Università degli Studi di Padova

Department of Industrial Engineering

Energy crops applied to landfills: functional, environmental and costs analysis

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Work groups and aims

Different steps

Scenario zero (Reference scenario) definition
Alternative scenarios → present study

Main aim

Strategies for reducing
"*landfill gate fee*"
(unit payment for landfill life cycle service)

Specific aims

- Evaluate the application of energy crops to landfill
- Compare energy crops solutions
- Suggest solutions able to reduce landfill cost, producing energy and increasing the environmental quality of the site

Methodology

Definition of criteria to use in the study

1) Economic
2) Energetic
3) Environmental

↓

Define landfill scenarios to compare with the "scenario zero"

1) Energetic maximization scenario
2) Leachate phytodepuration scenario
3) Environmental compensation scenario
4) Combination scenario

↓

Multi-Criteria Analysis

Criteria definition - Economic criteria

- Evaluate the total cost of the scenario
- Consideration of all the landfill phases
- $x_{ECONOMIC} = COST_{REFERENCE} - COST_{SCENARIO}$

Construction phase

Authorization and design phase

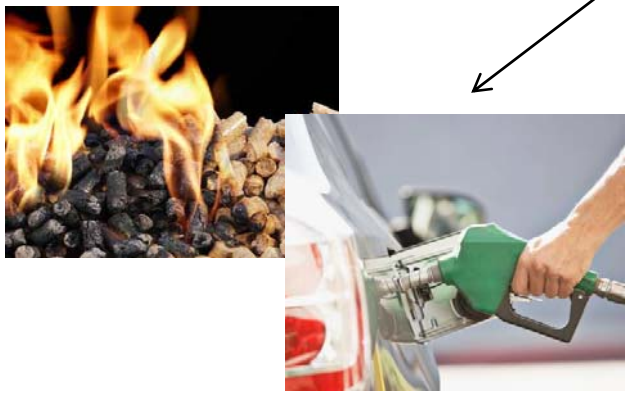
Aftercare phase

Operation phase

Criteria definition - Energetic criteria

- Evaluate the energetic net gain (unit of measure: Joule)
- $x_{ENERGETIC} = ENERGY_{SCENARIO} - ENERGY_{REFERENCE}$

ENERGETIC NET GAIN = **ENERGETIC OUTPUTS** – **ENERGETIC INPUTS**



Lower Heating value of products
(biomass, biodiesel, oil, ...)

Energy equivalent of inputs
(fuel, fertilizer, manpower, …)

We considered lignocellulosic and oleaginous plants

Criteria definition - Environmental criteria

- Evaluate the environmental impact of energy crops;
- Biological Territorial Capacity, BTC (unit of measure: Mcal/m^2/year);
- Defined for each landscape element;

→ landscape elements definition according to land use criteria

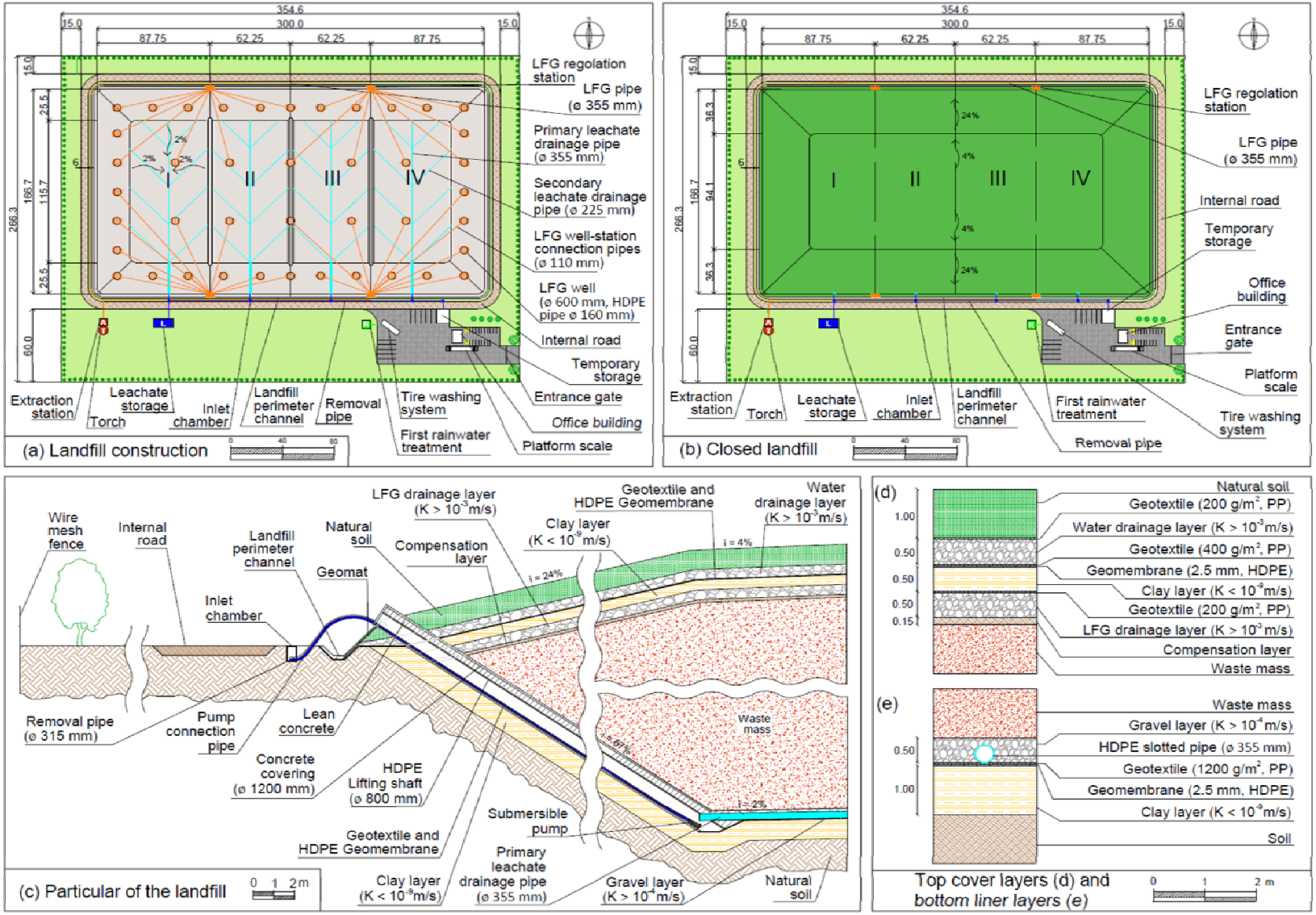
- $x_{ENVIRONMENTAL} = BTC_{SCENARIO} - BTC_{REFERENCE}$
- $$BTC_{mean} = \frac{(\sum_i S_i \cdot BTC_i)}{S_{domain}}$$

BTC_{mean} increase → Environmental quality improvement

BTC_{mean} decrease → Environmental quality degradation

❖ Pivato, A., Vanin, S., Barausse, A., Mangione, G., Rasera, M., and Monego, G., 2013. Biopotentiality as an index of environmental compensation for composting plants. Waste Managment 33, 1607-1615.

Scenario definition – Reference scenario



Scenario definition - Energetic maximization scenario

- Based on energetic potential of energy crops
- Application in the aftercare phase
- Landfill top cover with low slope

Miscanthus

- Dense and deep root system

assumption:
additional 50 cm thickness in top cover

Scenario definition - Leachate phytodepuration scenario

- Based on the possibility of leachate phytodepuration
- Application during the landfill operation phase
- 4 years of activity
- Landfill top cover with low slope

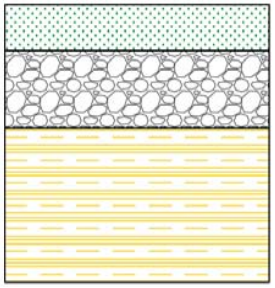
Oil crops

Phytodepuration basin

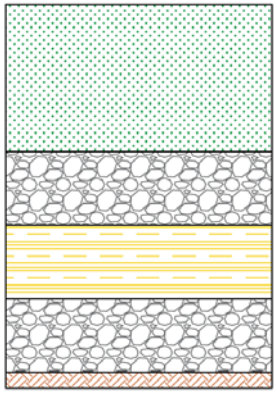
30 cm growing layer

50 cm drainage layer

1 m clay layer



Final top cover (D.Lgs 36/2003)



1 m natural layer

50 cm drainage layer

50 cm clay layer

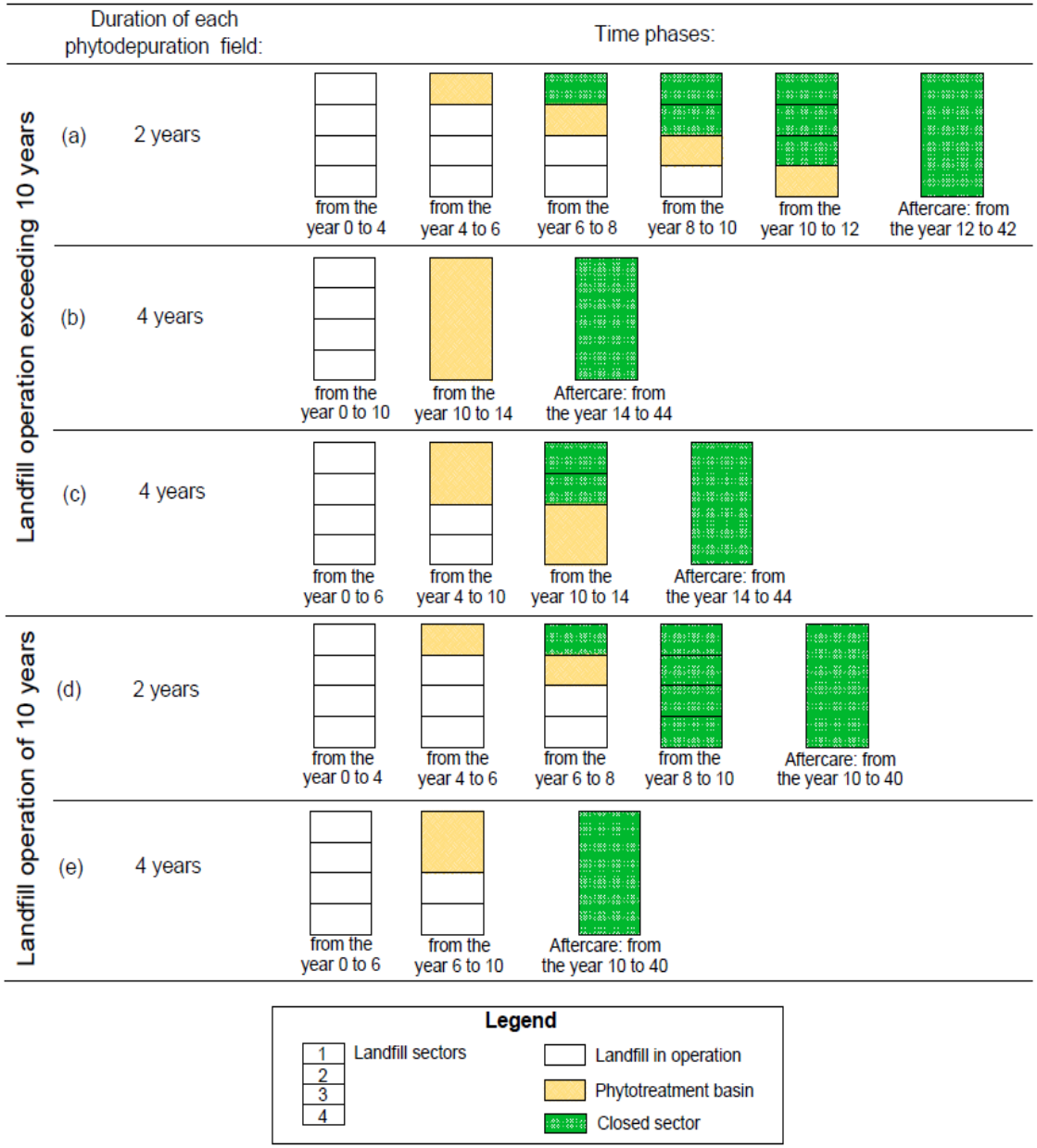
50 cm LFG dr. layer

compensation layer

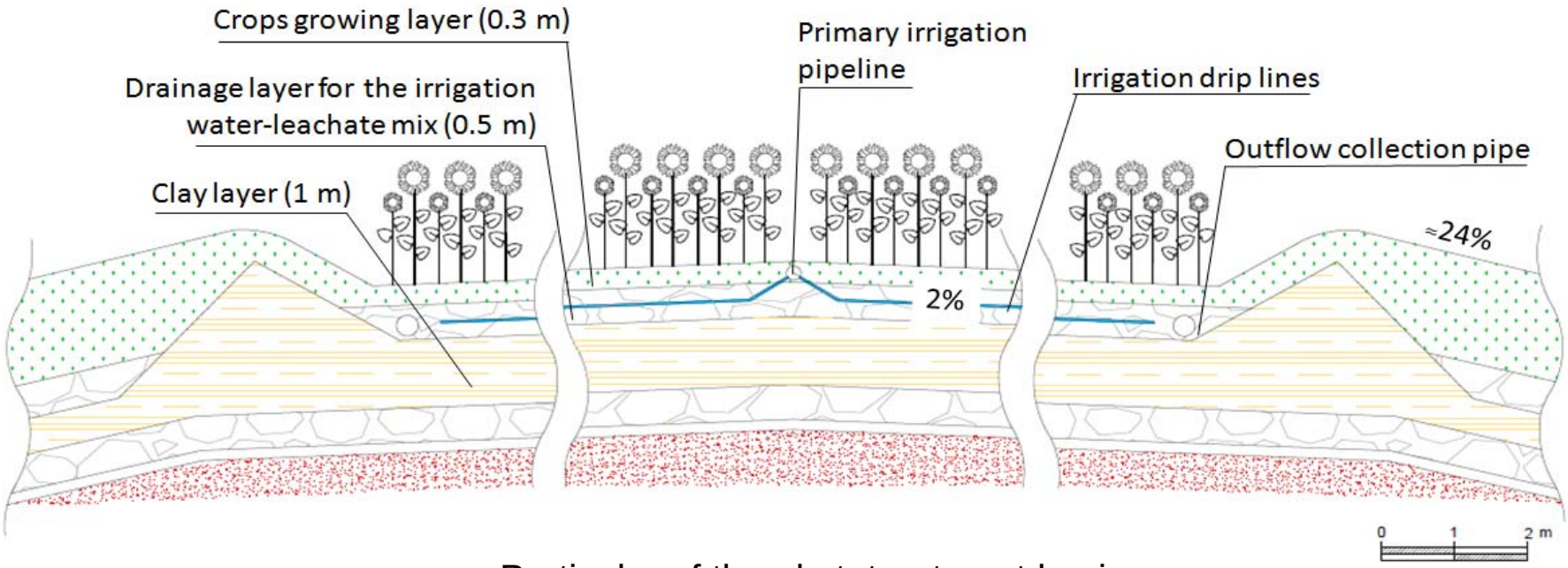
- Lavagnolo, M.C., Malagoli, M., Garbo, F., Pivato, A., and Cossu, R., 2016. Lab-scale phytotreatment of old landfill leachate using different energy crops. Waste Managment 55, 265–275
- Garbo, F., Lavagnolo, M.C., Malagoli, M., Schiavon, M., and Cossu, R., 2016. Different leachate phytotreatment systems using sunflowers. Waste Management, doi: 10.1016/j.wasman.2016.10.035

Scenario definition

- Leachate phytodepuration scenario



Scenario definition - Leachate phytodepuration scenario



Particular of the phytotreatment basin

Scenario definition - Environmental compensation scenario

➢ based on the introduction of environmental compensation measures

Poplar

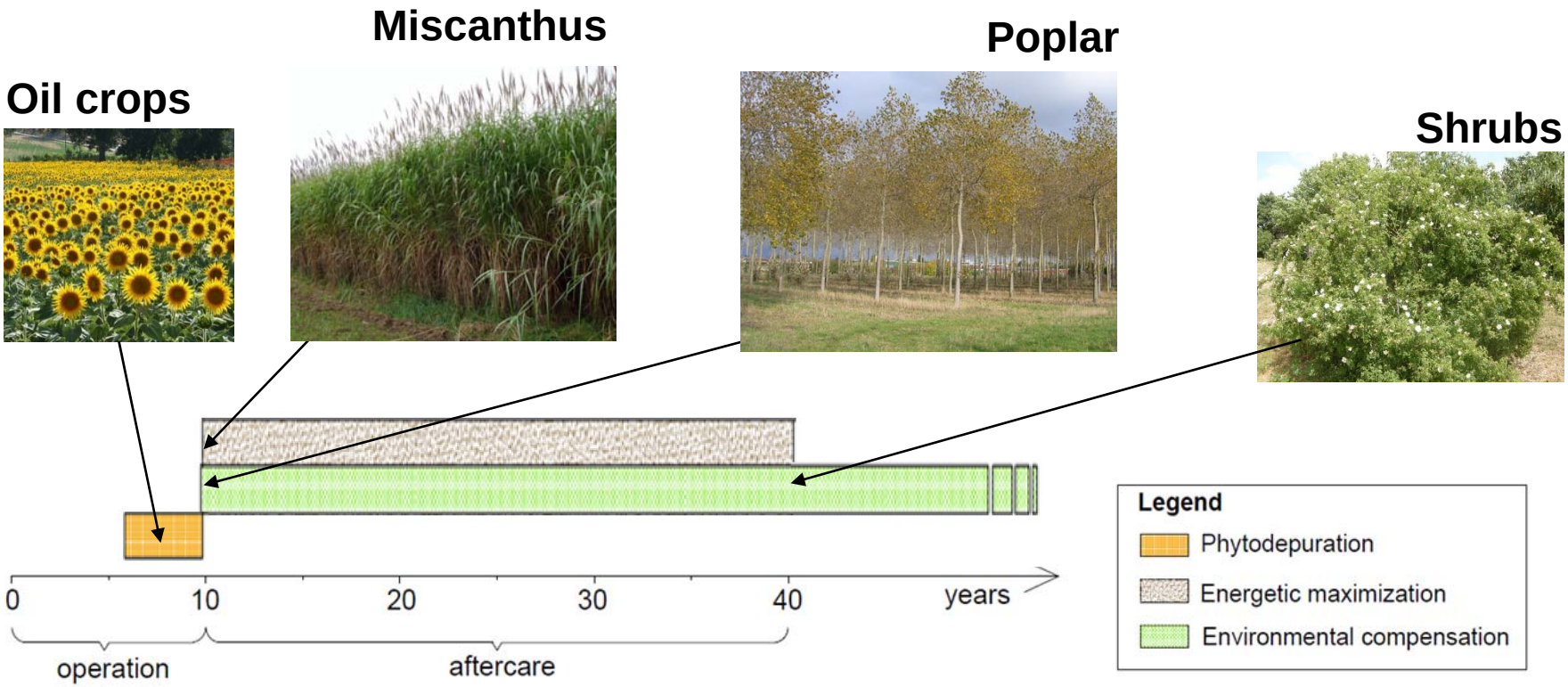
- around the landfill body
- energy crops with Medium Rotation Foresty (MRF) cutting cycle

Shrubs

- over the landfill top cover
- recreational area spaces and walking paths

Scenario definition - Combination scenario

- Combine the solutions adopted for the other scenarios
- Effects both in operation and aftercare phase



Multi-Criteria Analysis

- x_i defined for each criteria
- Interval linearization:

$$\frac{x_i - x_{min}}{x_{max} - x_{min}}$$

x_{min} and x_{max} are represent the minimum and the maximum x_i between the scenarios

- Final scoring: $$\text{Best scenario} = \text{Max} \sum_i x_i \, w_i$$
- *Assumption: equal weighting of the criteria*

Economic criteria

	Reference scenario	*Energetic maximization scenario*	*Leachate phytodepuration scenario*	*Environmental compensation scenario*	*Combination scenario*
TOTAL COST	68,833,045.81	69,279,106.78	68,952,498.16	69,139,071.58	69,189,190.40
		+446,060.98	+ 119,452.35	+306,025.78	+356,144.59
TOP COVER	4,671,169.43	4,903,115.54	4,697,521.94	4,671,169.43	4,872,542.55
FINAL WORKS	80,870.77	159,198.59	160,005.07	213,760.77	258,611.59
LEACHATE MANAG. IN OPERATION	1,917,973.00	1,917,973.00	1,834,596.98	1,917,973.00	1,834,596.98
LEACHATE MANAG. IN AFTERCARE	3,068,401.95	2,957,635.58	3,067,199.32	3,068,401.95	2,839,732.21
$x_{ECONOMIC}$	*0.00*	*-446,060.98*	*-119,452.35*	*-306,025.78*	*-356,144.59*

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		- 110,766.37	- 1,202.63	0.00	- 228,669.73
$x_{ECONOMIC}$	*0.00*	*-446,060.98*	*-119,452.35*	*-306,025.78*	*-356,144.59*

Energetic criteria

	Reference scenario	*Energetic maximization scenario*	*Leachate phytodepuration scenario*	*Environm. compensation scenario*	*Combination scenario*
INPUT (GJ)	0	1199.94	107.35	737.68	2,044.97
OUTPUT (GJ)	0	24,877.99	101.86	11,414.73	36,394.57
NET GAIN (GJ)	0	23,678.05	-5.49	10,782.06	34,454.62
$X_{ENERGETIC}$ *(GJ)*	0	23,678.05	-5.49	10,782.06	34,454.62

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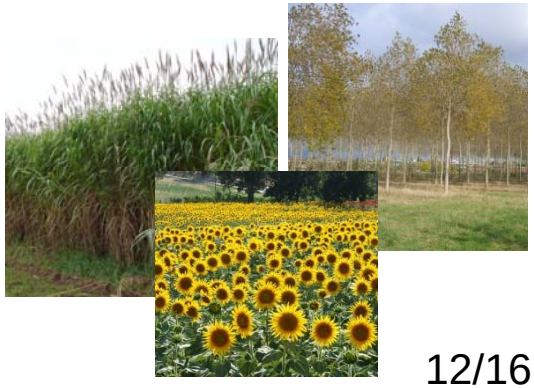

Environmental criteria

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t = 0 (Mcal/m^2/year)	0.89	0.89	0.89	0.89	0.89
t > 40 years (Mcal/m^2/year)	0.90	0.90	0.90	1.06	1.06
$x_{ENVIRONMENTAL}$ (Mcal/m^2/year)	0.00	0.00	0.00	0.16	0.16

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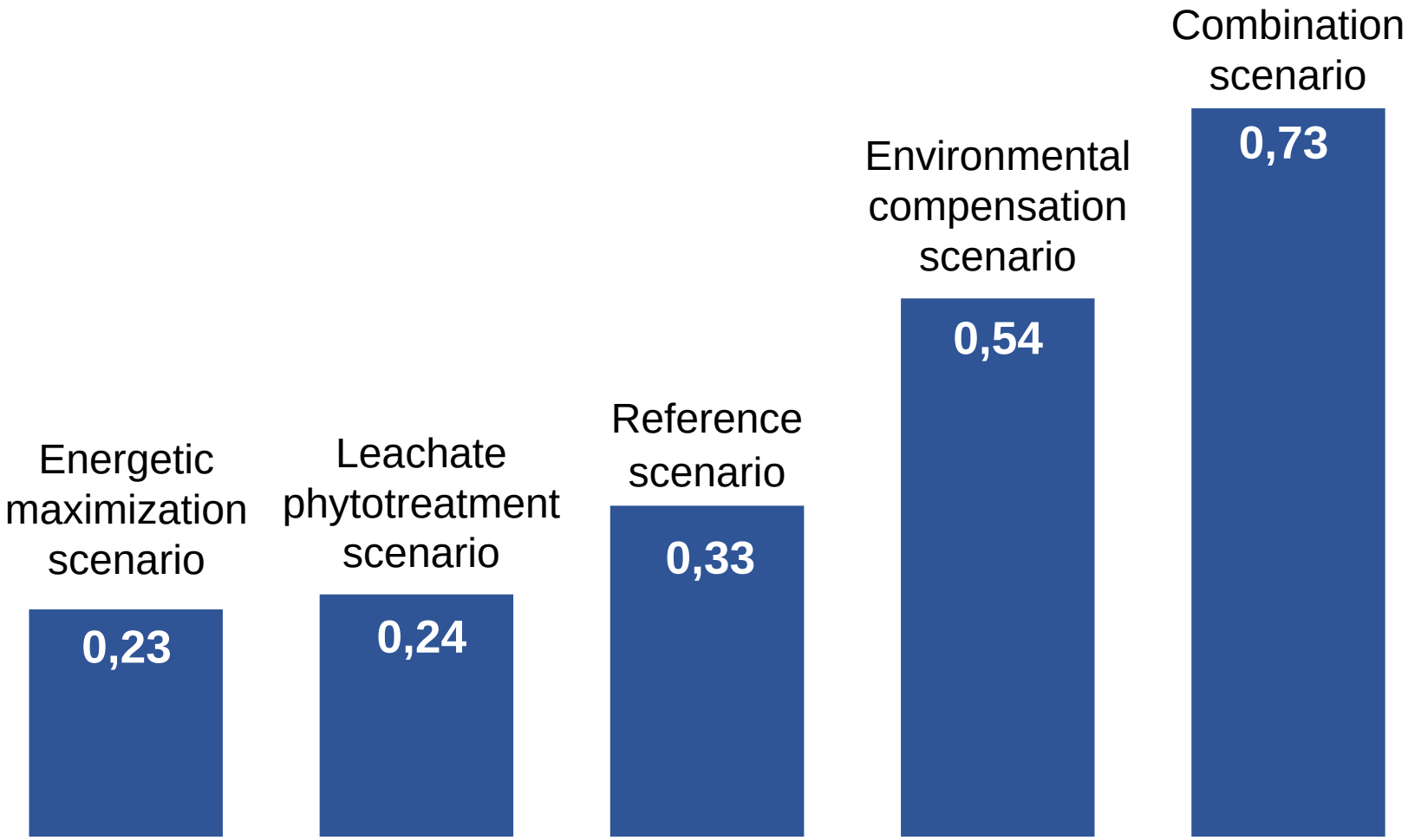
Energetic maximization scenario
0,23
Leachate phytotreatment scenario
0,24
Reference scenario
0,33
Environmental compensation scenario
0,54
Combination scenario
0,73

- The best scenario resulted the combination scenario;
- The energetic and the environmental criteria are maximized by applying lignocellulosic crops;
- All the scenarios showed an higher costs respect the reference case;
- The costs for additional layers on the top cover are not amortized by savings in leachate management;
- The phytodepuration scenario showed really promising economically. The current normative should integrate in a better way the application of new technologies.