Athens 2017
5th International Conference on Sustainable Solid Waste Management

How to optimize a metropolitan solid waste management system by integrating open data via Geographic Information System

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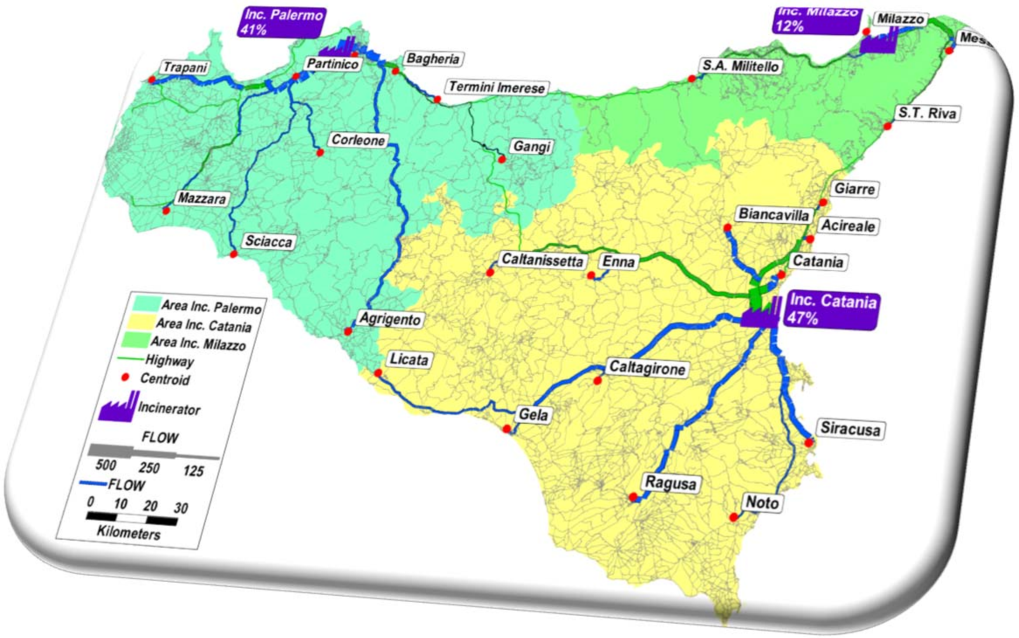


Athens
June 21st 2017

Background

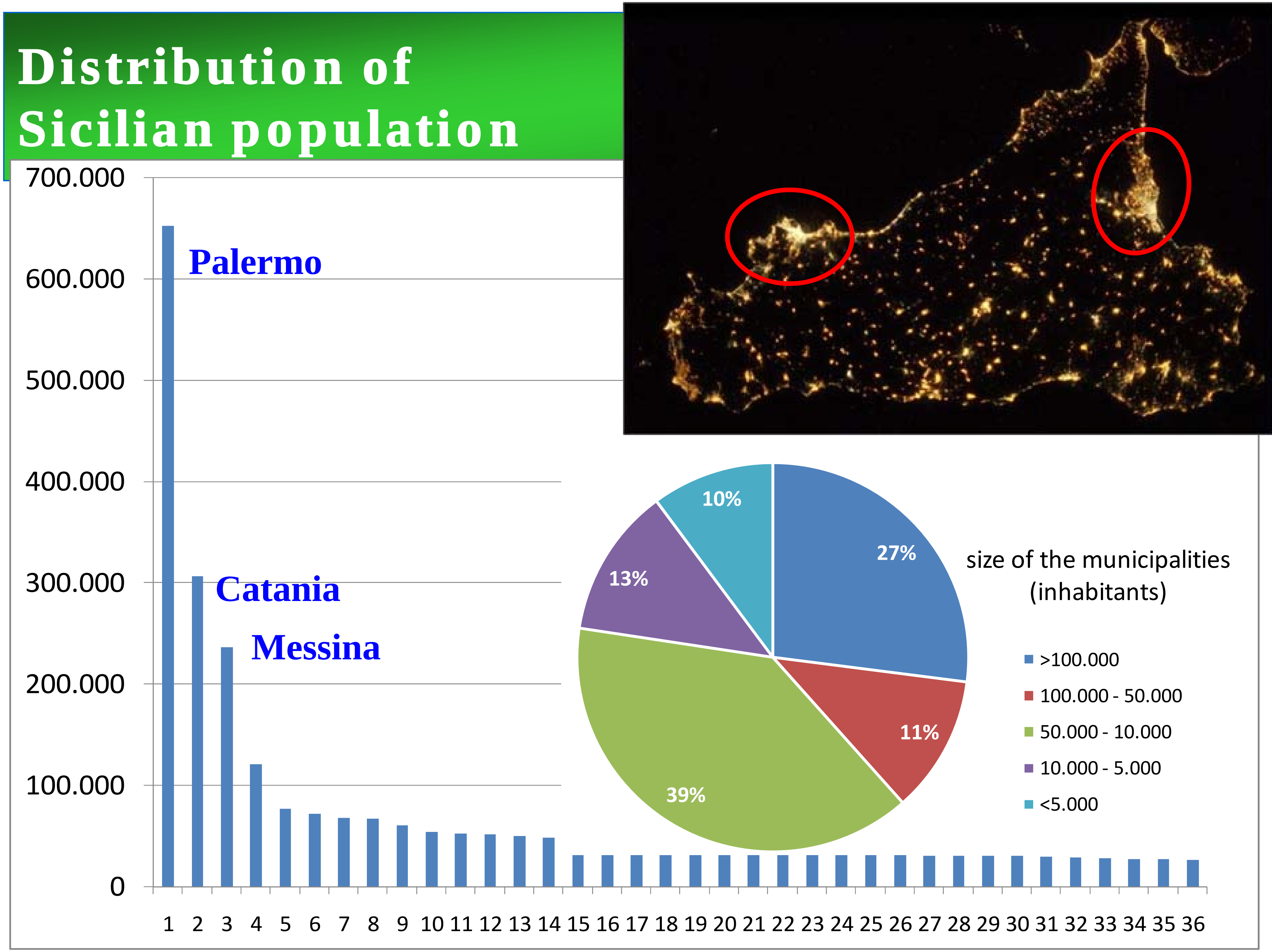
- Area = 25,711 km^2
- Population = **5,045,176** inhabitants
- Density = 196.23 inh/km^2
- MSW production = about **2,727,570** t/year
- MSW production per capita = 520 kg/capita/y
- Current separate collection level 12%

Dominant solution for MSW disposal

Landfills

(**about 90%**)

Distribution of Sicilian population



Waste “separate” collection in Catania

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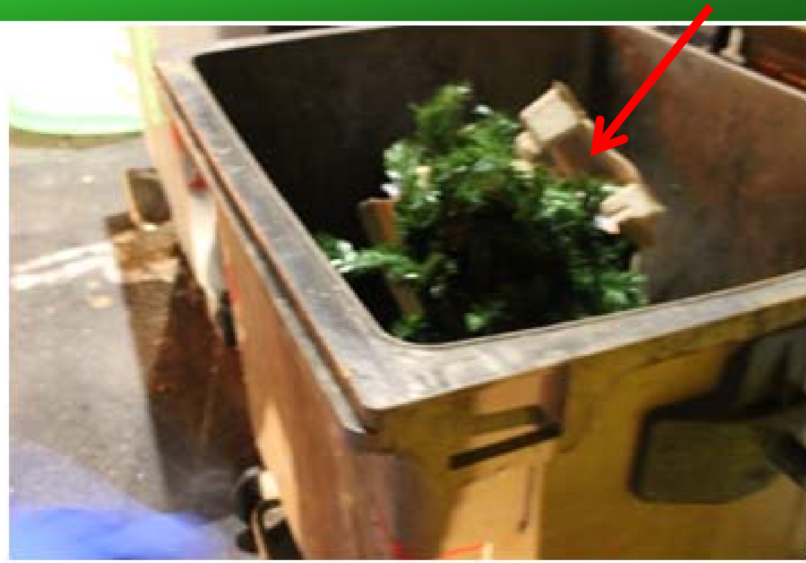
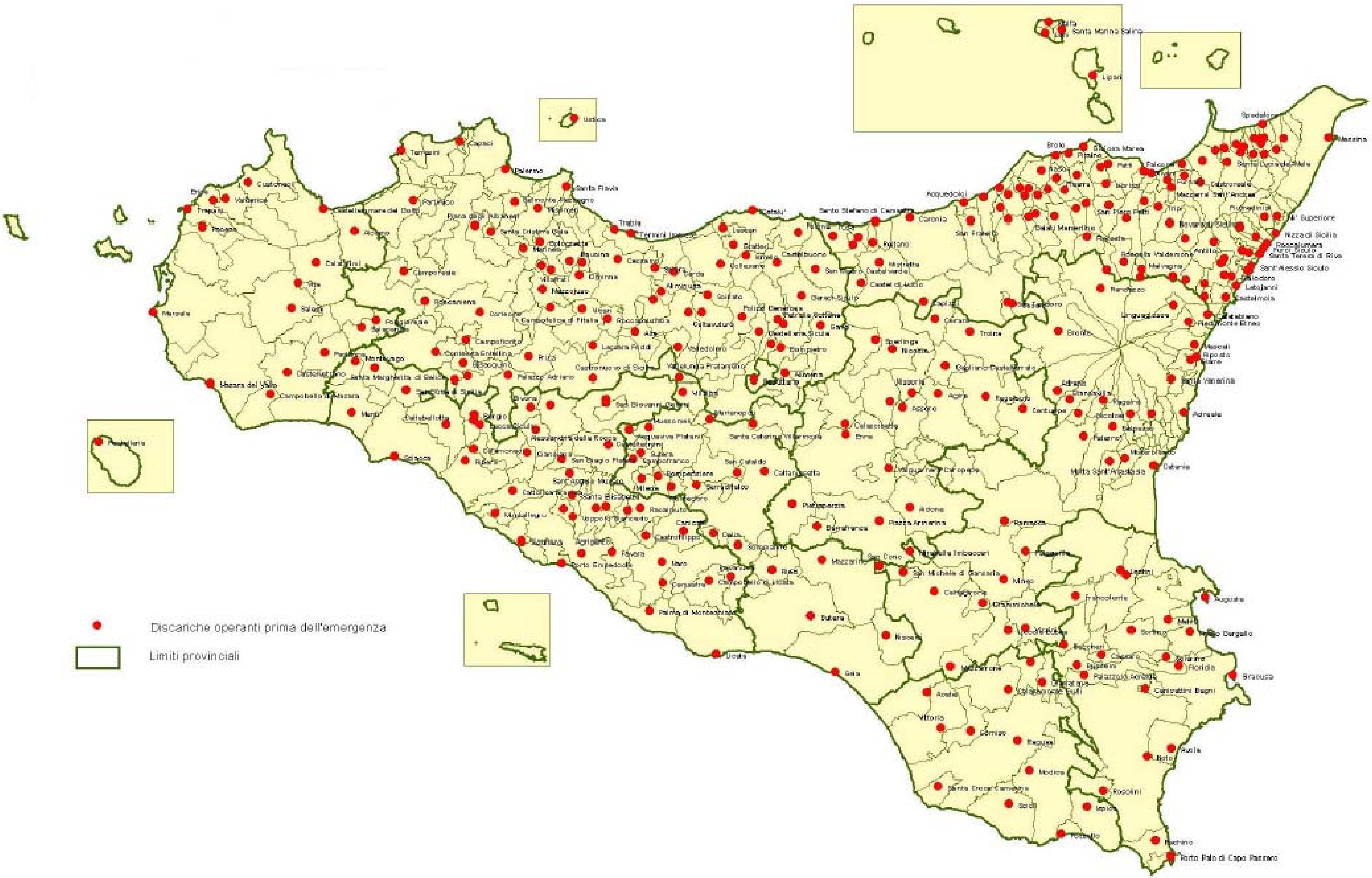


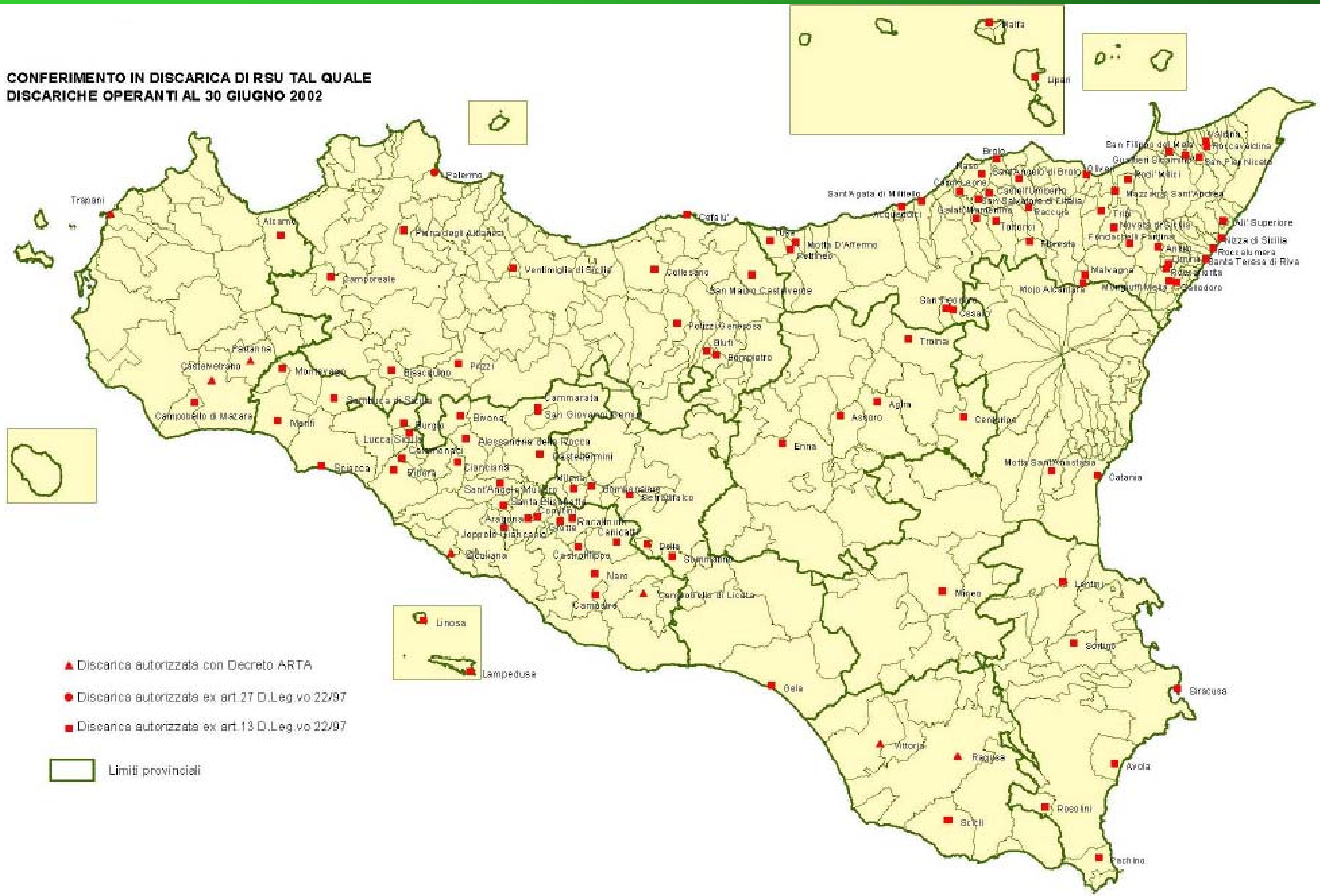
Waste “separate” collection in Catania

Waste “separate” collection in Catania

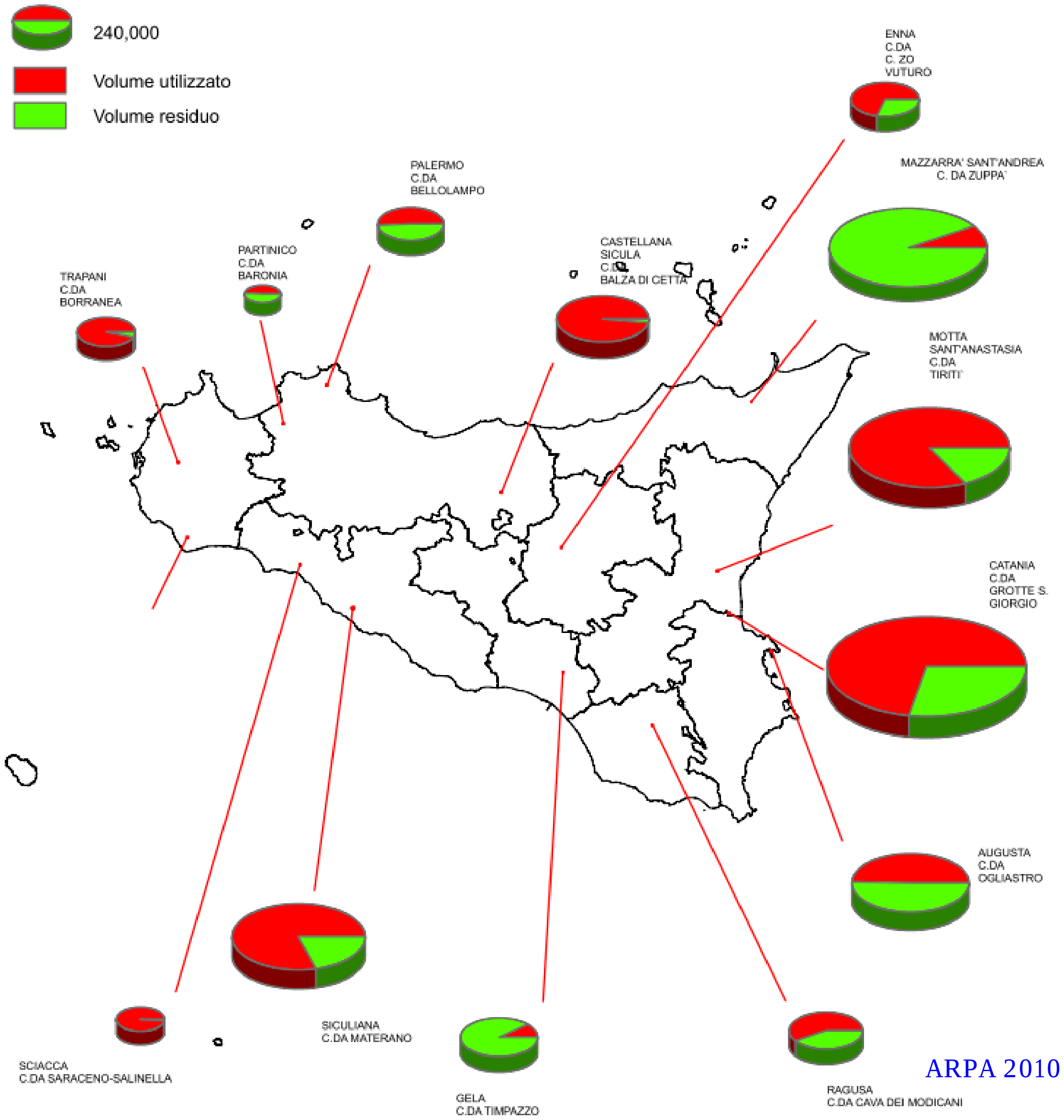
Landfills in in use Sicily before the state of emergency was declared in 1999



Landfills in use in 2002



Many of these landfill are almost full



ARPA 2010

Main objective in Sicily

TO DRAMATICALLY REDUCE THE PERCENTAGE OF WASTE DISPOSAL INTO LANDFILL

Development of facilities

Large mechanical/biological waste treatment plants

Poor results from mechanical selection

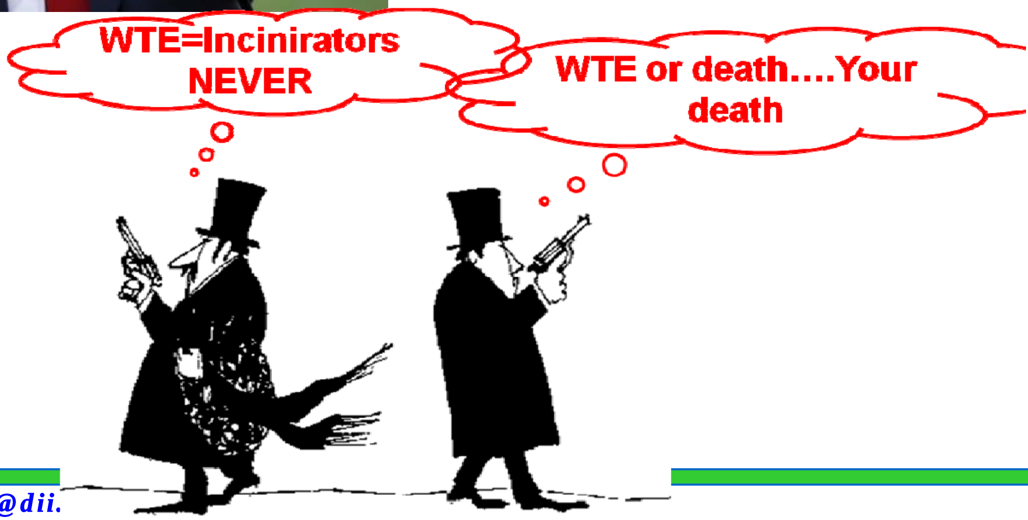
Almost zero recovery rate

“organic” fraction from separation

The national government VS the regional government:

Sicily must increase recovery and have 2 WTE plants, one in Catania and one in Palermo (700.000 tons)

Better 6 to 8 “small” gasification plants close to the existing landfills <u>to reduce transportation costs and impact on the traffic</u>



Ignorance and rigidity cause..... zero discussion

WTE=Incinirators NEVER

WTE or death….Your death

Zero waste

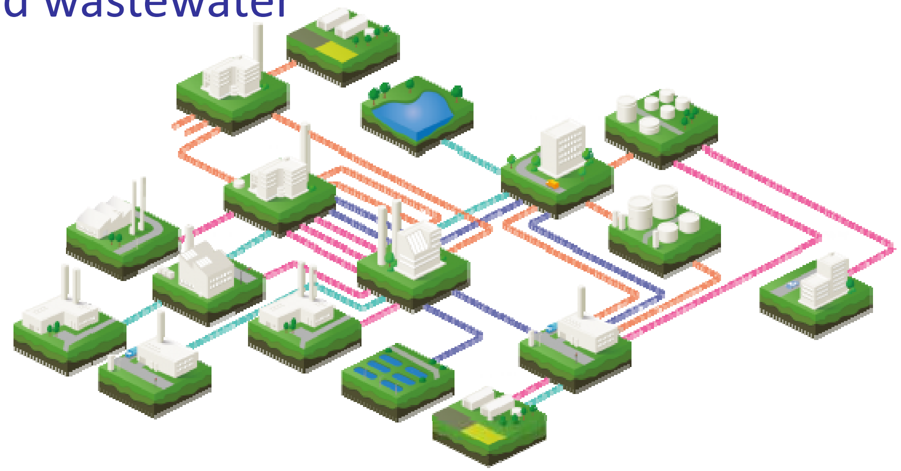
Zero brain

HOW TO CHANGE THE WASTE MANAGEMENT PARADIGM IN SICILY?

- Proposing a Holistic Approach

- Achieve a strong Industrial Symbiosis

- Prevent and Reduce the Environmental Impact associated with the management cycle of waste and wastewater



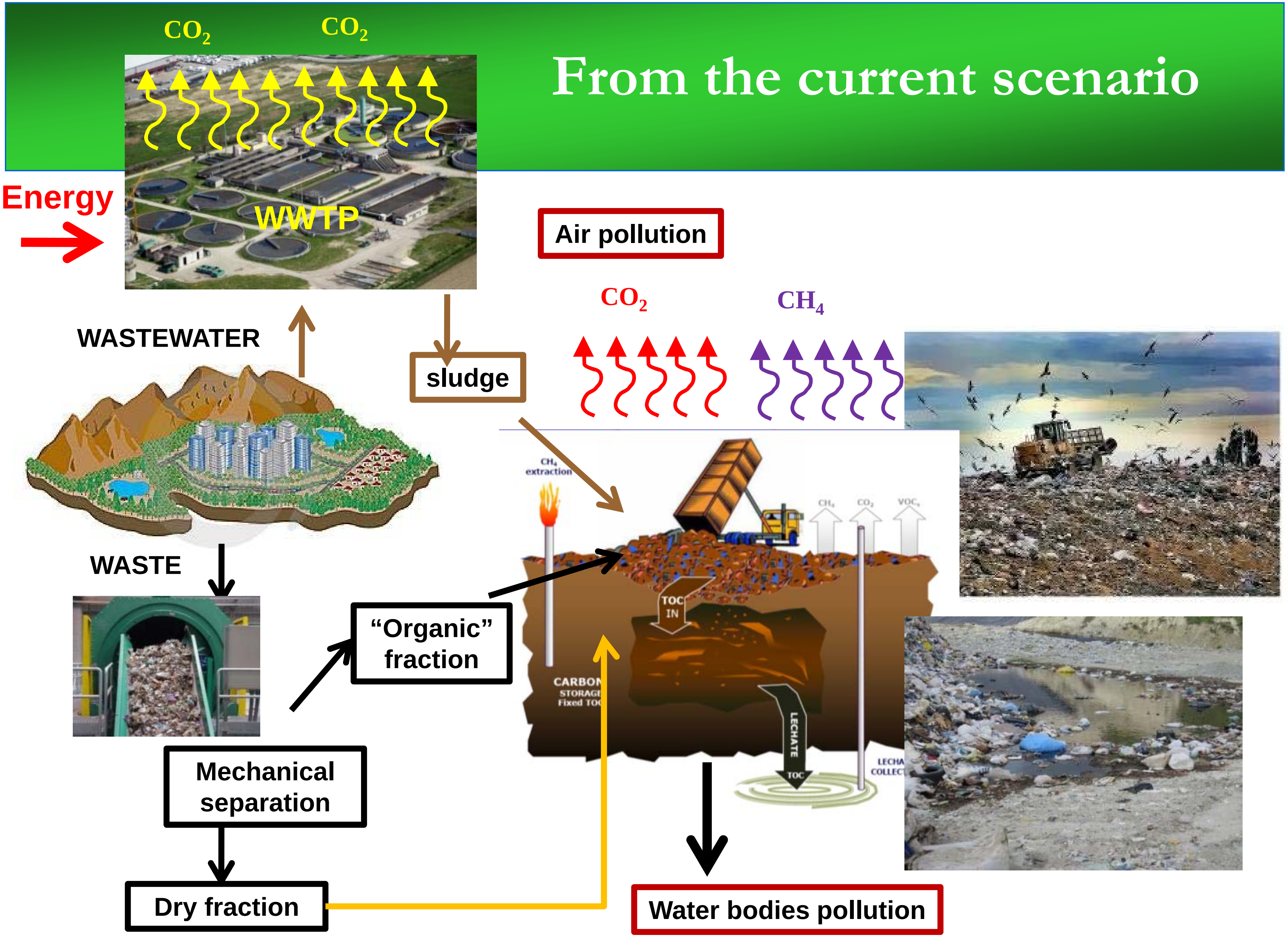
Goals

To propose a sustainable Metropolitan Solid Waste Management System (MSW-MS) by integrating demographic, territorial and economic Open Data, through a model based on Geographic Information System (GIS)

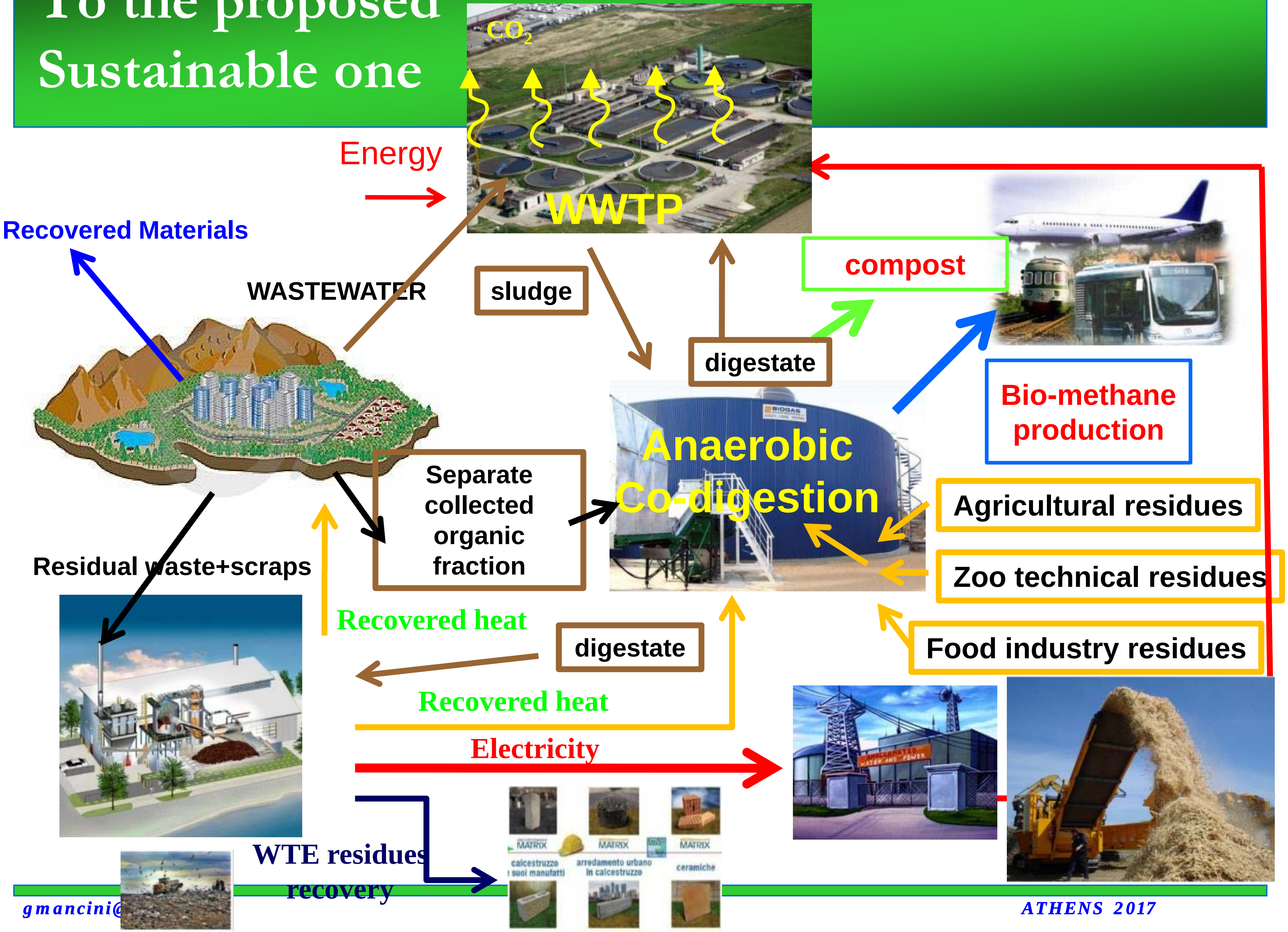
Starting from the actual production and distribution of the waste in Sicily the proposed MSW-MS define a differentiated path to achieve the 50% recovery target established by the European Union while optimizing the production of biogas in an holistic approach where the organic fraction of the waste is co-digested with sludge resulting from the wastewater treatment plant.

This scenario is finally compared to the current "landfill" scenario in terms of transportation cost and impacts through the use of the GIS-based model.

From the current scenario



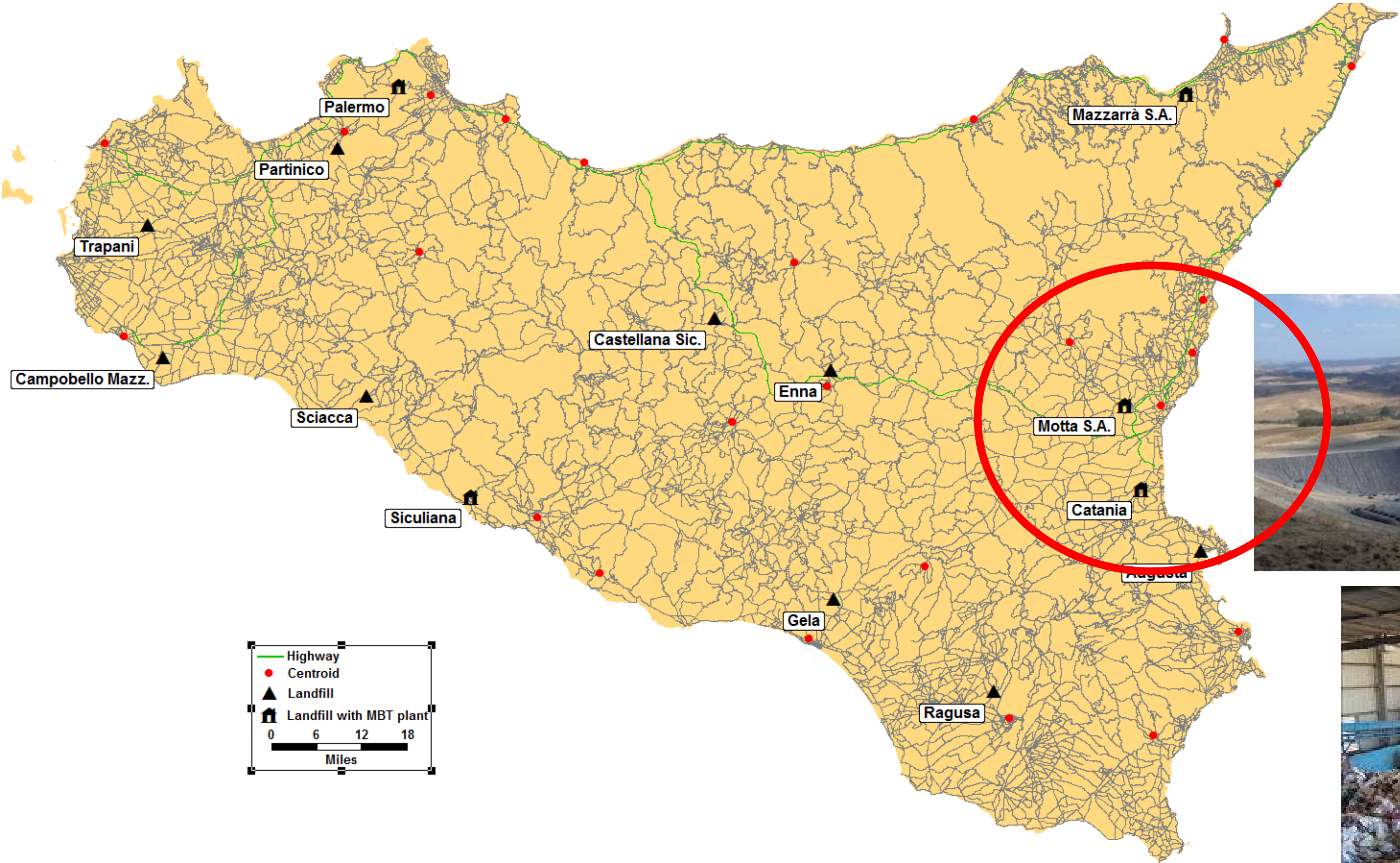
To the proposed Sustainable one



Integrating demographic, territorial and economic Open Data, through a model based on Geographic Information System (GIS)

Scenario 1

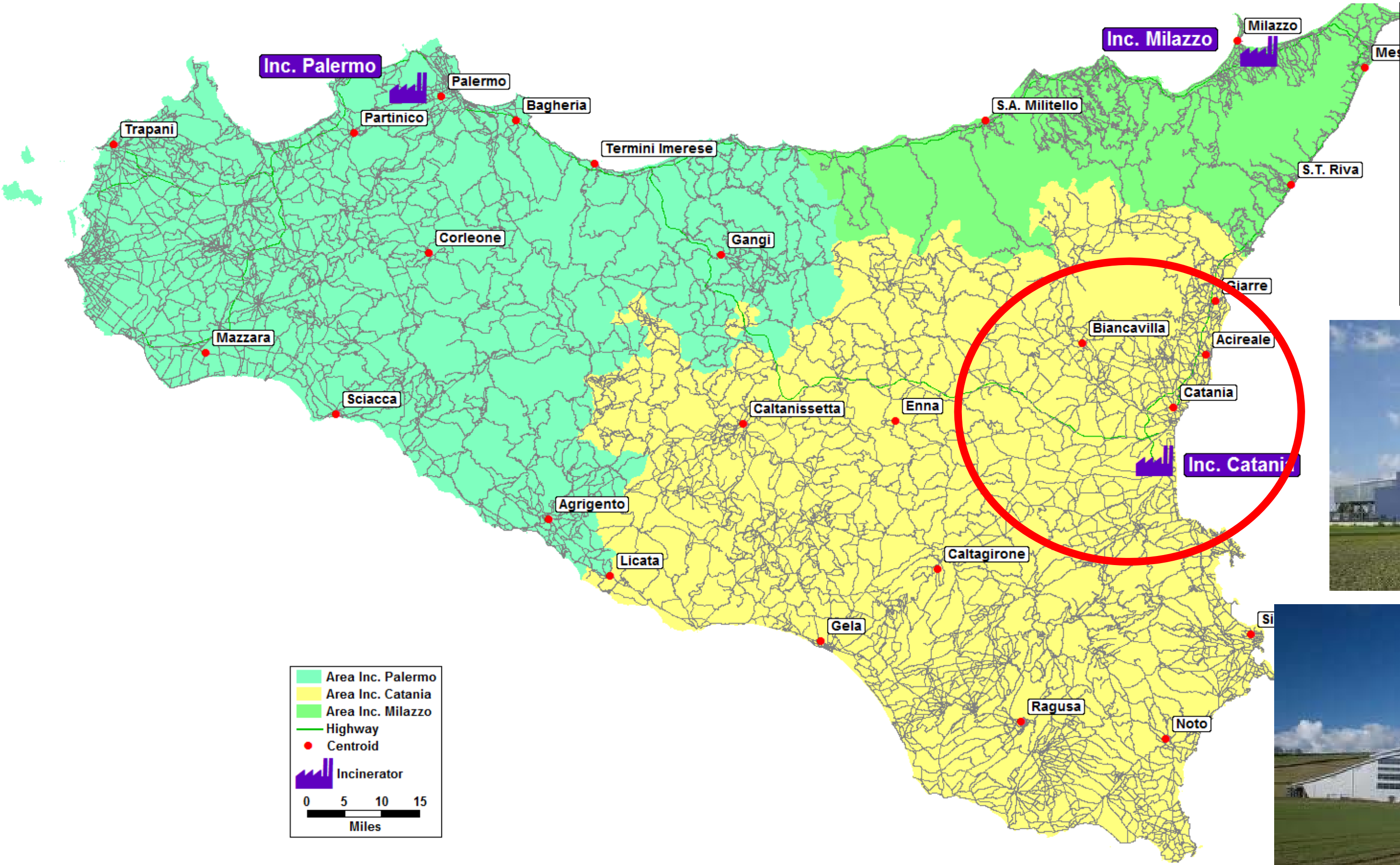
90% of MSW → Mechanical Biological Treatment → Landfills (n. 14)



To evaluate transportation costs and related impacts

Scenario 2

50% of MSW (residual) ⟹ LargeWTE plants (n. 3)



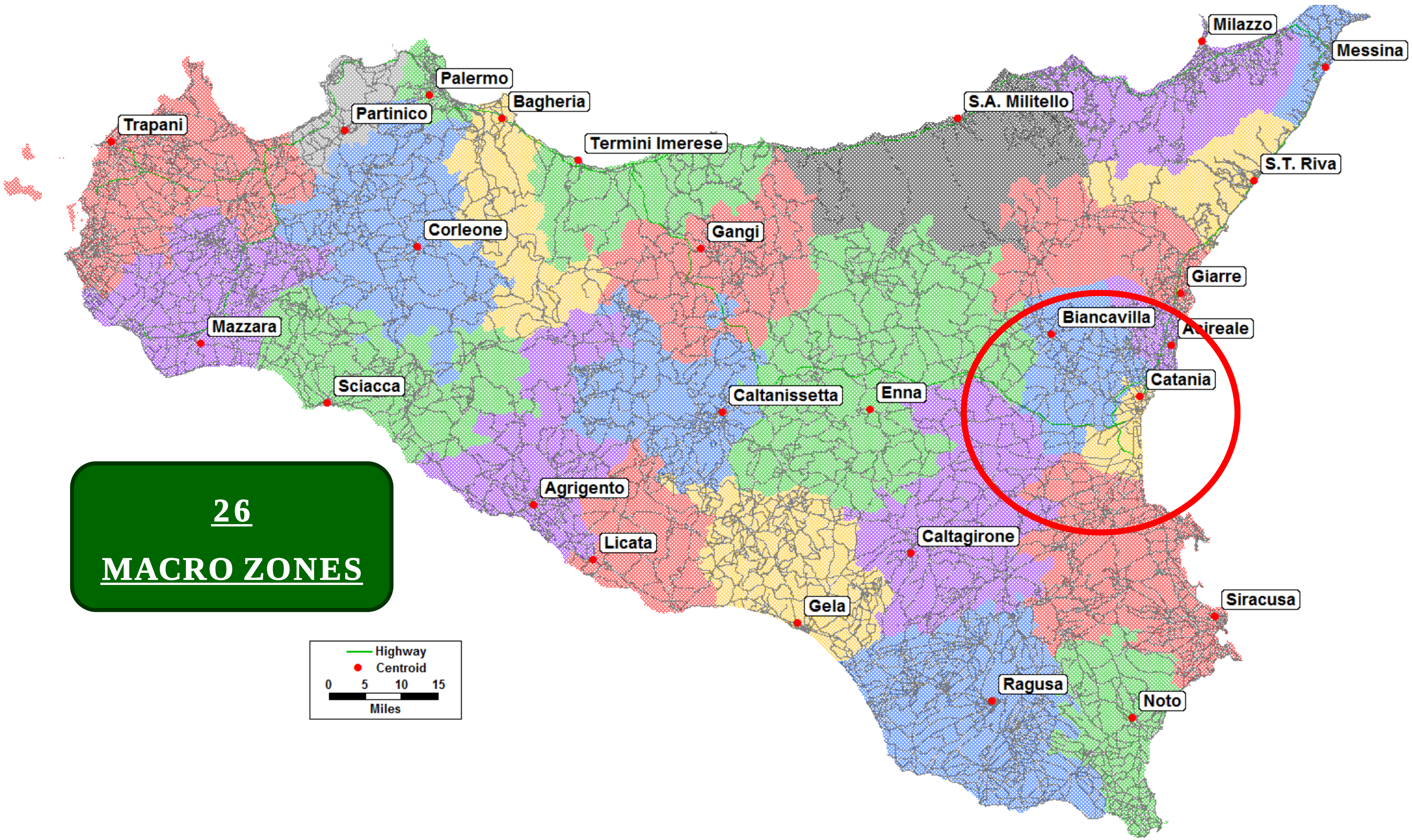
The transportation Model

The procedure is based on a mathematical model running within a **GIS software platform**, able to include all relevant socio-economic and territorial data.

TransCad was used to develop a model that:

- combines **GIS** and **transportation modeling** capabilities in a single integrated platform;
- can create and customize maps, build and maintain geographic data sets, and perform many different types of spatial analysis.

Zoning



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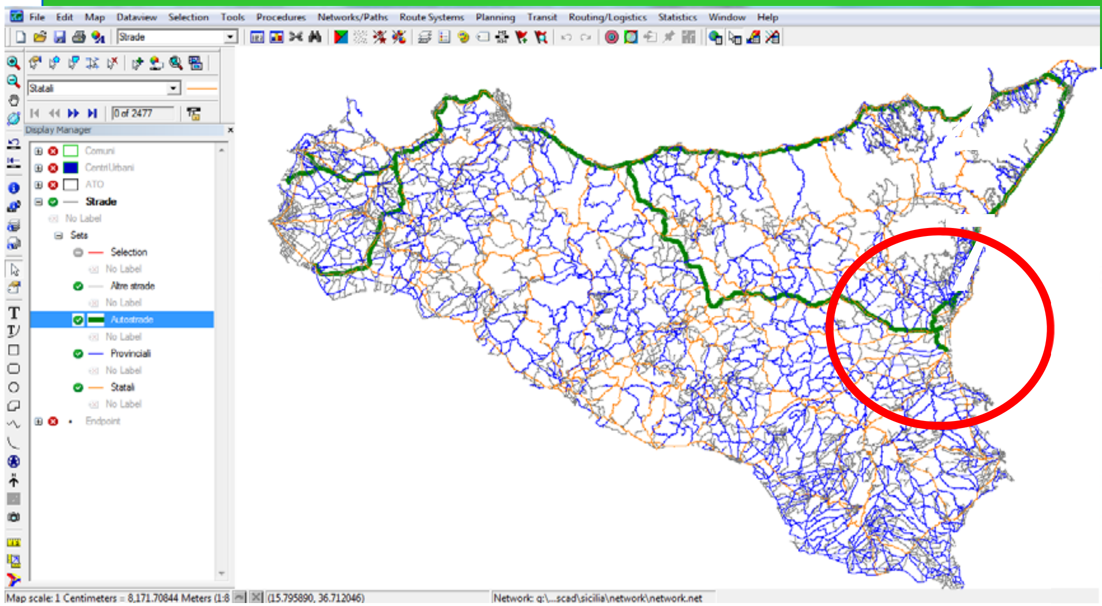
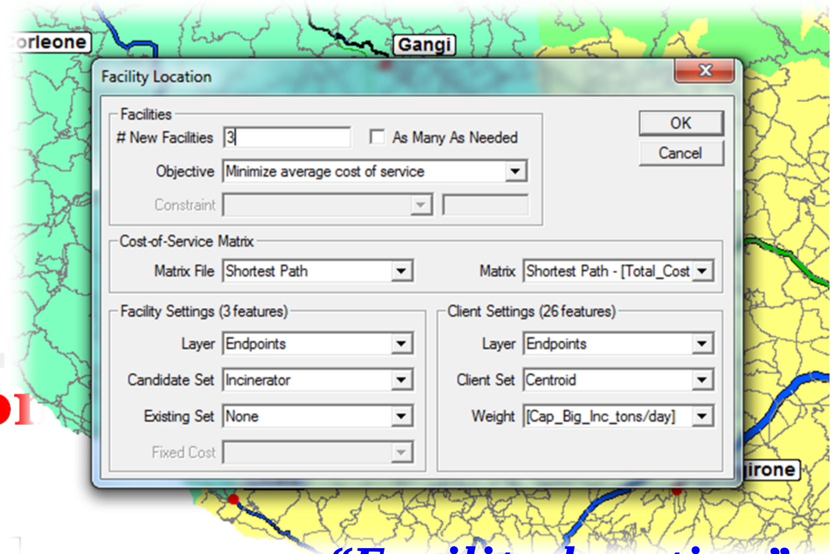
MACRO ZONES

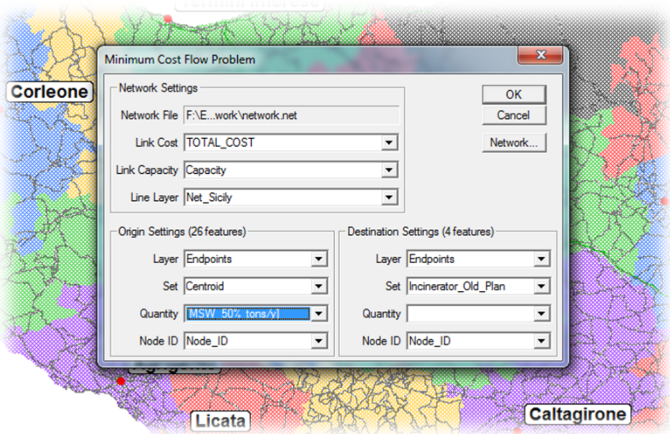
Model application



Road network digitalization



"Facility location"



"Minimum-cost flow"

Definition of transportation cost

$$C_{Tr} = C_f + C_t + C_{pt} + C_{tm} + C_p$$

C_{Tr} = Cost of transportation

C_f = Fuel Cost

C_t = Tires Cost

C_{pt} = Property Tax

C_{tm} = Truck Maintenance Costs

C_p = Personnel Costs

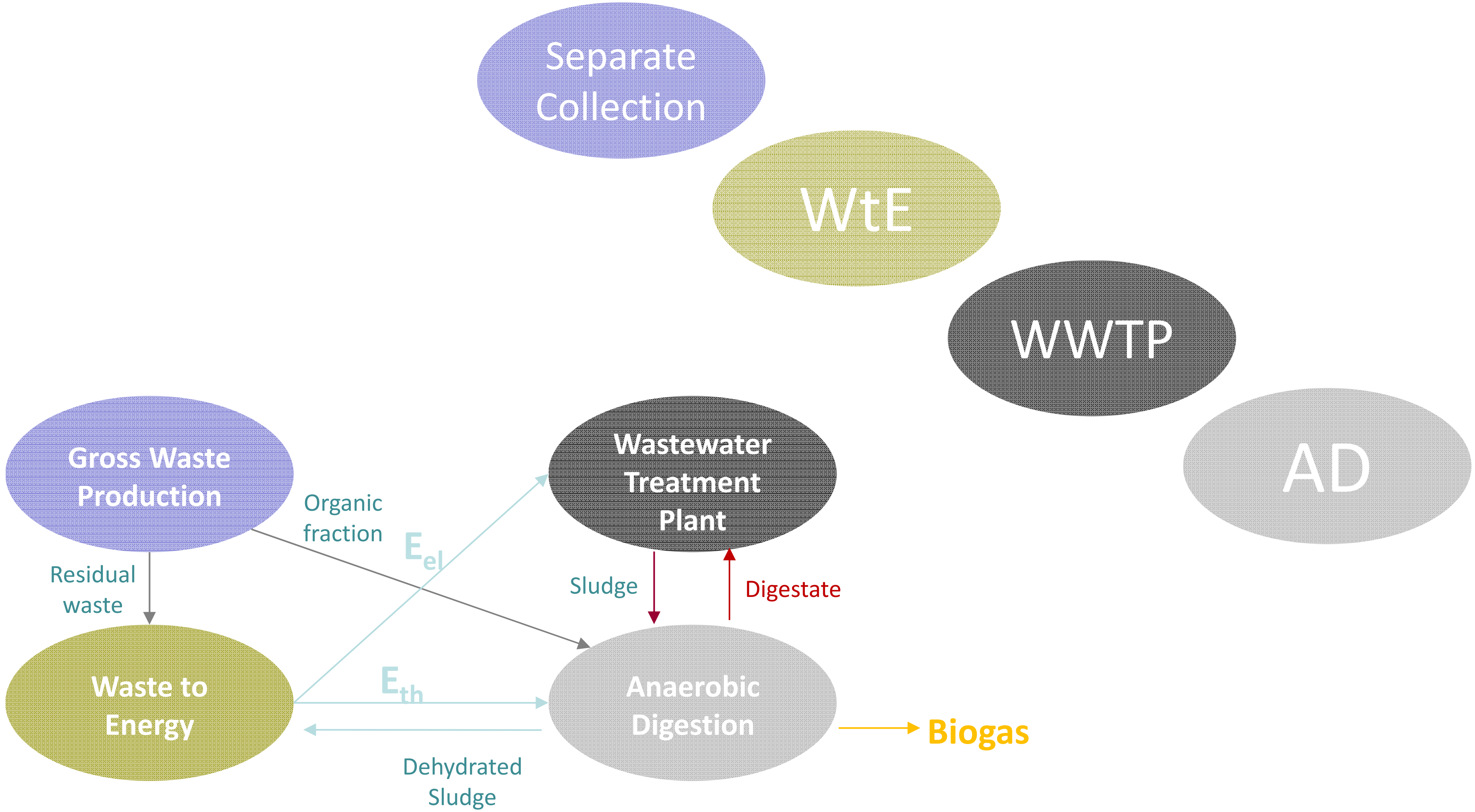
Using the above specific costs and assuming and **average speeds** of 30 km/h in the urban road network and 55 km/h in the extra-urban road network, a **unit transportation cost** of 0.11-0.13 €/ton-km was estimated.

WHERE?

- The "Sustainable Model" is validated on the Metropolitan Area of Catania

- It consider 1 million p.e. in terms of waste production and 500,000 p.e. in terms of the WWTP capacity

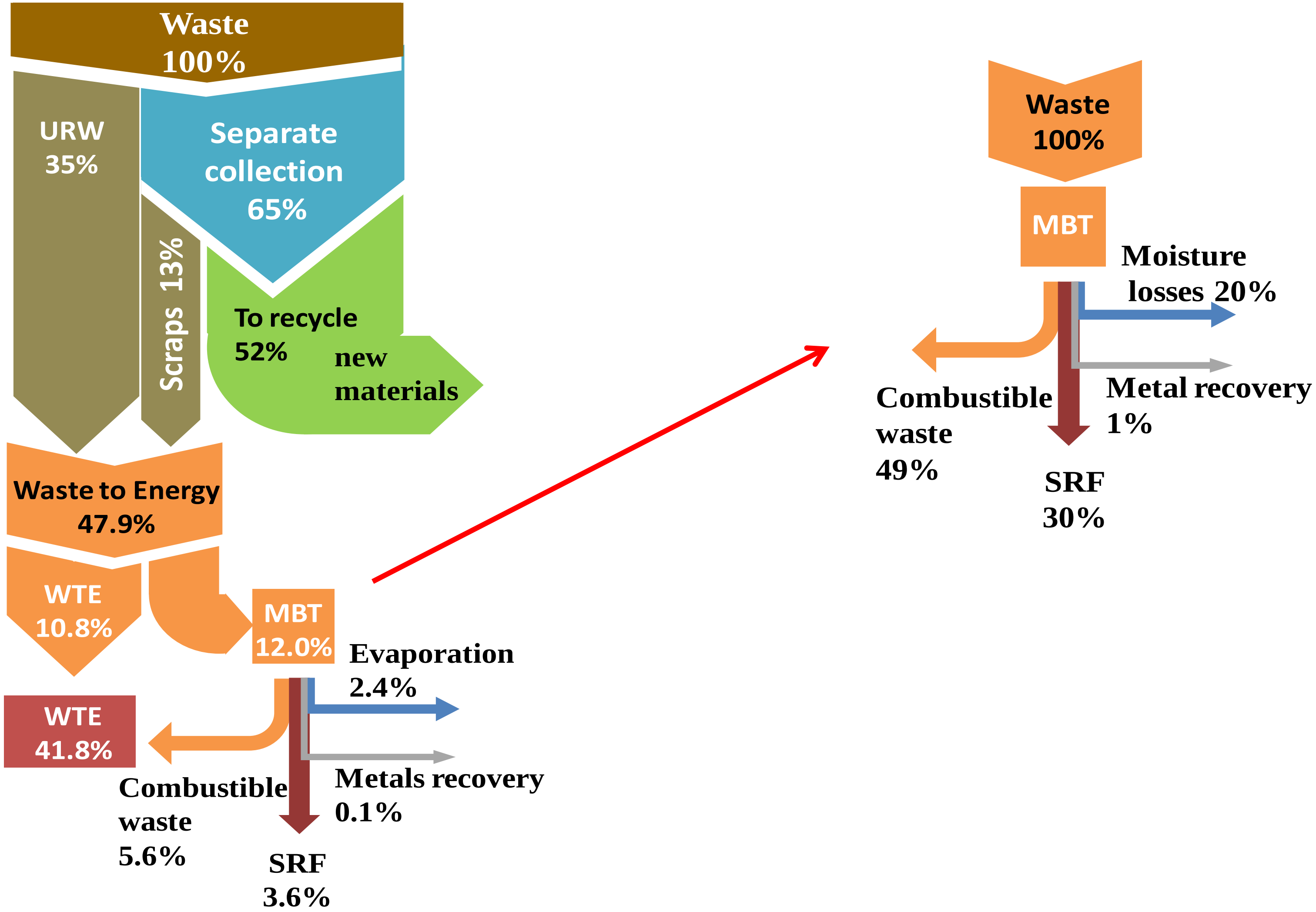
ANALYSIS OF THE SYSTEM MAIN MASS AND ENERGY FLUXES



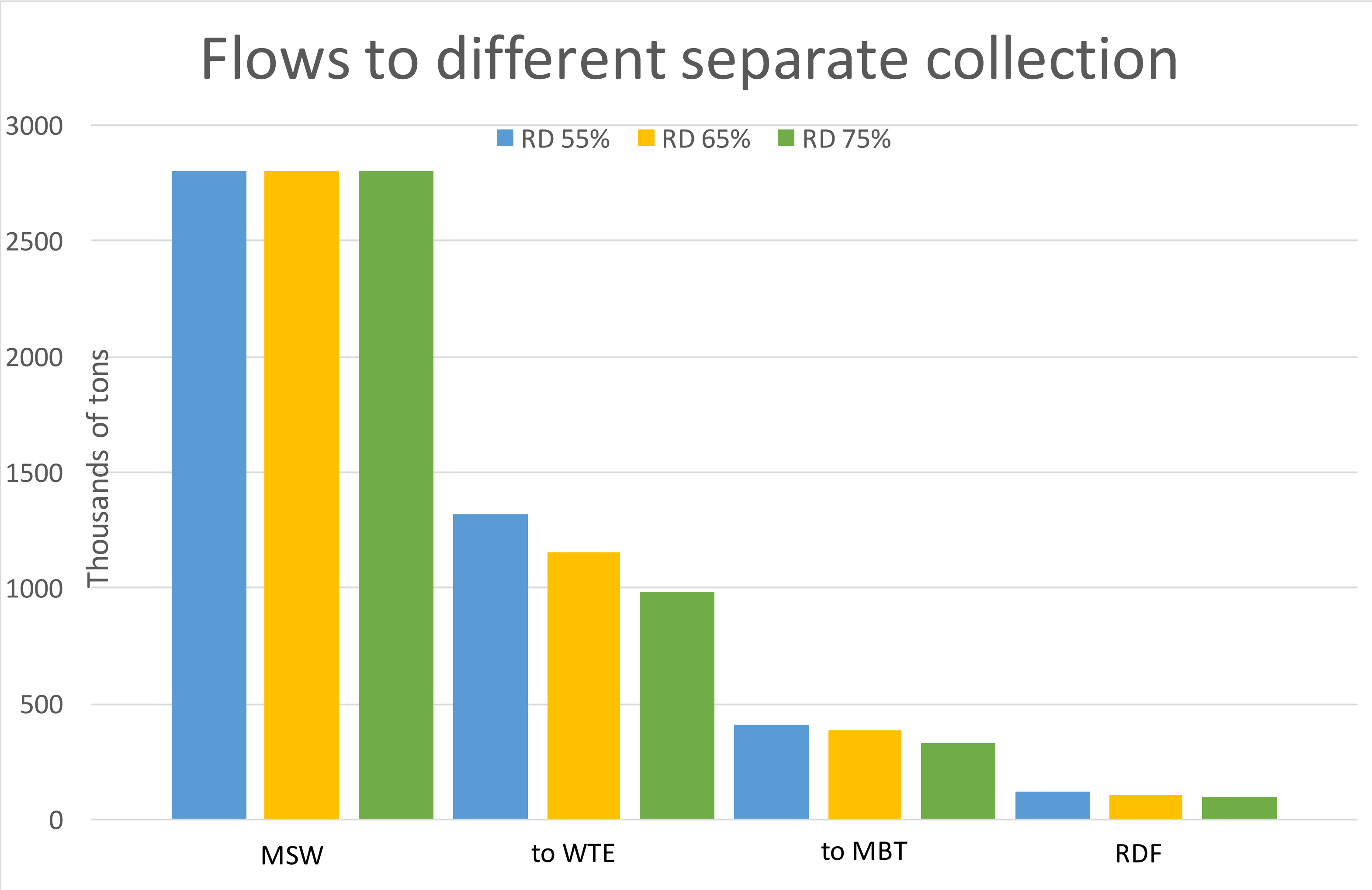
Efficiencies in waste separate collection and fluxes definition

Fractions	Percentage of each fractions with respect to the overall waste (%)	Scrap produced by the single fraction selection treatment (%)	Percentage of the single scrap production with respect to the overall scrap (%)	Percentage of the single scrap production with respect to the overall waste
Green	13.94	15.00	3.22	2.09
Organics	14.07	35.00	7.57	4.92
Glass	0.30	0.00	0.00	0.00
Paper	13.94	15.00	3.22	2.09
Plastic	4.60	50.00	3.54	2.30
Ferrous Materials	1.21	0.00	0.00	0.00
Aluminum	0,00	0.00	0.00	0.00
Wood	3.46	15.00	0.80	0.52
Multimaterial Glass	9.88	0.00	0.00	0.00
Multimaterial Metals	0.63	0.00	0.00	0.00
Waste Equipment	1.00	0.00	0.00	0.00
Other SC	0.78	50.00	0.60	0.39
Bulky Recovery	1.21	50.00	0.93	0.61
Total Differentiated	**65.00**	**-**	**19.9**	**12.9**
Residual Waste				
Urban Refusal	26.90	-		26.90
Bulky Residues	5.09	-		5.09
Road Sweeping	2.99	-		2.99
Total Unsorted Collection	**35.00**	-		**35**
TOTAL Separate + Unsorted	**100.00**	-	-	**47.9**

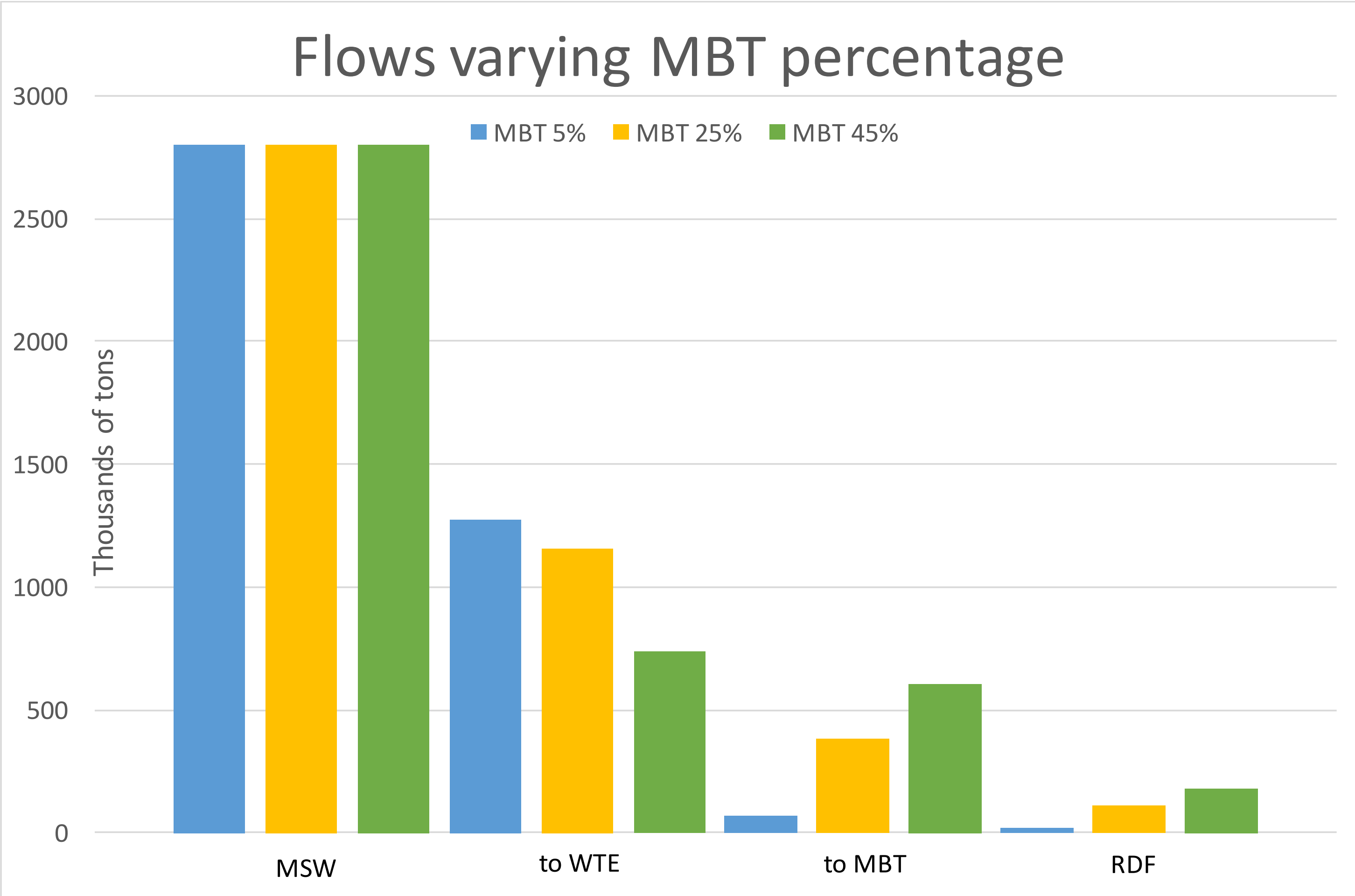
Main fluxes for the residual waste (+ scraps)



Sensitivity Analysis



SENSITIVITY ANALYSIS



MAIN FLUXES FROM THE WASTE SEPARATE COLLECTION

- three basic fluxes are estimated from gross waste production

Percentage of three streams output

	%	%	t/d	t/y	
Net Green	11.85	20.99	315	114,945	to Anaerobic Digestion
Net Organics	9.15				
Scraps	12.92	47.92	719	262,365	to WtE
Urban waste	35				
Material Recovery	31.09	31.09	466	170,190	to Material Recovery

WASTE TO ENERGY

- Different (LHV) Lower Heating Value (MJ/kg) were considered from the literature depending on the waste and plant characteristics

LHV for different plants

City	Flow rate [ton/d]	Flow rate [ton/yr]	Electric Energy production [MWh/h]	Energy production TEP / yr	LHV (MJ/Kg)	Reference
Bologna	600	219,000	22	37,000	11.72	gruppohera.it
Rimini	384	140,160	10.5	18,500	-	
Forlì	384	140,160	10.5	22,000	10.46	
Ferrara	460	167,900	13	20,500	10.46	
Modena	538	196,370	19	-	-	
Ravenna	-	-	6.25	11,000	-	
Milano		467,076			10.736	Grosso et al., (2012)
Athens					9.75	Antonopoulos et al., (2010)
Celje					10 - 12	Kokalj et al. (2013)

η_{th} = 58%

η_{el} = 26%

Thermal Energy produced: 4,483 GJ

Electrical Energy produced: 2,006 GJ

SLUDGE PRODUCTION FROM WWTP

- The estimated per-capita sludge production on dry basis (gr/pe d) considered was evaluated by the following literature

Per capita sludge production on dry basis

Per capita sludge production (g/pe d)	Reference
90	ISWA's Working Group, 1997
87	Passino, 1999
70	Metcalf & Eddy, 2003
80	Masotti, 2005
35 – 45 (I sludge) 60 - 90 (total)	Cleverson et al., 2007
50 – 55 (I sludge) 70 – 80 (I mixed sludge and WAS)	Bonomo, 2008
60	Leite et al., 2016

Per capita sludge production: 80 gr on dry basis/pe d

Dry sludge total production: 43.5 t/d

AD OPERATING CONDITIONS

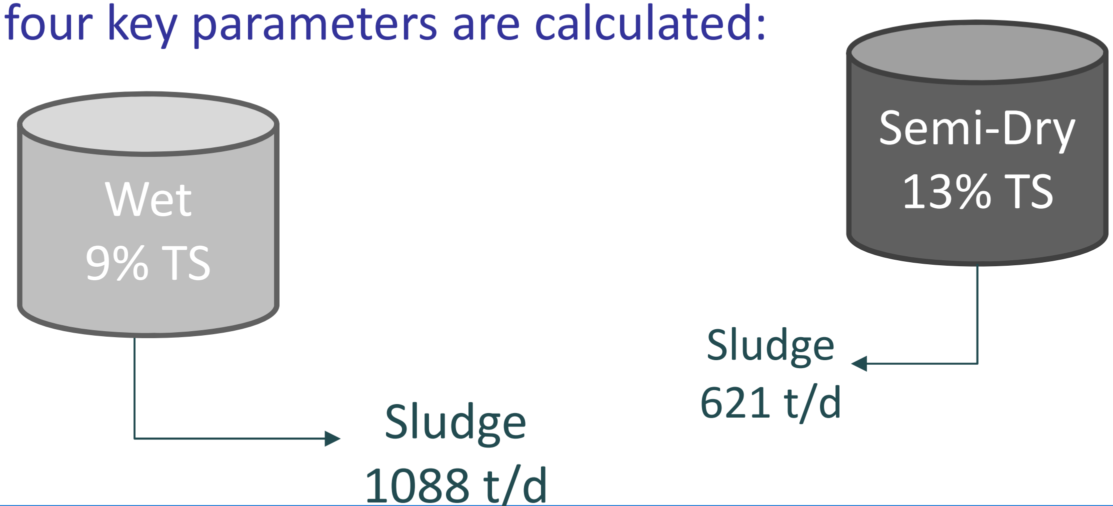
- The input OF-MSW flowrate to the anaerobic digester is 21% total gross waste, equal to **315 t/d**

- Total solids Concentration mixture (OF-MSW and Sludge) fed to the reactor (Wet 9% TS, Semi-Dry 13% TS)

- Digestion process Operating Temperature in Mesophilic conditions (35°C) and in Thermophilic conditions (55°C)

For each condition considered, four key parameters are calculated:

1. Digester Volume (m^3)
2. Biogas Flow Rate (t/d)
3. Digestate Flow Rate (t/d)
4. AD Heat Requirement (GJ)



SPECIFIC GAS PRODUCTION

- The estimated SGP (m^3 biogas/kg_{TVS}) was evaluated considering the following literature data

Specific Gas Production

Specific Gas Production (m^3 biogas/kg_{TVS})	Reference
0.33 Mesophilic 0.45 Thermophilic	Bolzonella et al. (2012)
0.35 Mesophilic 0.55 Thermophilic	Cavinato et al. (2013)
0.419 Meso and Thermo	Sosnowsky et al. (2003)
0.31 Mesophilic 0.51 Thermophilic	Kerroum et al. (2012)
0.25 WAS 0.7-0.8 OF-MSW	Spin-off Risa (2010)

Mesophilic
0.35 m^3 biogas/kg_{TVS}

Thermophilic
0.55 m^3 biogas/kg_{TVS}

METHODOLOGICAL APPROACH

Heat Requirement

- It depends on the temperature difference between incoming feed flow and digester operating temperature

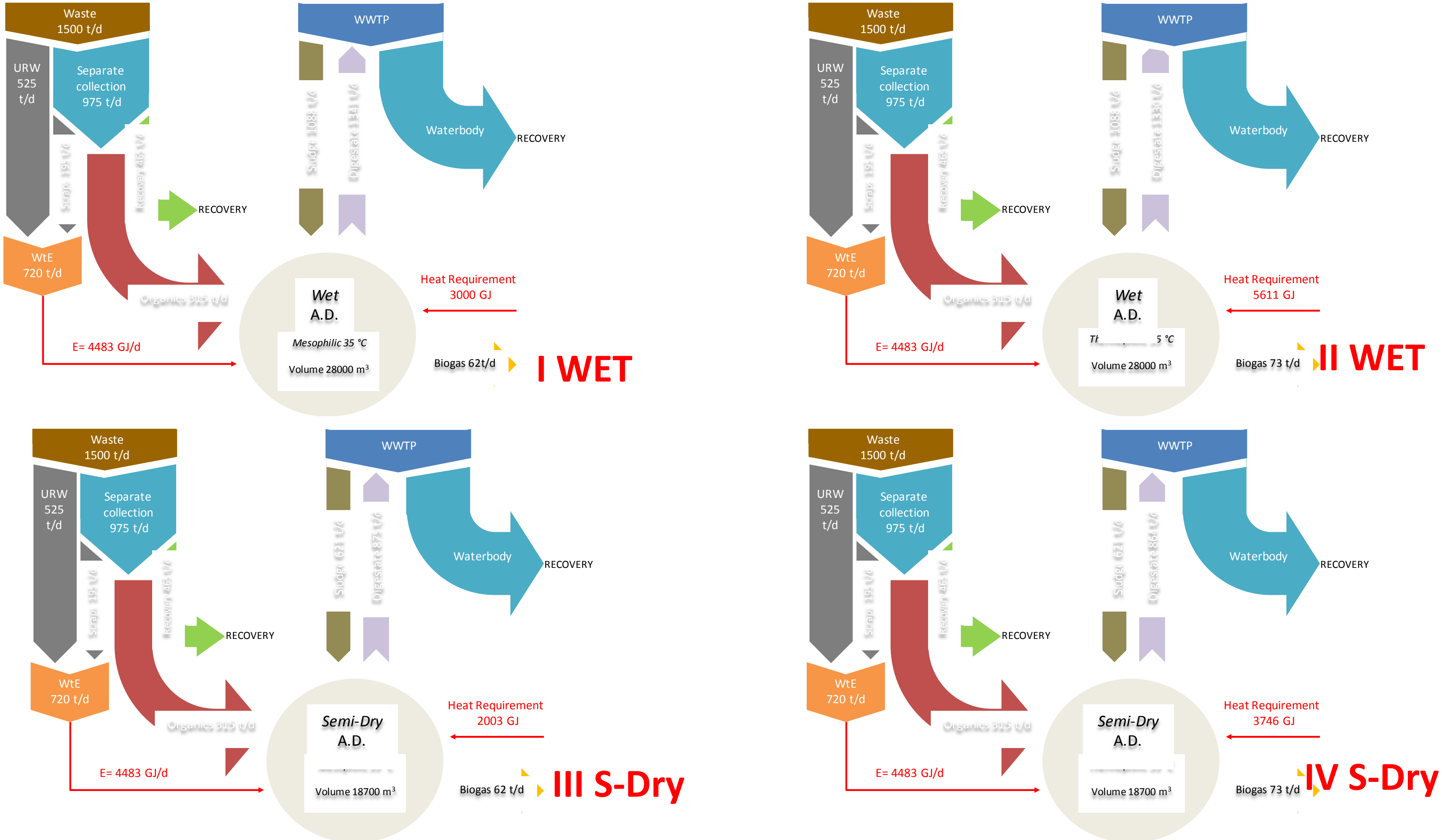
- Heat losses through reactor walls, floor and roof, piping, estimated to 10% of total heat required

$$Q_H = m_f * c_p * (T_{AD} – T_f)$$

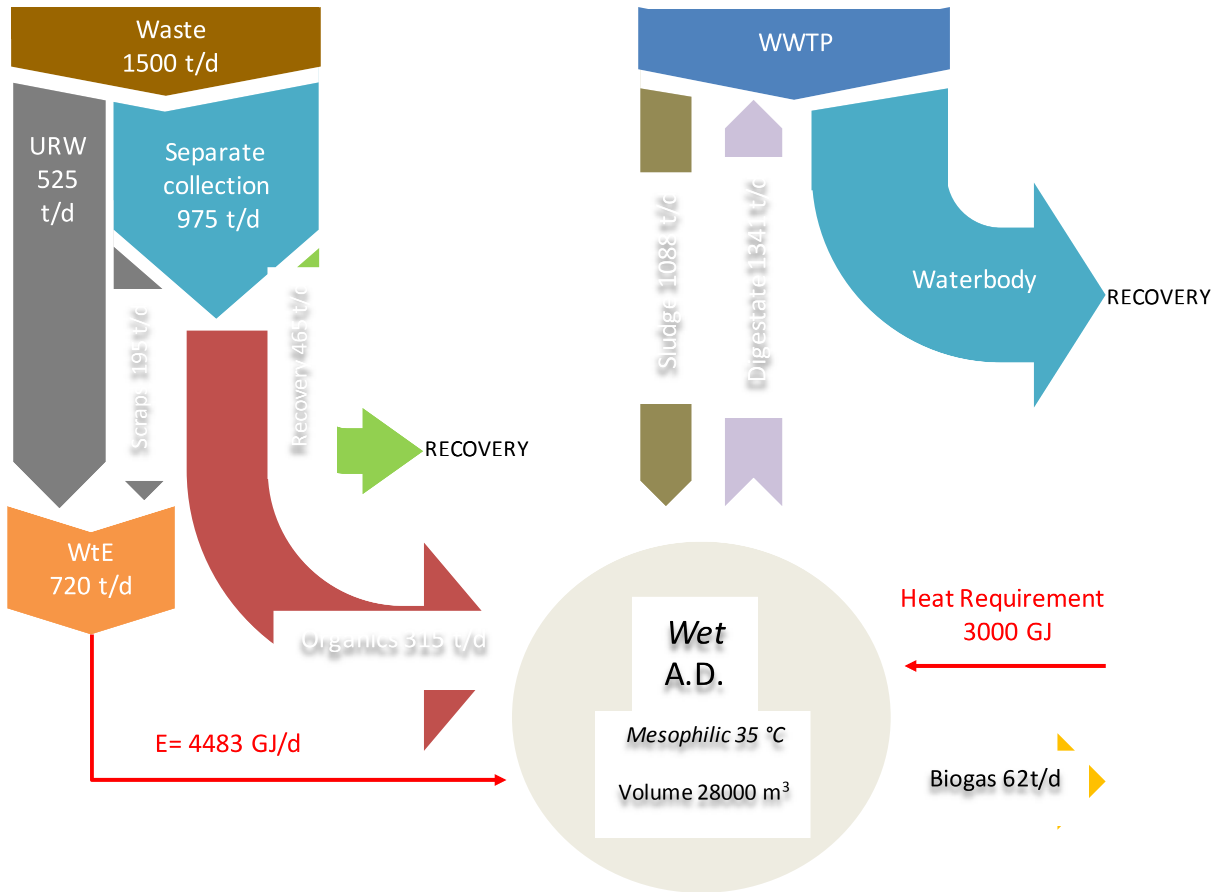
I SCENARIO

I SCENARIO – WET MESOPHILIC		
ṁ OF-MSW	315	t/d
OF-MSW $_{TS}$	25	%
OF-MSW $_{TVS}$	80	%
ṁ Sludge	1,088	t/d
Sludge $_{TS}$	4	%
Sludge $_{TVS}$	70	%
ṁ Mixture	1,403	t/d
Mixture $_{TS}$	8.70	%
Volume Digester	28,060	m^3
OL *OF-MSW*	63	t_{TSV}/d
OL sludge	30	t_{TSV}/d
OL Mixture	93	t_{TSV}/d
OLR	3.3	kg_{TSV}/m^3 d
SGP	0.55	m^3biogas/kg $_{TVS}$
T_{feed} Mesophilic	12	°C
T_{out} Mesophilic	35	°C
v° BIOGAS	51,397	m^3biogas/d
ṁ BIOGAS	62	t/d
ṁ DIGESTATE	1,341	t/d
Heat Requirement	3,000	GJ

Comparison of the different operating conditions



RESULTS AND DISCUSSION

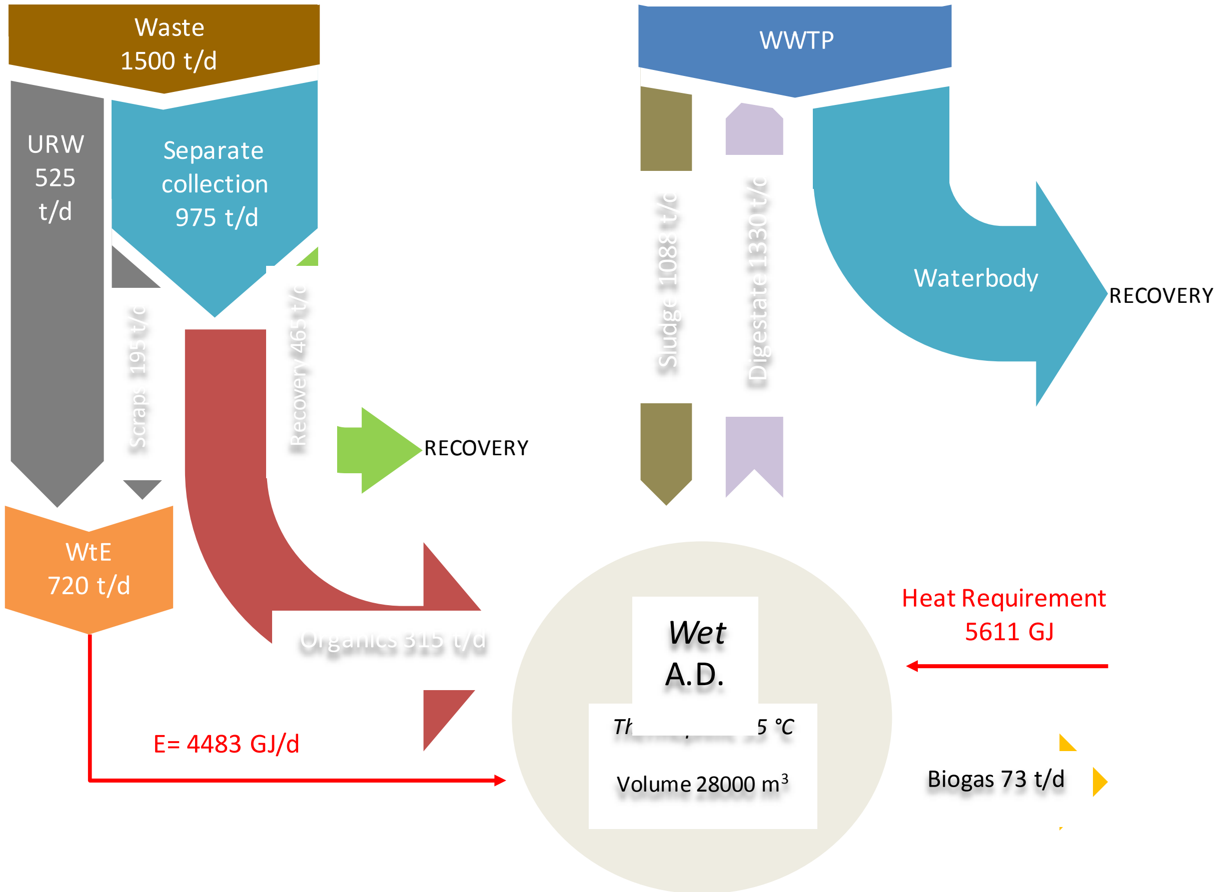


Results and discussion

II SCENARIO

II SCENARIO – WET THERMOPHILIC		
ṁ OF-MSW	315	t/d
OF-MSW $_{TS}$	25	%
OF-MSW $_{TVS}$	80	%
ṁ Sludge	1,088	t/d
Sludge $_{TS}$	4	%
Sludge $_{TVS}$	70	%
ṁ Mixture	1,403	t/d
Mixture $_{TS}$	8.70	%
Volume Digester	28,060	m^3
OL *OF-MSW*	63	t_{TSV}/d
OL sludge	30	t_{TSV}/d
OL Mixture	93	t_{TSV}/d
OLR	3.3	kg_{TSV}/m^3 d
SGP	0.65	m^3biogas/kg $_{TVS}$
T_{feed} Thermophilic	12	°C
T_{out} Thermophilic	55	°C
v° BIOGAS	60,752	m^3biogas/d
ṁ BIOGAS	73	t/d
ṁ DIGESTATE	1,330	t/d
Heat Requirement	5,611	GJ

II SCENARIO

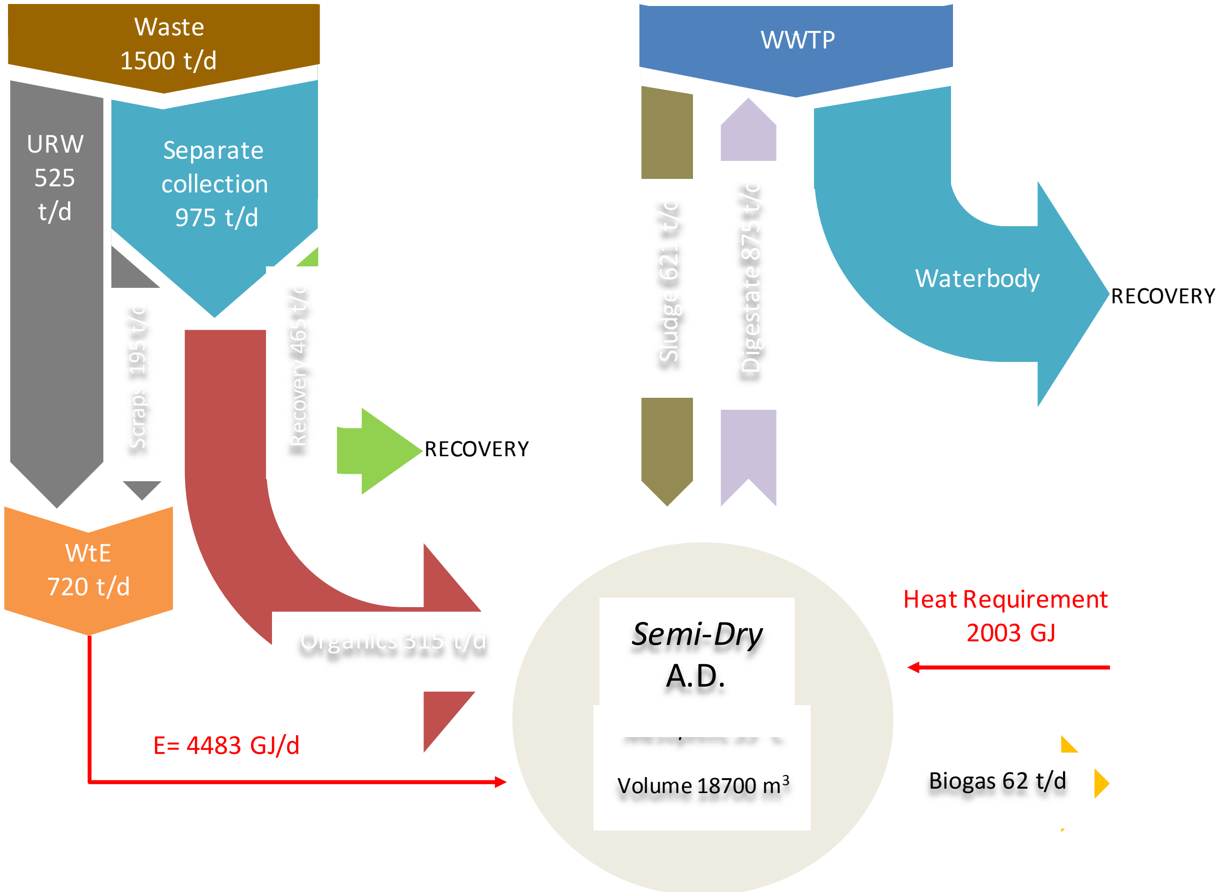

Waste
1500 t/d
URW
525
t/d
Separate
collection
975 t/d
Scraps 195 t/d
Recovery 465 t/d
RECOVERY
WtE
720 t/d
Organics 315 t/d
E= 4483 GJ/d
WWTP
Sludge 1088 t/d
Digestate 1330 t/d
Waterbody
RECOVERY
Wet
A.D.
Volume 28000 m³
Heat Requirement
5611 GJ
Biogas 73 t/d

III SCENARIO

III SCENARIO – SEMI-DRY MESOPHILIC		
ṁ OF-MSW	315	t/d
OF-MSW $_{TS}$	25	%
OF-MSW $_{TVS}$	80	%
ṁ Sludge	621	t/d
Sludge $_{TS}$	7	%
Sludge $_{TVS}$	70	%
ṁ Mixture	937	t/d
Mixture $_{TS}$	13	%
Volume Digester	18,728	m^3
OL *OF-MSW*	63	t_{TSV}/d
OL sludge	30	t_{TSV}/d
OL Mixture	93	t_{TSV}/d
OLR	4.9	kg_{TSV}/m^3 d
SGP	0.55	m^3biogas/kg $_{TVS}$
T_{feed} Mesophilic	12	°C
T_{out} Mesophilic	35	°C
v° BIOGAS	51,400	m^3biogas/d
ṁ BIOGAS	62	t/d
ṁ DIGESTATE	875	t/d
Heat Requirement	2003	GJ

RESULTS AND DISCUSSION

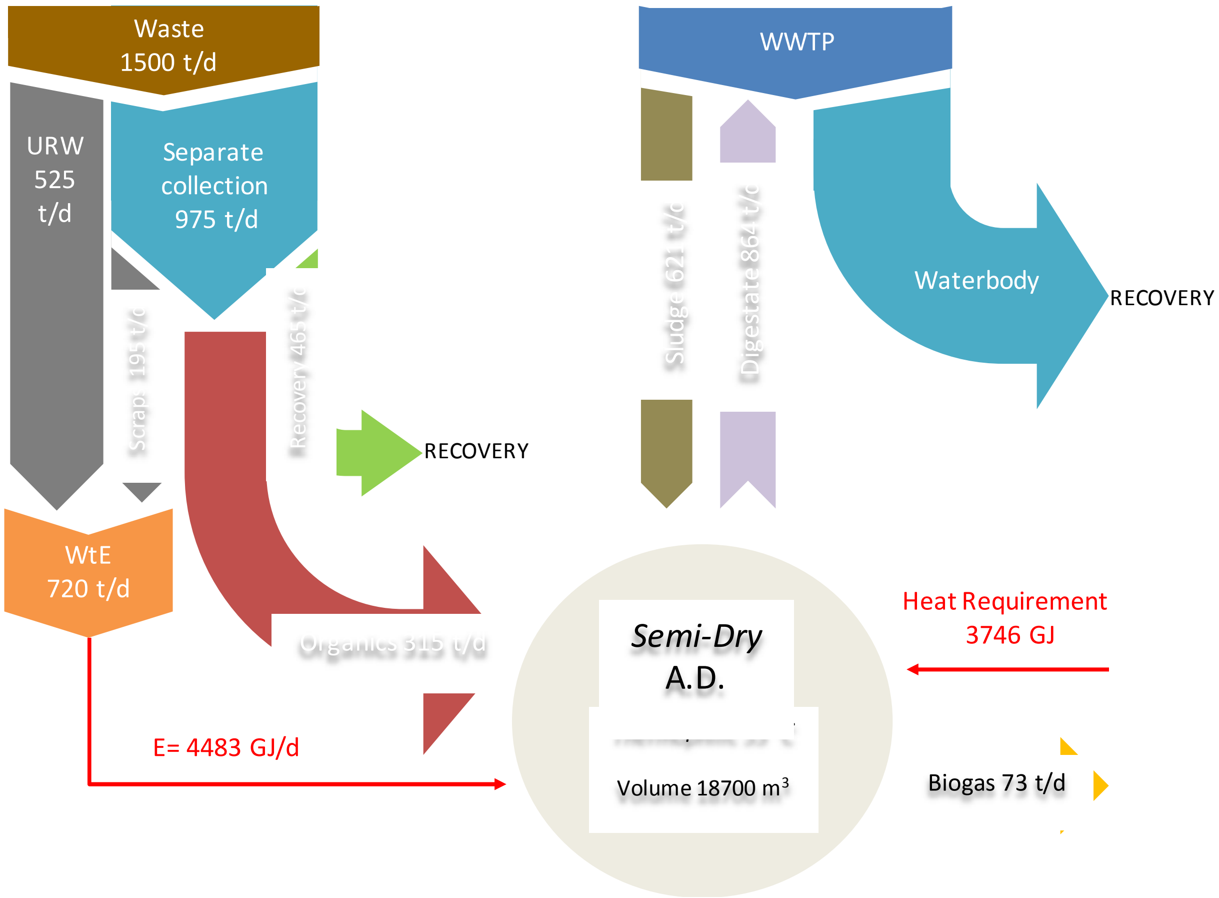
III SCENARIO



IV SCENARIO

IV SCENARIO – SEMI-DRY THERMOPHILIC		
ṁ OF-MSW	315	t/d
OF-MSW $_{TS}$	25	%
OF-MSW $_{TVS}$	80	%
ṁ Sludge	621	t/d
Sludge $_{TS}$	7	%
Sludge $_{TVS}$	70	%
ṁ Mixture	937	t/d
Mixture $_{TS}$	13	%
Volume Digester	18,728	m^3
OL *OF-MSW*	63	t_{TSV}/d
OL sludge	30	t_{TSV}/d
OL Mixture	93	t_{TSV}/d
OLR	4.9	kg_{TSV}/m^3 d
SGP	0.65	m^3biogas/kg $_{TVS}$
T_{feed} Thermophilic	12	°C
T_{out} Thermophilic	35	°C
v° BIOGAS	60,752	m^3biogas/d
ṁ BIOGAS	73	t/d
ṁ DIGESTATE	864	t/d
Heat Requirement	3746	GJ

IV SCENARIO



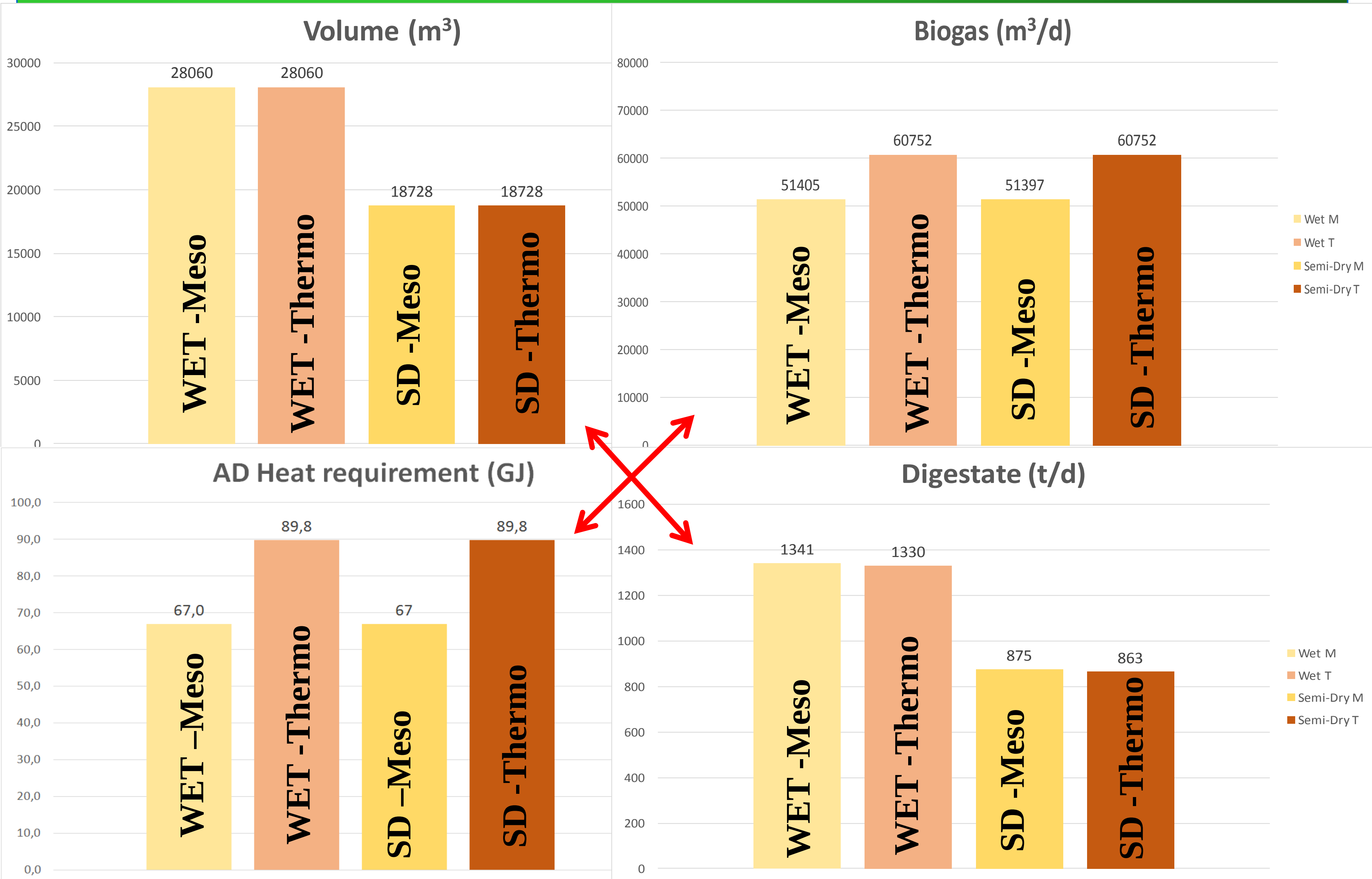
Waste
1500 t/d
URW
525
t/d
Separate collection
975 t/d
Scraps 195 t/d
Recovery 465 t/d
RECOVERY
WtE
720 t/d
Organics 315 t/d
E= 4483 GJ/d
WWTP
Sludge 621 t/d
Digestate 864 t/d
Waterbody
RECOVERY
Semi-Dry
A.D.
Volume 18700 m³
Heat Requirement
3746 GJ
Biogas 73 t/d

termovalorizzazione

rifiuto (RUR + scarti) (t)	Potere calorifico (MJ/t)	energia totale (GJ)	rendimento termico (GJ)	energia termica prodotta all'anno	rendimento elettrico (GJ)	Energia elettrica	% scorie	scorie a recupero (t)
719	10736	7719	0,58	4477	0,26	2007	15%	108

Volume digestore (m3)	T iniziale miscela (°C)	T di processo miscela (°C)	Perdita dalle pareti (%)	kcal/ton (m3)	Mcal	Gcal	GJ
22000	12	55	10%	1000	9.469	9,5	40

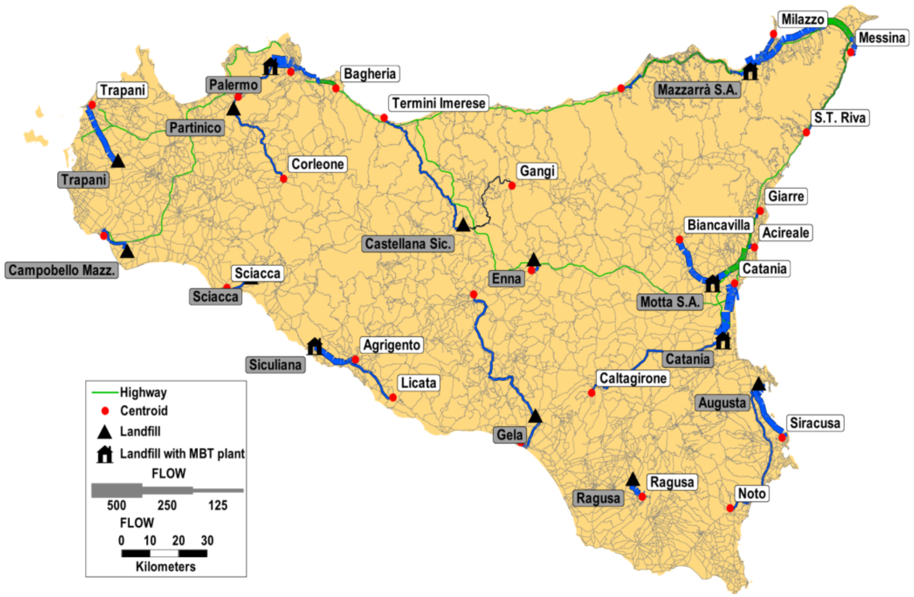
Comparison of the different operating conditions

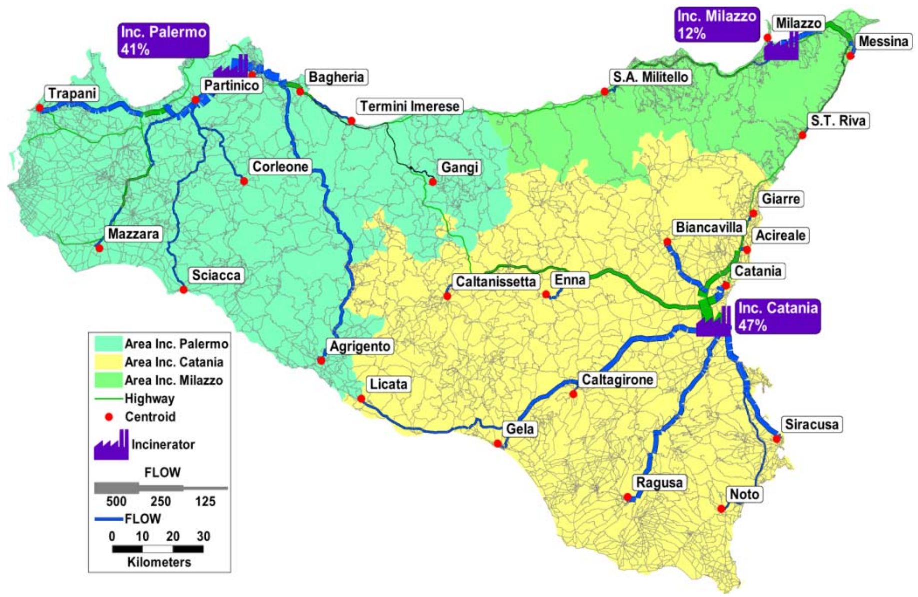


Key results for different scenarios

Scenario	Volume (m^3)	Biogas (t/d)	Digestate (t/d)	Heat Requirement (GJ)
I	28,060	62	1,341	3,002
II	28,060	72.9	1,330	5,612
III	18,728	62	875	2,003
IV	18,728	72.9	864	3,746

Comparison of the two waste management scenarios in Sicily





Scenario	Separate collection (%)	Recovery (%)	Composting plants[1] (%)	AD (%)	MBT (%)	WTE (%)	Landfill (%)	Total Transportation cost (€/day)	CO_2 emissions (Kg/day)
Current	15	12	5	0	90[2]	0	88	5580	6510
Expected	65	52	0	20[1]	0	48	2[3]	7350	8400

CONCLUSIONS

- Transportation issues are not so critical when compared to treatment and disposal issues
- The differences in transportation cost are even less significant when compared to all the other relevant components of a sustainable and holistic approach (i.e. landfill requirement reduction, energy saving, CO_2 reduction).

- Thermophilic + Semi-Dry is the best option in co-digestion process for sludge/biowaste mixtures treatment. It shows the best performances in terms of biogas yields and digestate management

- Energy request from thermophilic process can be easily supported when considering the heat recovery from WTE plant

- The proposed model could represent a prospective solution for stakeholders to significantly improve waste and sludge issues currently affecting Southern Europe regions in large metropolitan areas where industrial symbiosis can be profitably applied

Take home message…..

National

Sicily to send its rubbish to Austria

Published: 29 Dec 2014 09:19 GMT+01:00

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Trash from the Italian island of Sicily will next year be processed at special treatment plants in Austria.

After years of problems with waste disposal, the Italian island of Sicily has signed a deal to send a significant portion of its increasing piles of trash to Austria for processing.

Sicilian media reported that hundreds of tonnes of garbage will be transferred by ship and train to Austria during 2015, for disposal by specialized waste treatment plants in the central-European country.

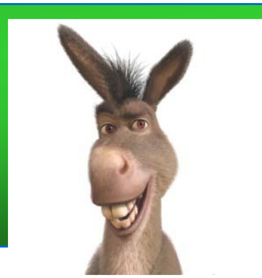
The Sicilian Regional Assembly received the green light from Rome for this option, despite criticism by local media for the expected tax hikes required to pay for the transport and processing.

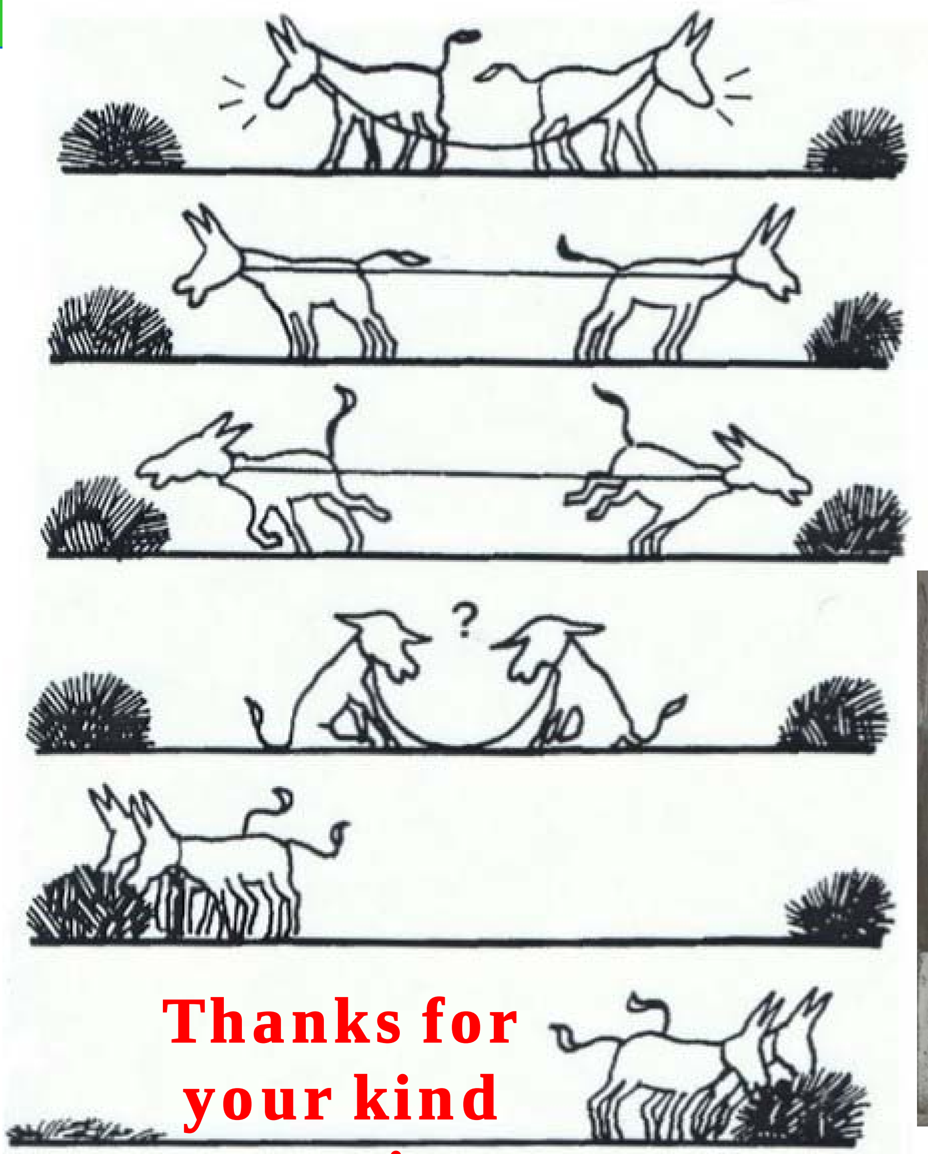
Rosario Crocetta, the former communist and openly-gay president of the regional assembly of Sicily, pushed through the proposals in the face of opposition from the leftist SEL party, which accused the president of failing to properly address the island's mounting environmental problems.

Crocetta became president after achieving a strong anti-Mafia reputation, and has persevered in driving an anti-corruption program, despite several attempts on his life.

....and of course going on with landfill disposal

Stop politically fighting and simply start working (and thinking) like a Donkey





Separate waste collection in Castelbuono (Sicily)

Thanks for your kind attention