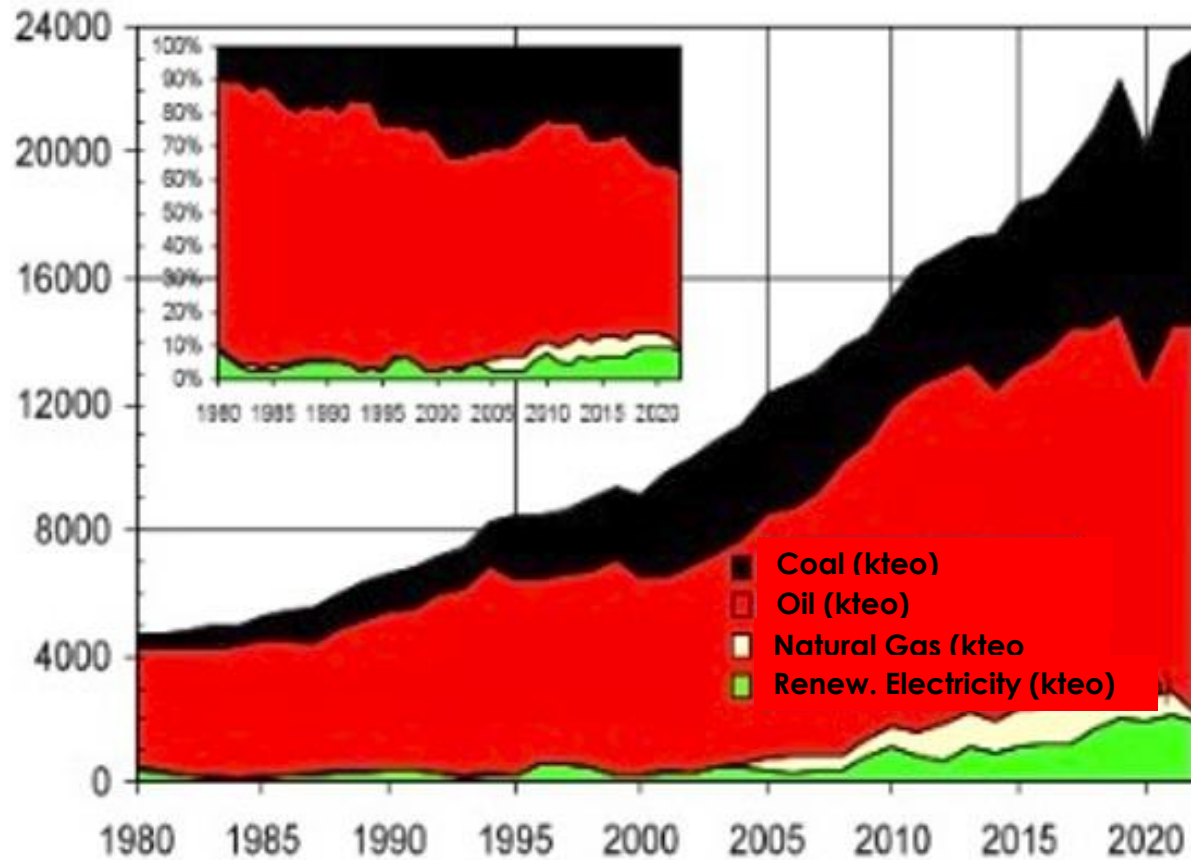
Natural gas market:

- **1980-2004:** 50 millions tones
- **2016:** 1.15 billion tones

Petroleum products market : Composition & Variation

Case of Morocco (1980 -2022)

(Amine Bennouna, 2023)



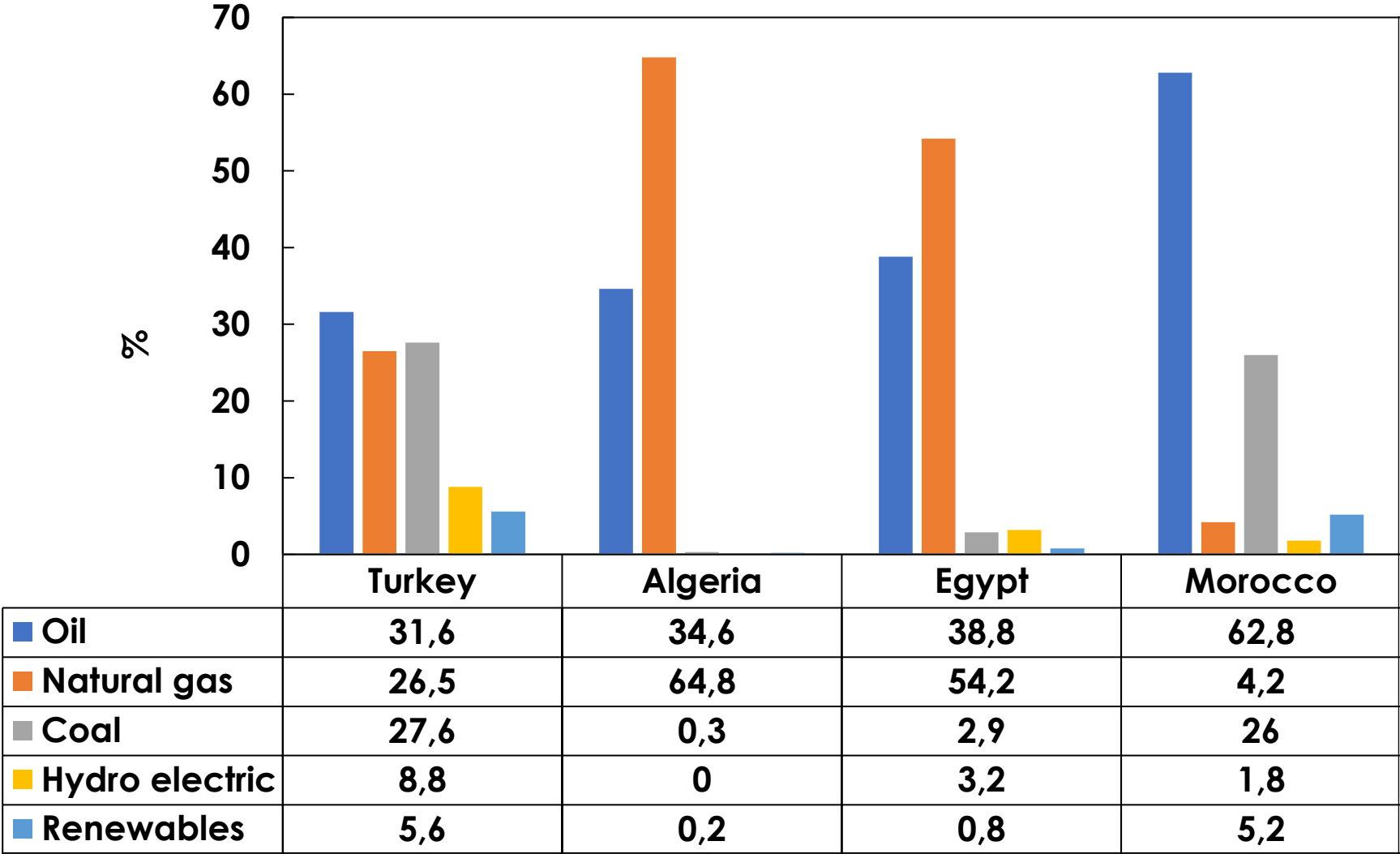
- Energy consumption is dominated by oil, followed by coal.
- Electricity based on renewable energies is in third place.

Smoothed primary energy growth :

- 1995: Maximum a little over 5%.
- End 2022: Fall to above 2.5 %

Middle East and North Africa

Primary Energy Consumption by Fuel, 2018 (%)



High dependance on fossil fuels

Middle East and North Africa

Main Sustainable Energy Targets in Selected Countries

Country	Target (compared to BAU)		Year
Algeria	Renewables	27% of electricity generation	2030
	GHG Emissions	Reduction by 7 to 22%	2030
	Efficiency	10% reduction in the demand for energy	2030
Egypt	Renewables	42% of installed capacity mix	2035
	GHG Emissions	Reduction by 10%	2030
	Efficiency	Decreasing energy intensity by 14%	2030
Morocco	Renewables	52% of electricity generating capacity	2030
	GHG Emissions	Reduction by 42%	2030
	Efficiency	Reducing energy consumption by 15%	2030
Turkey	Renewables	30% of electricity production	2023
	GHG Emissions	Reduction by 21 %	2030
	Efficiency	Decreasing energy intensity by 20%	2023

Biomass potential: Morocco

Summary: 2015

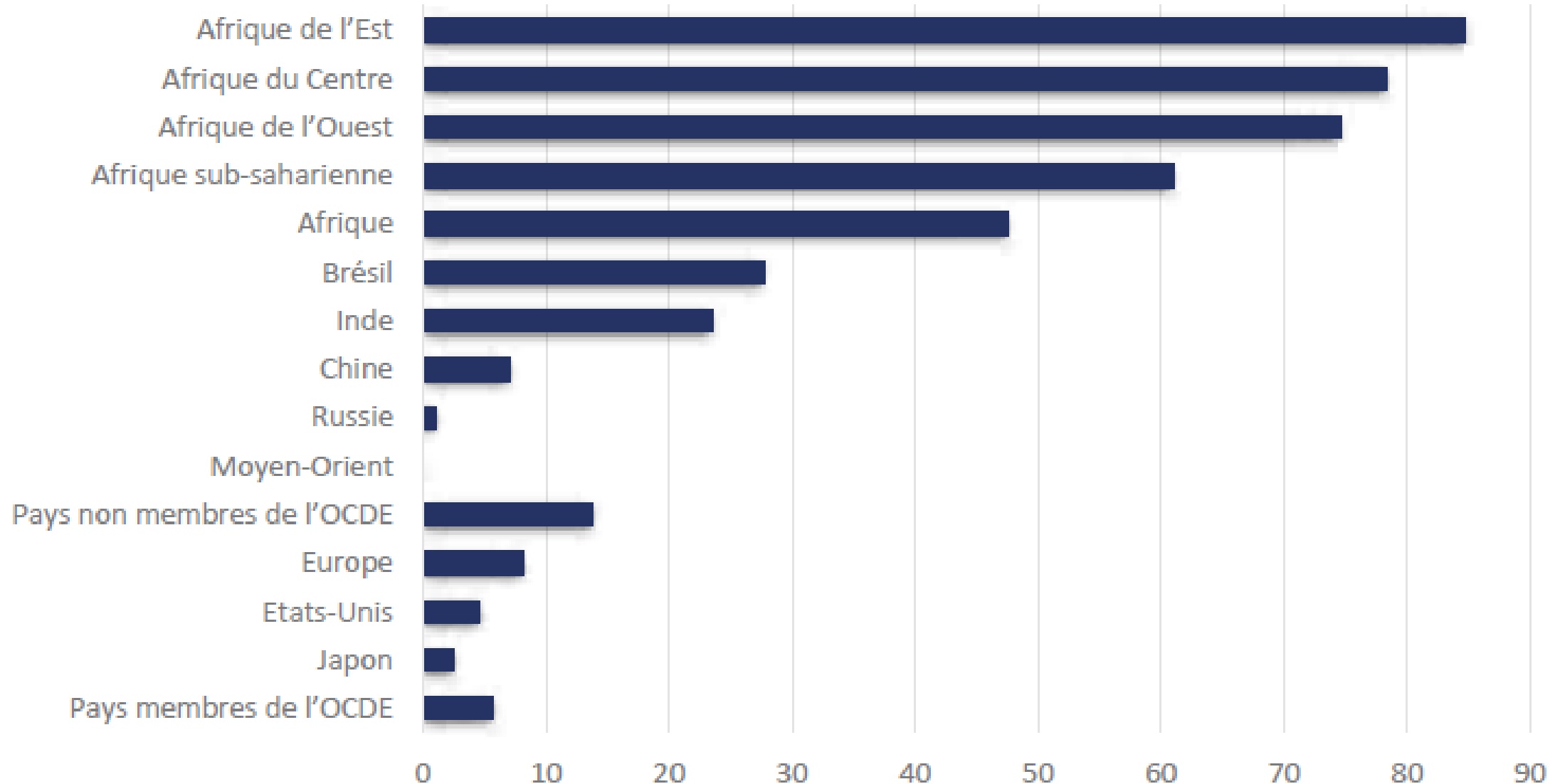
Région/Secteur	Agriculture*	Foresterie	Déchets**	Eaux usées	TOTAL
Tanger-Tetouan-Al Hoceima	696.993	546.131	289.058	10.388	1.542.569
Oriental	292.228	433.785	208.067	14.420	948.499
Fès-Meknès	935.280	590.606	529.265	58.828	2.113.979
Rabat-Salé-Kénitra	867.356	532.464	388.840	2.884	1.791.544
Béni Mellal-Khénifra	623.694	494.236	196.463	24.101	1.338.494
Casablanca-Settat	601.932	164.676	752.846	5.360	1.524.813
Marrakech-Safi	795.300	333.901	352.936	66.710	1.548.847
Drâa-Tafilalet	194.475	147.570	55.061	1.887	398.993
Souss-Massa	506.329	222.366	139.424	8.420	876.540
Guelmim-Oued Noun	14.764	14.233	21.655	1.652	52.303
Laayoune-Sakia El Hamra	905	0	19.936	468	21.309
Eddakhla-Oued Eddahab	407	0	6.738	4.954	12.099
TOTAL (MWh/a)	5.529.662	3.479.967	2.960.288	200.072	12.169.989

* : plus le potentiel national de l'aviculture de 1.000.000 MWh/a

** : plus 96.000 MWh/a des abattoirs et 20.000 MWh/a des laiteries

Share of biomass in primary energy: Global

Biomass part in primary energy (%)



Energy From Biomass: Morocco

Roadmap For Biomass Energy Recovery by 2030

Ministry of Energy and Mines: biomass energy is estimated at **11.5 million MWh/year**.

- ✓ **Green waste** :3 million MWH,
- ✓ **Agriculture**: 6.6 million MWh/a
- ✓ **Forestry**: 1.7 million MWH
- ✓ **Wastewater**: 0.2 million MWH.

The potential achievable by 2030 represents :

- 950 MW of electricity ;
- 4.8 million tones/year of CO₂ avoided;
- 2.1 million TOE/year saved;
- 2,200 jobs created.

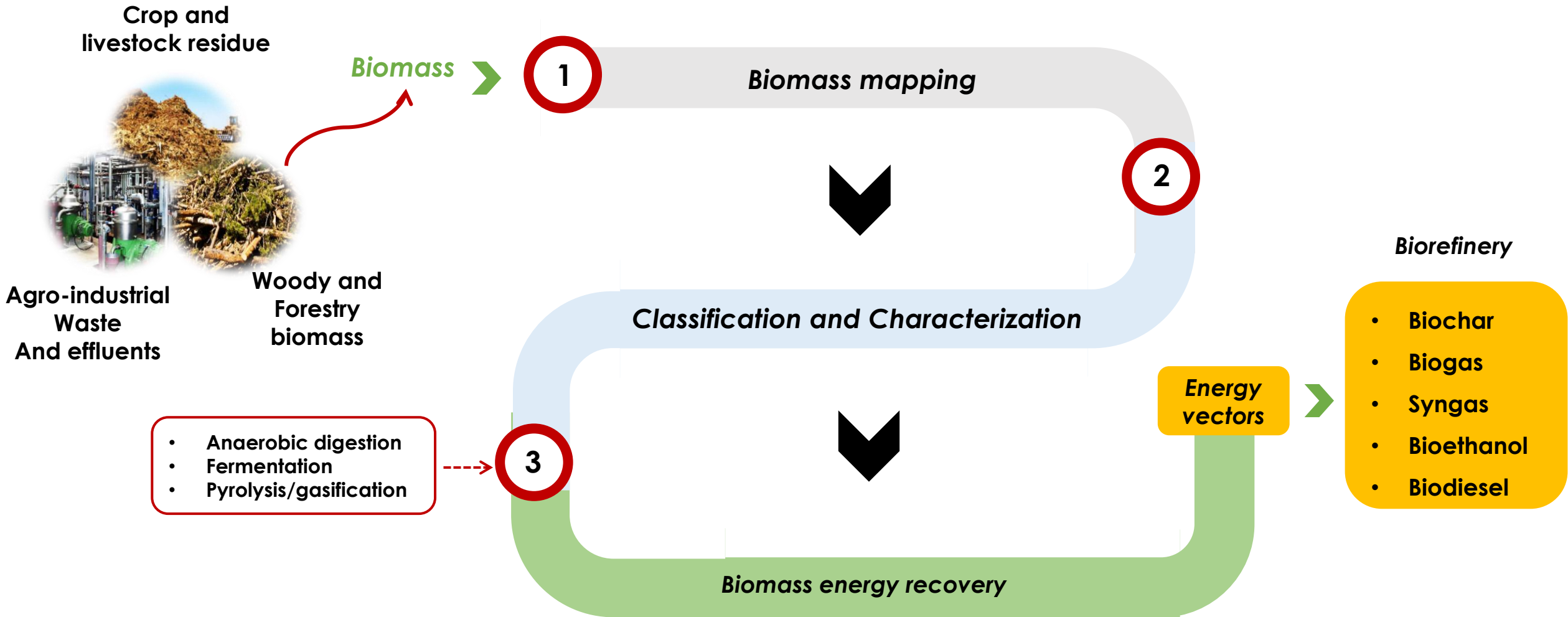
Energy From Biomass: Case of Morocco

National initiatives Projects

- 1. Biogas dissemination program in the Souss-Massa region (ADEREE -GIZ - ORMVA du Souss-Massa):**
 - The aim of this program is to make available to the rural population a new source of domestic energy (biogas) used for cooking, lighting, heating and electricity production.
- 2. Energy improvement program for hammams (ADEREE-MEM-AFD)**
 - The aim is to reduce demand for firewood in the hammam sector by modernizing 140 public hammams and showers.
- 3. Pilot program for sustainable biomass management in Morocco (GERES-Fondation Mohamed VI pour l'Environnement- MEMEE)**
 - The aim of the program is to set up a sustainable biomass management framework in the province of **Chefchaouen**, in order to remedy deforestation problems and bring comfort to rural populations in isolated areas by installing solar ovens and hot water for sanitary facilities and heating.
- 4. Study on the sustainable management of agricultural waste (FCAMDD-IAV Hassan II)**
 - launched an innovative study project in Morocco aimed at implementing sustainable management of agricultural waste.

Waste to Energy approach

Roadmap For Biomass Energy Recovery



Waste to Energy Research

ATLASS Project packages:

- **WP1:** Biomass Characterization, Pretreatment and Fractionation
- **WP2:** Methanization and Composting
- **WP3:** Thermochemical transformation of biomass and residues
- **WP4:** New generation biofertilizers
- **WP5:** Effluent valorization and microalgae cultivation
- **WP6:** Design of a knowledge-based methodology for the evaluation of the sustainability of biofertilizer biorefineries,



“the identification and innovation of new ways of transformation of biomass and waste”

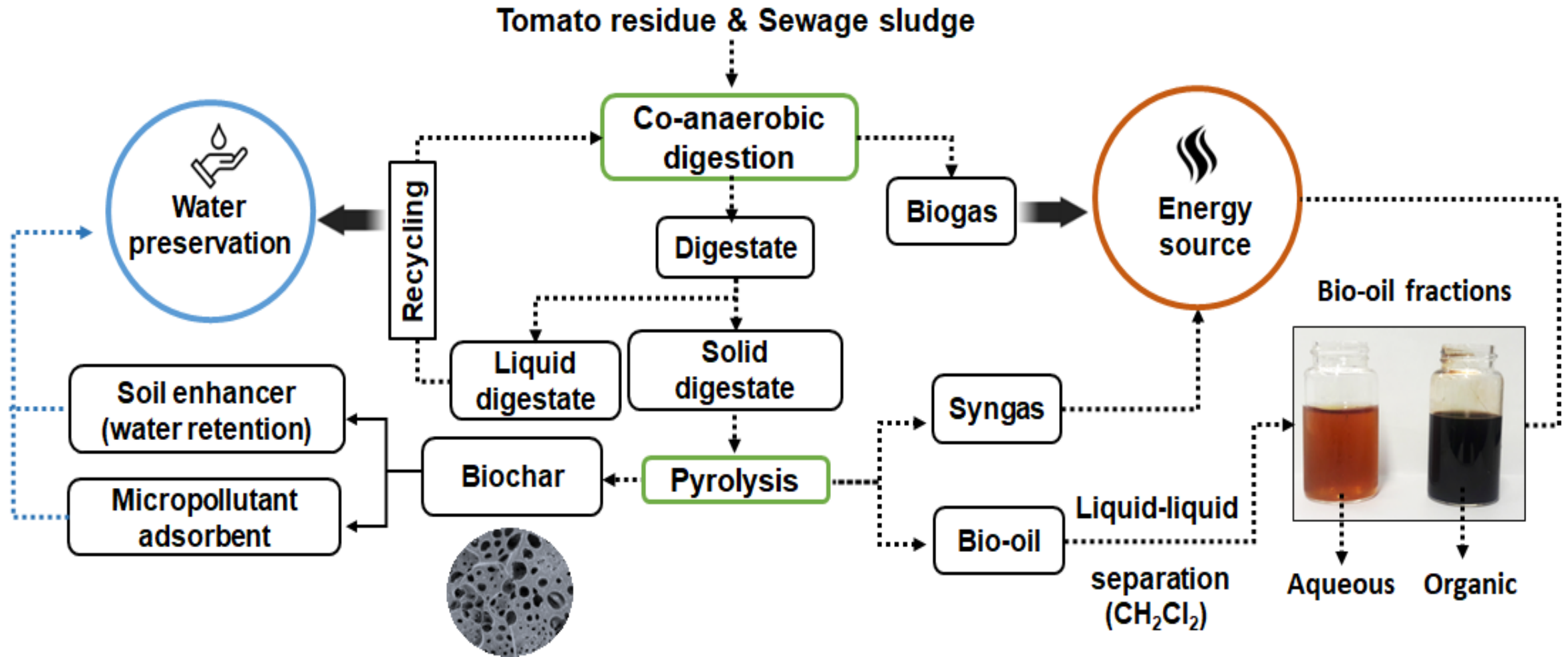


Project Partners



l'institut Agro
agriculture • alimentation • environnement

Montpellier
SupAgro



Waste to Energy Research

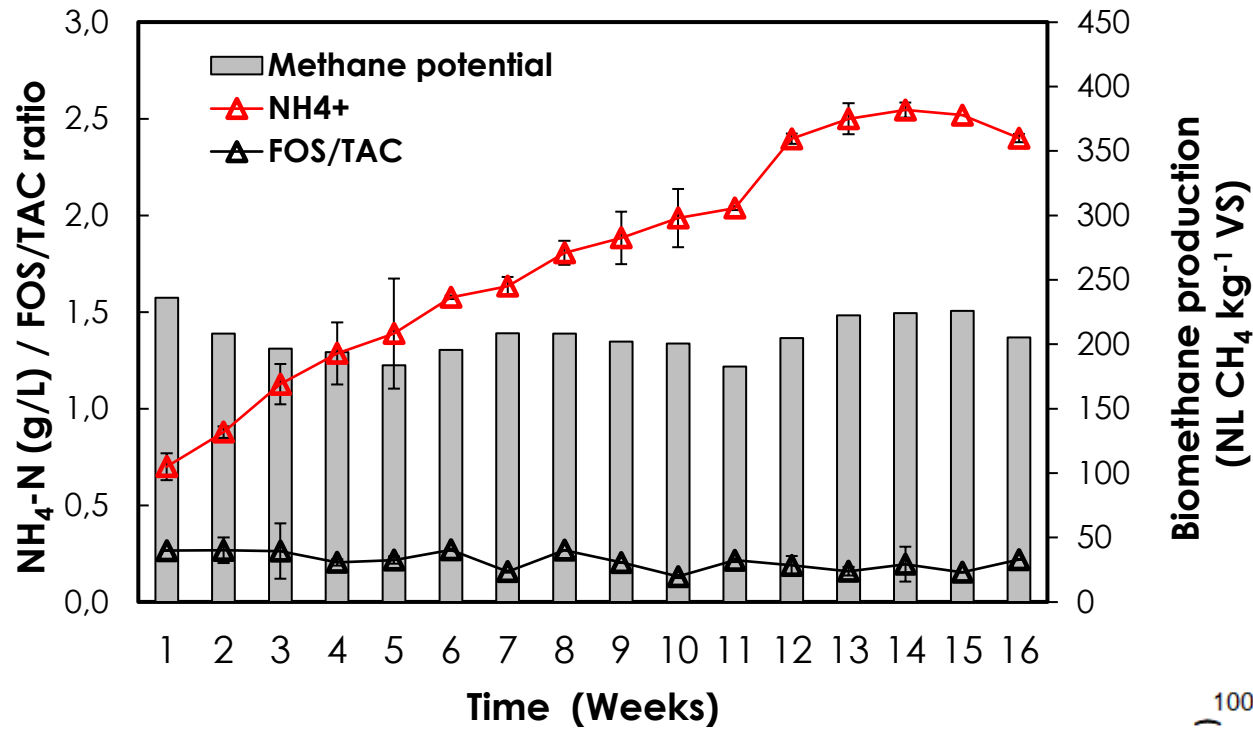


Figure 1. Biomethane, $\text{NH}_4\text{-N}$, and FOS:TAC ratio evolution during the AD

- Methane percentage: **58 %**
- The final specific methane production was **219.3 NL $\text{CH}_4/\text{kg VS}$**



Corresponded to 98% of the predict value

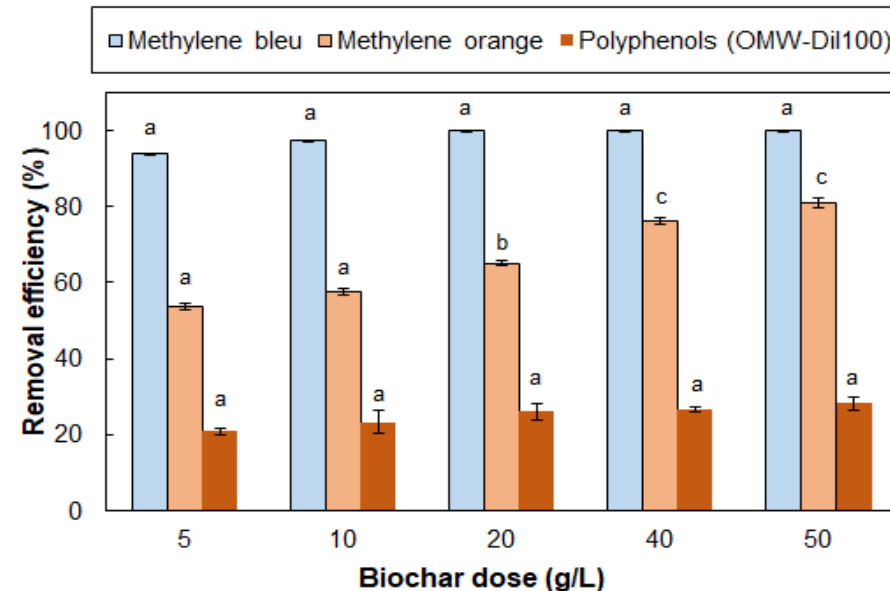
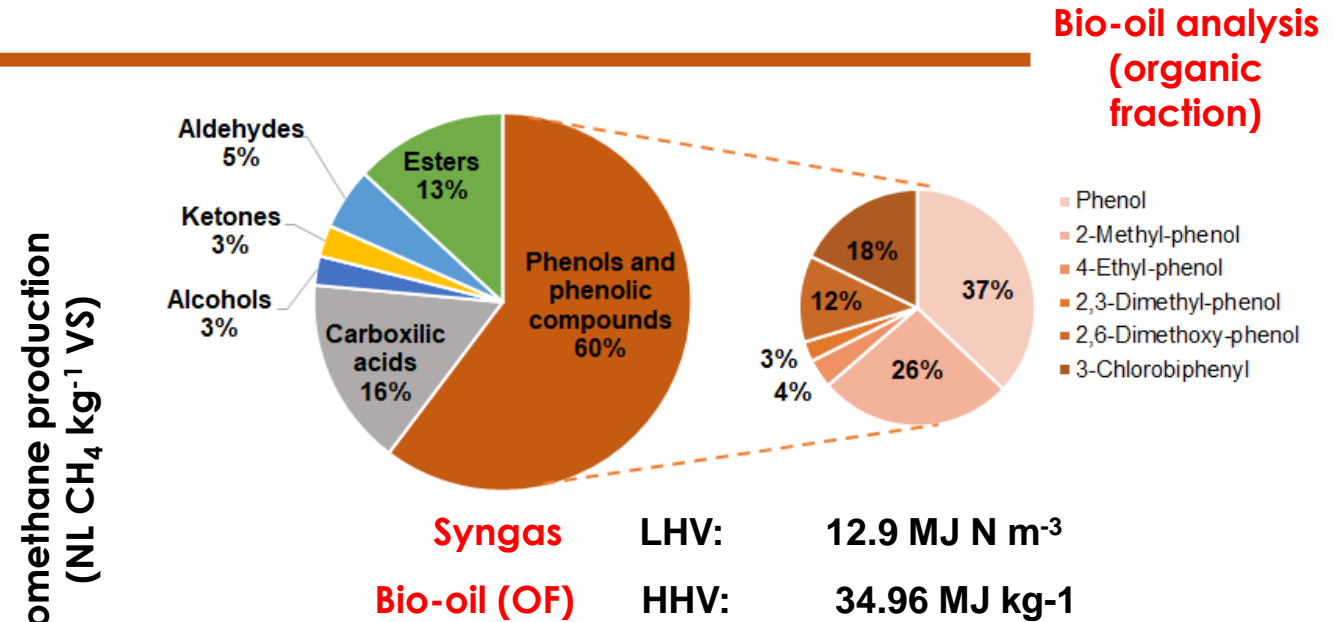
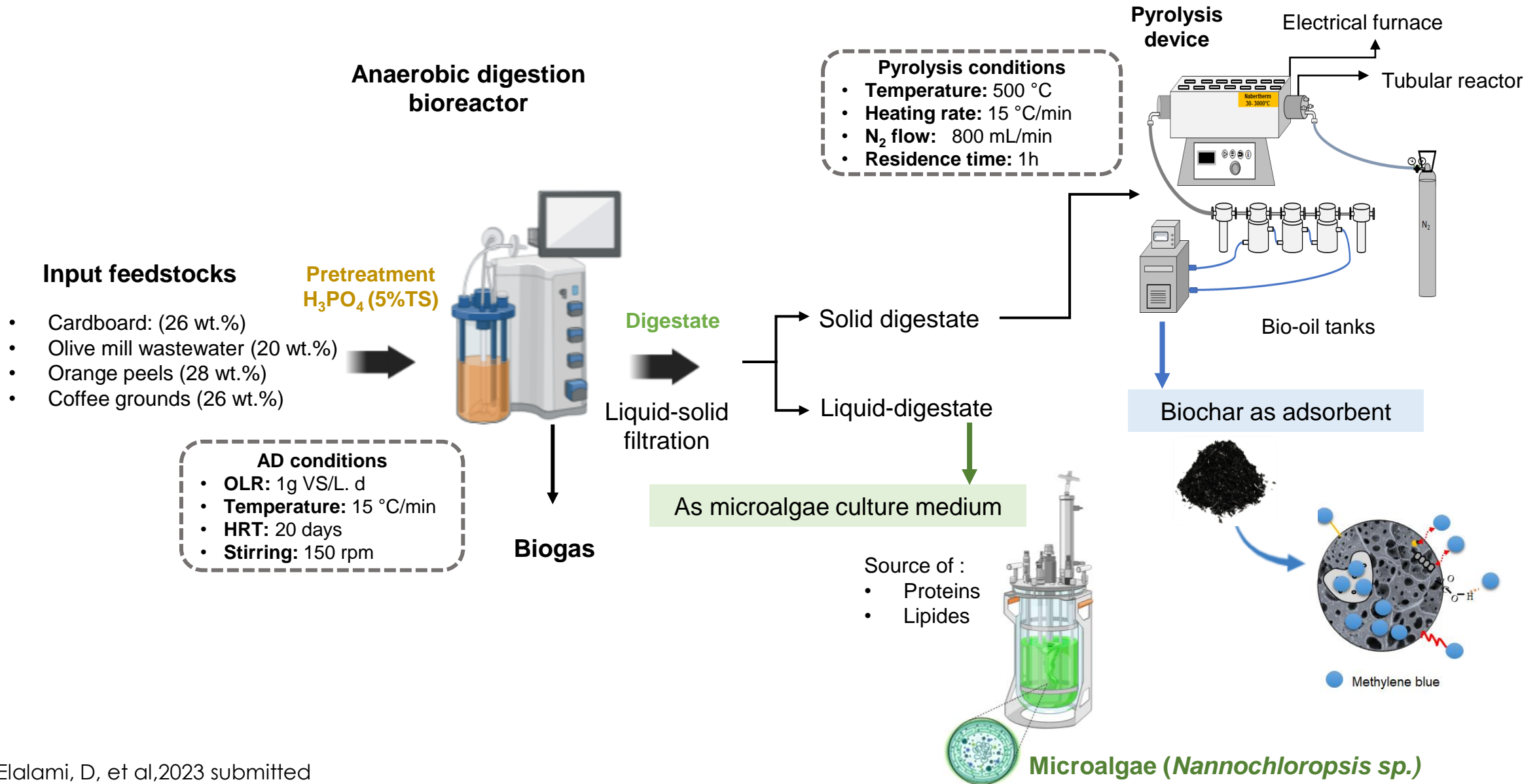


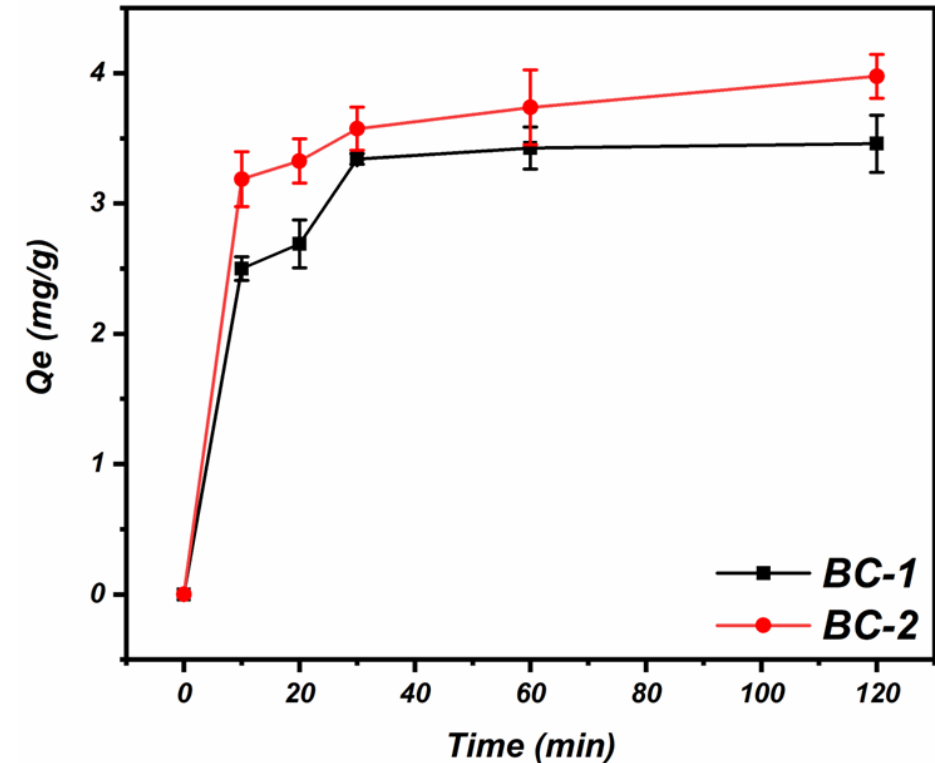
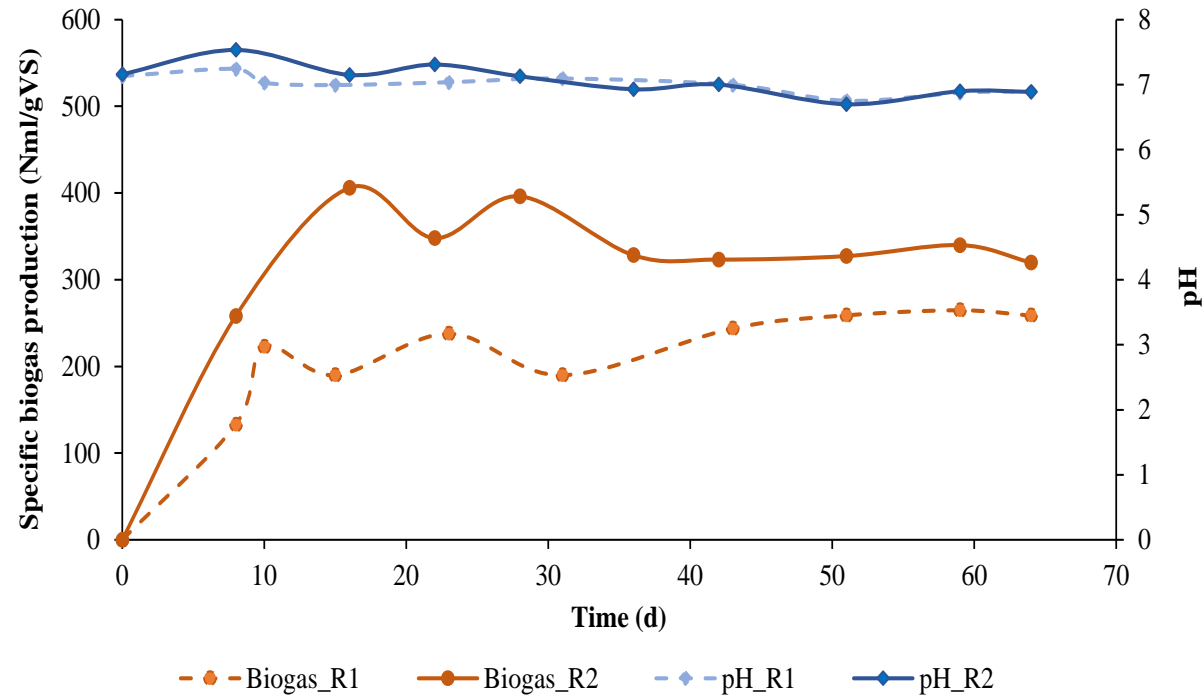
Figure 2. Biochar dose effect on the adsorption of the micropollutant

MB and MO: 50 ppm
Polyphenols (OMW-Dil100): 103 ppm

Waste to Energy Research

Scenario 2





- H_3PO_4 pretreatment enhanced the biogas production by 28 % compared to untreated.
- Biochar yield production was 44 % for both digestate



- MB adsorption by Biochar from treated digestate was 14,3 % higher than untreated one



- Digestate base media for microalgae showed low growth rate, biomass, carbohydrate and protein but higher lipid content (+480%)

Course Title:

Conversion Technology of Biomass Residue for Sustainable Agriculture

- Concept of sustainable agriculture and its significance
- Diverse types of agricultural residues and their potential as valuable resources
- conversion technologies, including biochemical and thermochemical processes
- Environmental impacts of conversion technologies
- Develop a sense of responsibility and commitment to preserving the environment for future generations.



Thank you