ENEA
ITALIAN NATIONAL AGENCY FOR NEW TECHNOLOGIES, ENERGY AND SUSTAINABLE ECONOMIC DEVELOPMENT

UNIVERSITÀ CATTOLICA del Sacro Cuore

Introduction to Life Cycle Assessment

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Outline

- Introduction to Life Cycle Assessment:
- Environmental performances of Agrovoltaico systems
- Environmental performances of Agrovoltaico systems combined with biogas from maize
- Interpretation, conclusions and future work

Introduction to Life Cycle Assessment:

- Definitions, principles and framework (ISO 14040:2006)

Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle

Principles

- **Life cycle perspective**
- LCA considers the entire life cycle of a product, from raw material extraction and acquisition, through energy and material production and manufacturing, to use and end of life treatment and final disposal. Through such a systematic overview and perspective, the shifting of a potential environmental burden between life cycle stages or individual processes can be identified and possibly avoided.
- **Environmental focus**
- LCA addresses the environmental aspects and impacts of a product system. Economic and social aspects and impacts are, typically, outside the scope of the LCA. Other tools may be combined with LCA for more extensive assessments.
- **Relative approach and functional unit**
- LCA is a relative approach, which is structured around a functional unit. This functional unit defines what is being studied. All subsequent analyses are then relative to that functional unit, as all inputs and outputs in the LCI and consequently the LCIA profile are related to the functional unit.
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Principles

- **Transparency**
- Due to the inherent complexity in LCA, transparency is an important guiding principle in executing LCAs, in order to ensure a proper interpretation of the results.
- **Comprehensiveness**
- LCA considers all attributes or aspects of natural environment, human health and resources. By considering all attributes and aspects within one study in a cross-media perspective, potential trade-offs can be identified and assessed.
- **Priority of scientific approach**
- Decisions within an LCA are preferably based on natural science. If this is not possible, other scientific approaches (e.g. from social and economic sciences) may be used or international conventions may be referred to. If neither a scientific basis exists nor a justification based on other scientific approaches or international conventions is possible, then, as appropriate, decisions may be based on value choices.
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Phases of an LCA

- LCA studies comprise four phases.

- These are:
- – the goal and scope definition,
- – inventory analysis,
- – impact assessment, and
- – interpretation
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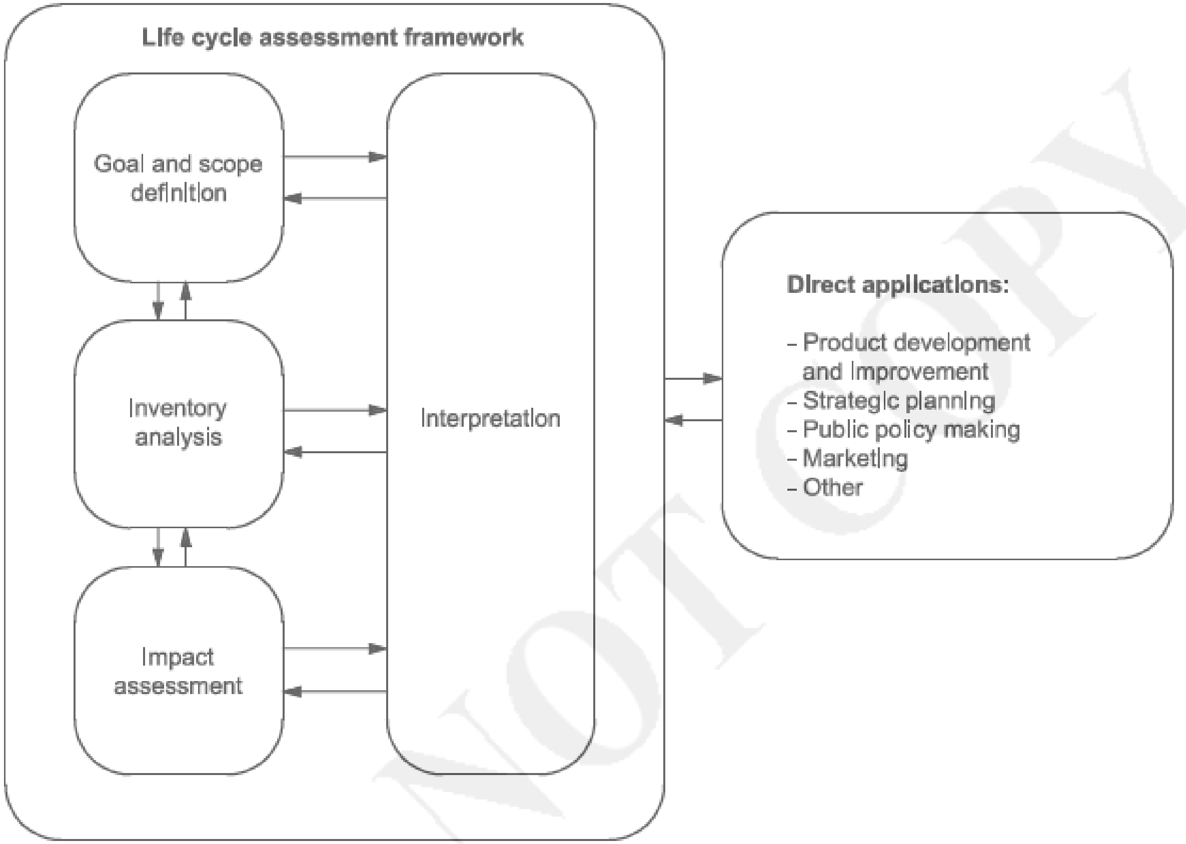

Environmental performances of Agrovoltaico systems

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Goal and Scope Definition

- GOAL:
- Assessment of the potential environmental impacts of agrovoltaic systems. Optimisation of the agrovoltaic performances.

- SCOPE:
- Comparative of 3 different sun tracking configurations: biaxial (2A), monoaxial (1A), static (ST)
- 25 y lifetime
- Potential climate change impact
- Functional unit: 1 MJ electricity
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Environmental performances of Agrovoltaico systems

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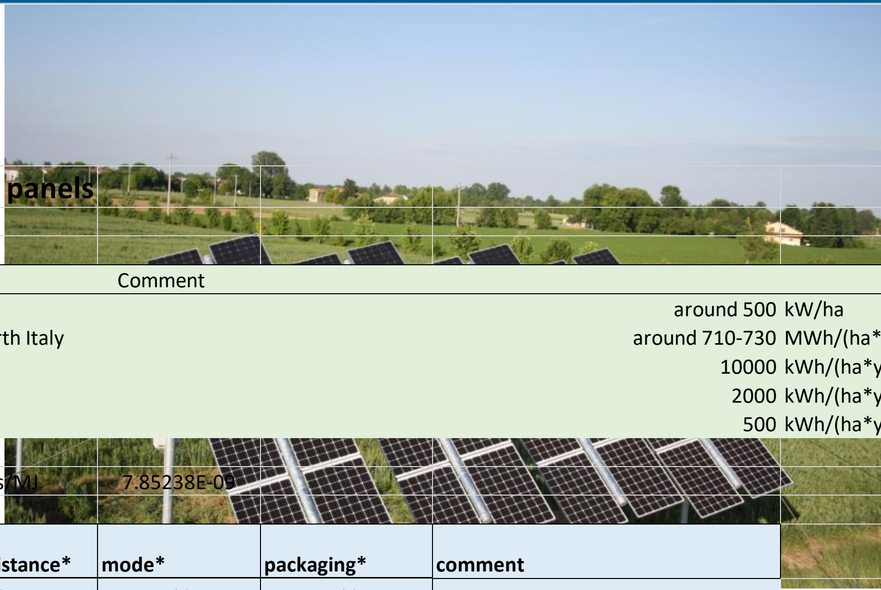
Life Cycle Inventory



Inventory for 2 axis sun tracking agrofotovolatico systems: high density of PV panels

MAIN DATA					Comment		
installed capacity	**1000 kW**					around 500	kW/ha
power production	**1420-1460 MWh/Year**	**1440000**	kWh/(MW*y)	Latitude north Italy		around 710-730	MWh/(ha*
power consumption	**auxiliaries**	**20000**	kWh/(MW*y)	1.3889%		10000	kWh/(ha*y
	sun tracking	**4000**	kWh/(MW*y)	0.2778%		2000	kWh/(ha*y
	inverters	**1000**	kWh/(MW*y)	0.0694%		500	kWh/(ha*y
	tot in 25 years	127350000		pieces/MJ	7.85238E-09		

SUB-System	component	material	weight (kg)	transport distance*	mode*	packaging*	comment
support structure	stilts	concrete	not required	nr	nr	nr	
		steel	29,300	Italy	trucking	wooden	
	support structure	steel	29,710	China	shipping	containers	
	horizontal main axes	steel	69,600	China	shipping	containers	
	secondary axes	steel	79,280	China	shipping	containers	
		alluminium	11,800	China	shipping	containers	
PV modules	number of cells	1920/tracker					60 celle 156*156=1.460160 m2/pannello
	number of moduls	32/tracker					
	size of panel	1x1.65					
	number of panels	3571.428571					
	panels surface	5214.857143					
auxiliaries	fundations	concrete	13,125	Italy	trucking	nr	
		steel	372	Italy	trucking	nr	
	inverters	Steel,copper,plastic	45	Italy	trucking	nr	
	wiring	copper, rubber	2,950	Italy	trucking	wooden	
	control units	electronic	11	Italy	trucking	cardboard	
sun tracking system	electric motors	Steel,copper,plastic	606	Italy	trucking	cardboard	

sun

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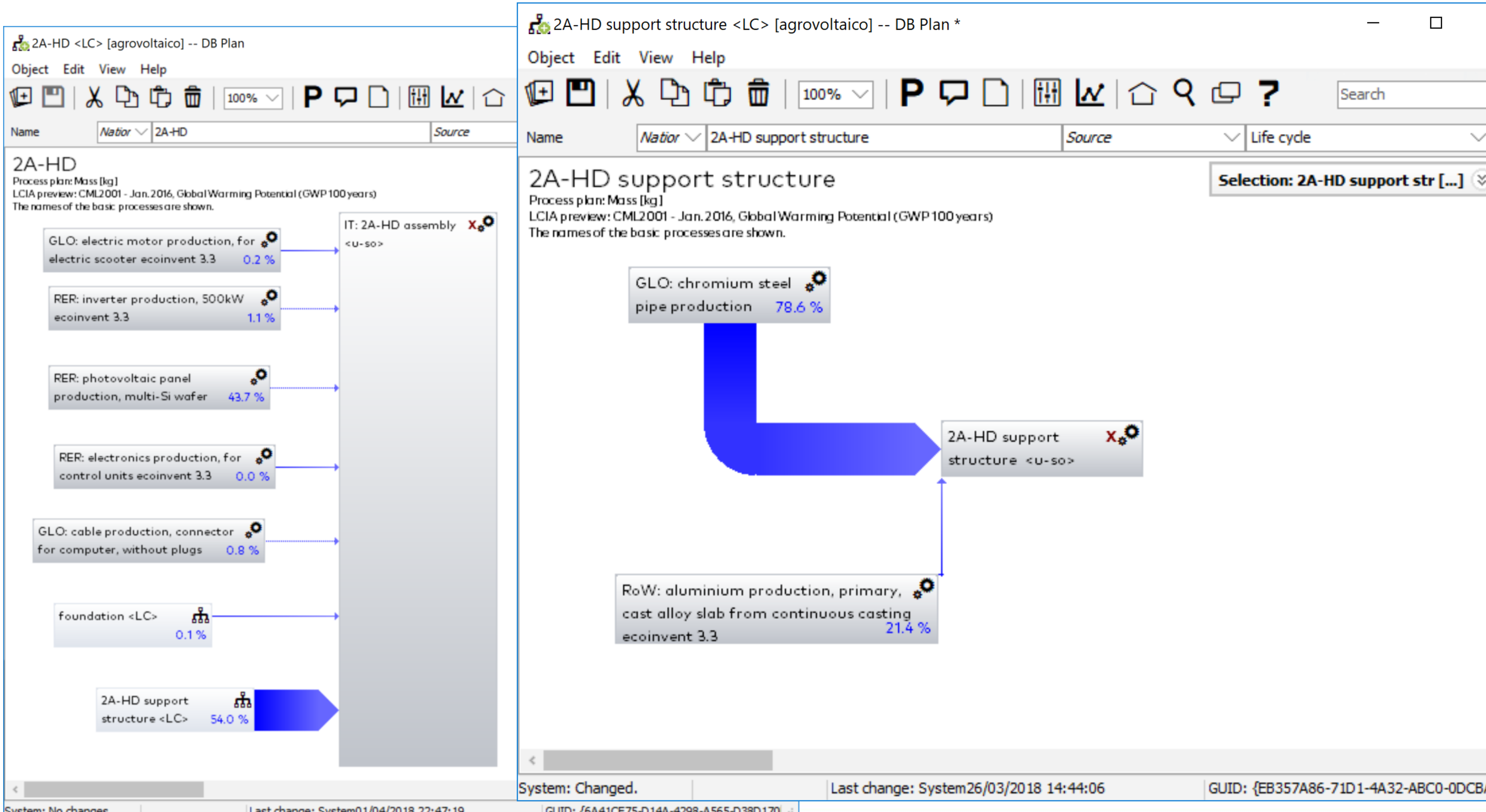
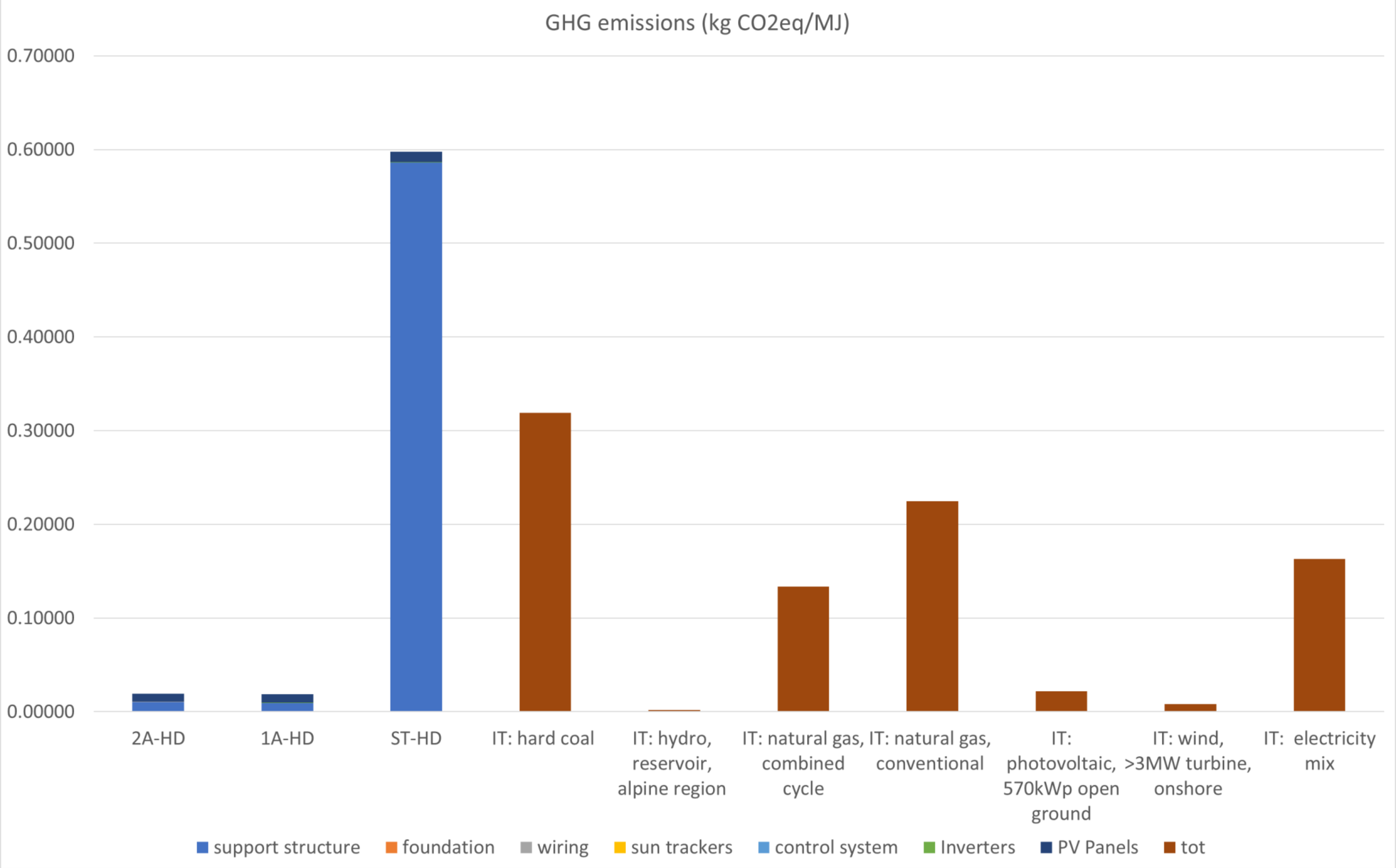
Life Cycle Impact Assessment



Environmental performances of Agrovoltaico systems



Environmental performances of Agrovoltaico systems

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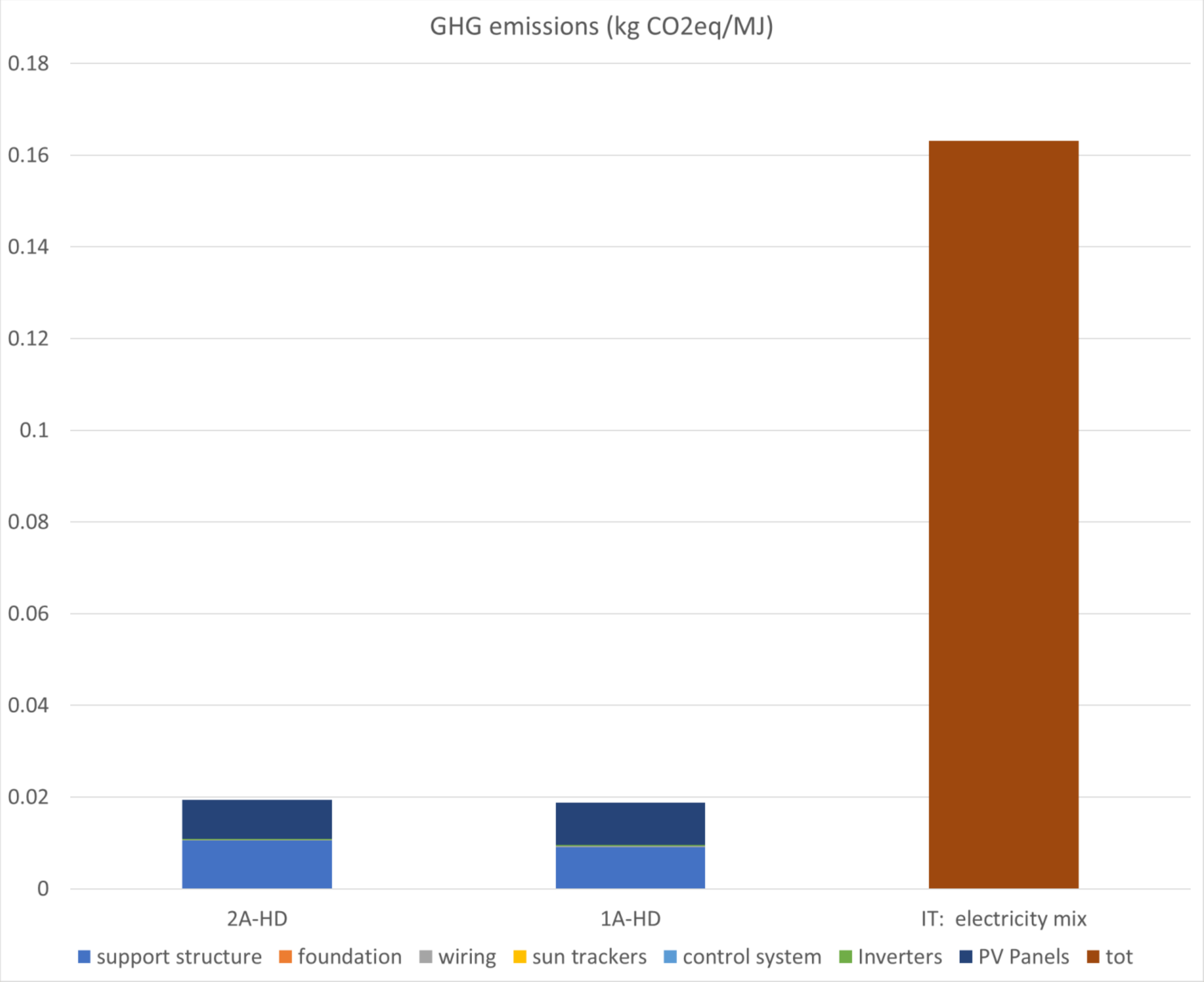
Inventory for static agrofotovolatico systems: high density of PV panels

MAIN DATA					Comment	
installed capacity	**1000 KWp**	around 680	kW/ha			
power production	**1100 MWh/year**	around 760	kWh/(ha*y)		1100000	
power consumption	**auxiliaries**	10000	kWh/(ha*y)		14705.88235	
	sun tracking	0	kWh/(ha*y)		0	
	inverters	500	kWh/(ha*y)		735.2941176	
tot in 25 years	97610294.12		pieces/MJ	1.02448E-08		
SUB-System	**component**	**material**	**weight (kg)**	**tra**		**packaging***
support structure	stilts	concrete	704,000			containers
		steel	693,000			containers
	support structure	steel	176,000			containers
	horizontal main axes	steel	195,360	China	shipping	containers
	secondary axes	steel				
PV modules	number of cells	72/beam				
	number of moduls	13/beam				
	size of panel	1x2 m				
auxiliaries	fundations	concrete	13,125	Italy	trucking	nr
		steel	10,216	Italy	trucking	nr
	inverters	Steel,copper,plastic	45	Italy	trucking	nr
	wiring	copper, rubber	800	Italy	trucking	wooden
	control units	electronic	5	Italy	trucking	cardboard
sun tracking system	electric motors		nr	nr	nr	nr

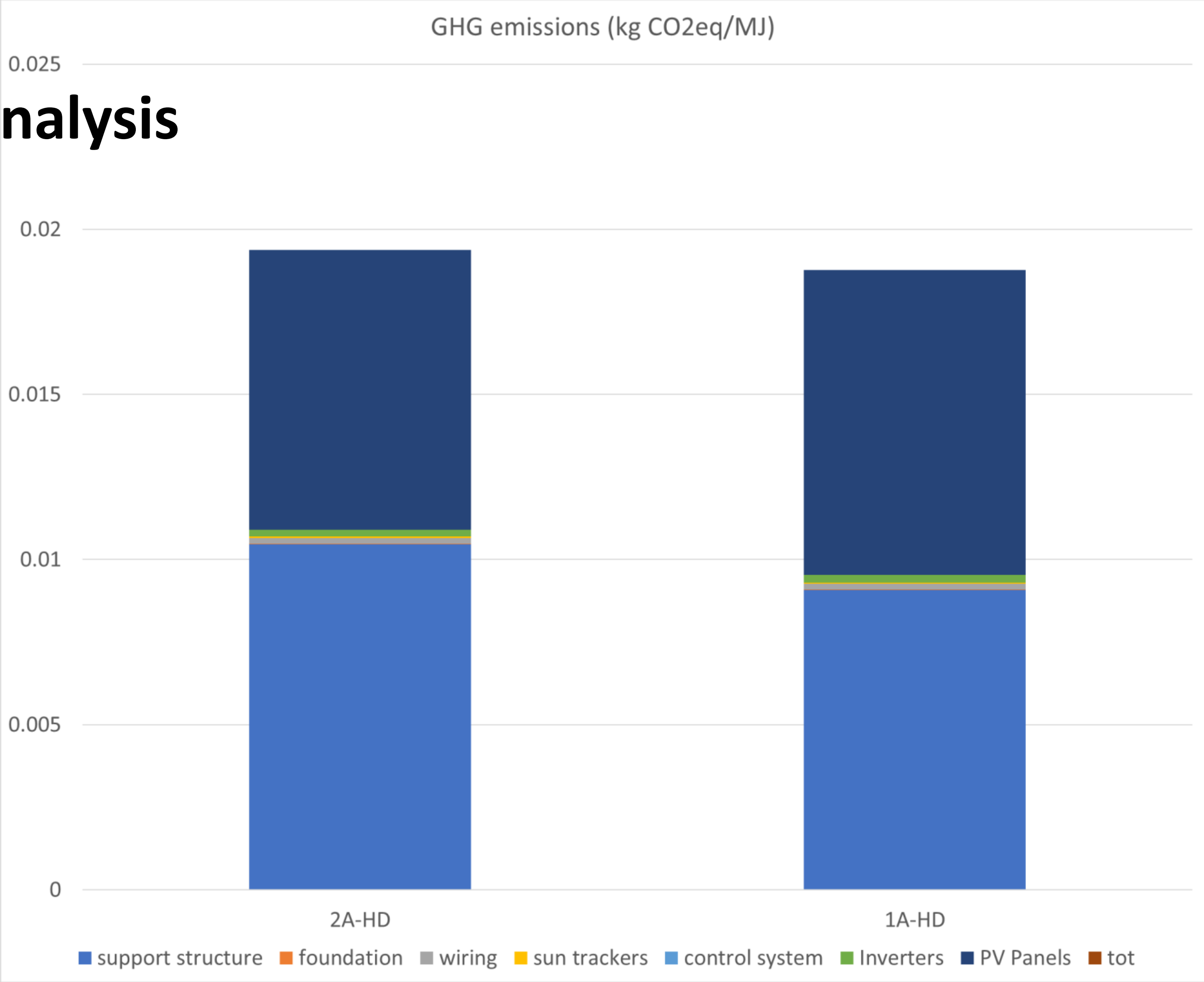
1000 t steel
700 t concrete

Environmental performances of Agrovoltaico systems



Environmental performances of Agrovoltaico systems

Contribution analysis



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Environmental performances of Agrovoltaico systems

Conclusions

- **Agrovoltaico systems can substantially contribute to reduce GHG emissions in comparison to many other sources of electricity**
- **The reduction of the amount of material used for the supporting infrastructure is of paramount importance**
- **The replacement of steel with aluminium is counterproductive**

Limitations

- **Preliminary results**
- **Only GHG emissions are analysed**
- **.**

Environmental performances of Agrovoltaico systems combined with biogas from maize

- GOAL:
- Assessment of the potential environmental impacts of agrovoltaic systems combined with biogas production. Optimisation of the agrovoltaic-biogas environmental performances.

- SCOPE:
- Comparative of 4 agrivoltaico systems resulting from the combination of 2 different sun tracking configurations: biaxial (2A), static (ST), and 2 densities of PV panels (HD, LD). The systems include the production of electricity from anaerobic digestion of maize cultivated under the agrovoltaico systems
- 25 y lifetime
- Potential climate change impact
- Functional unit: 1 MJ electricity
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Environmental performances of Agrovoltaico systems combined with biogas from maize

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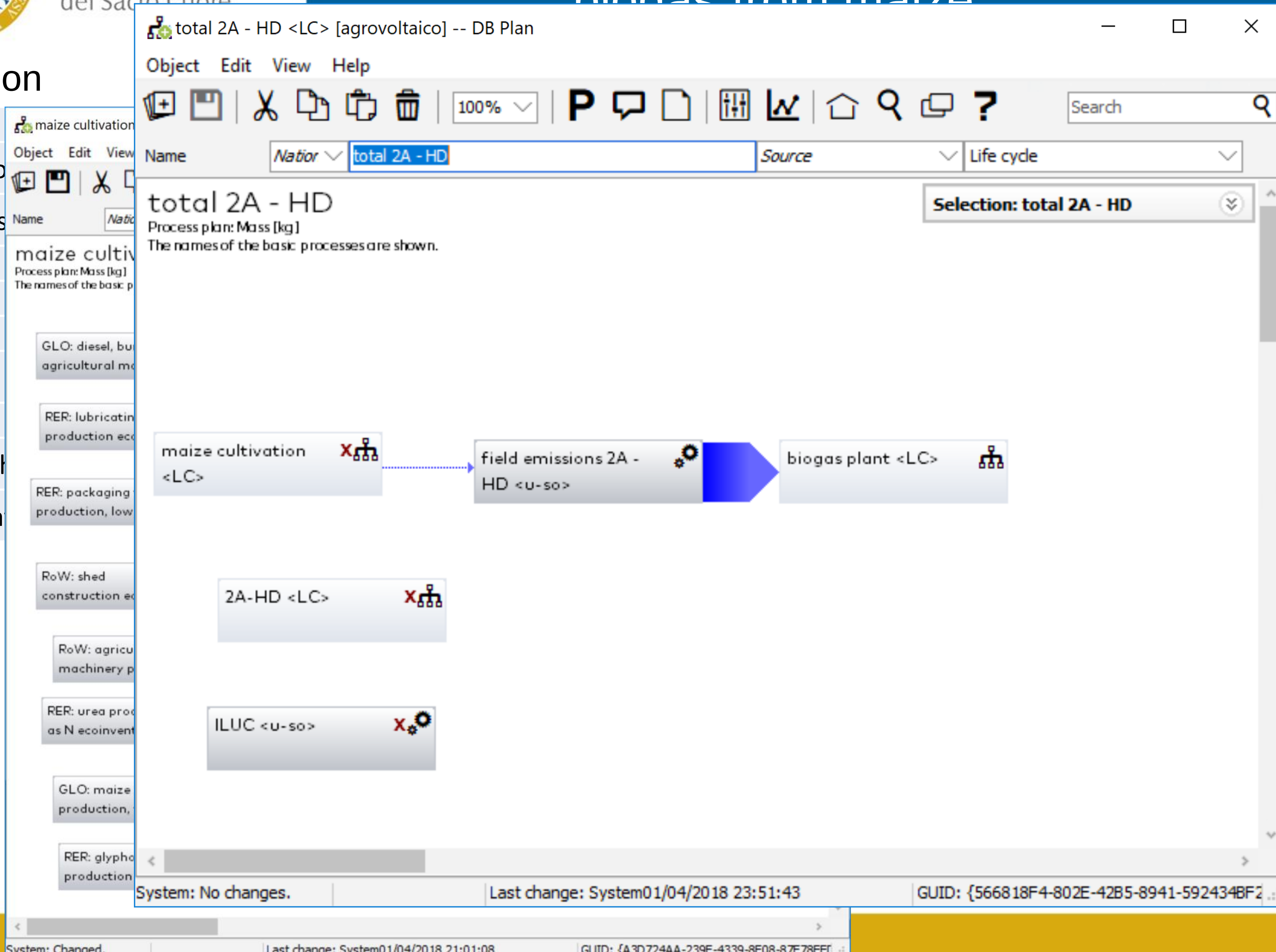
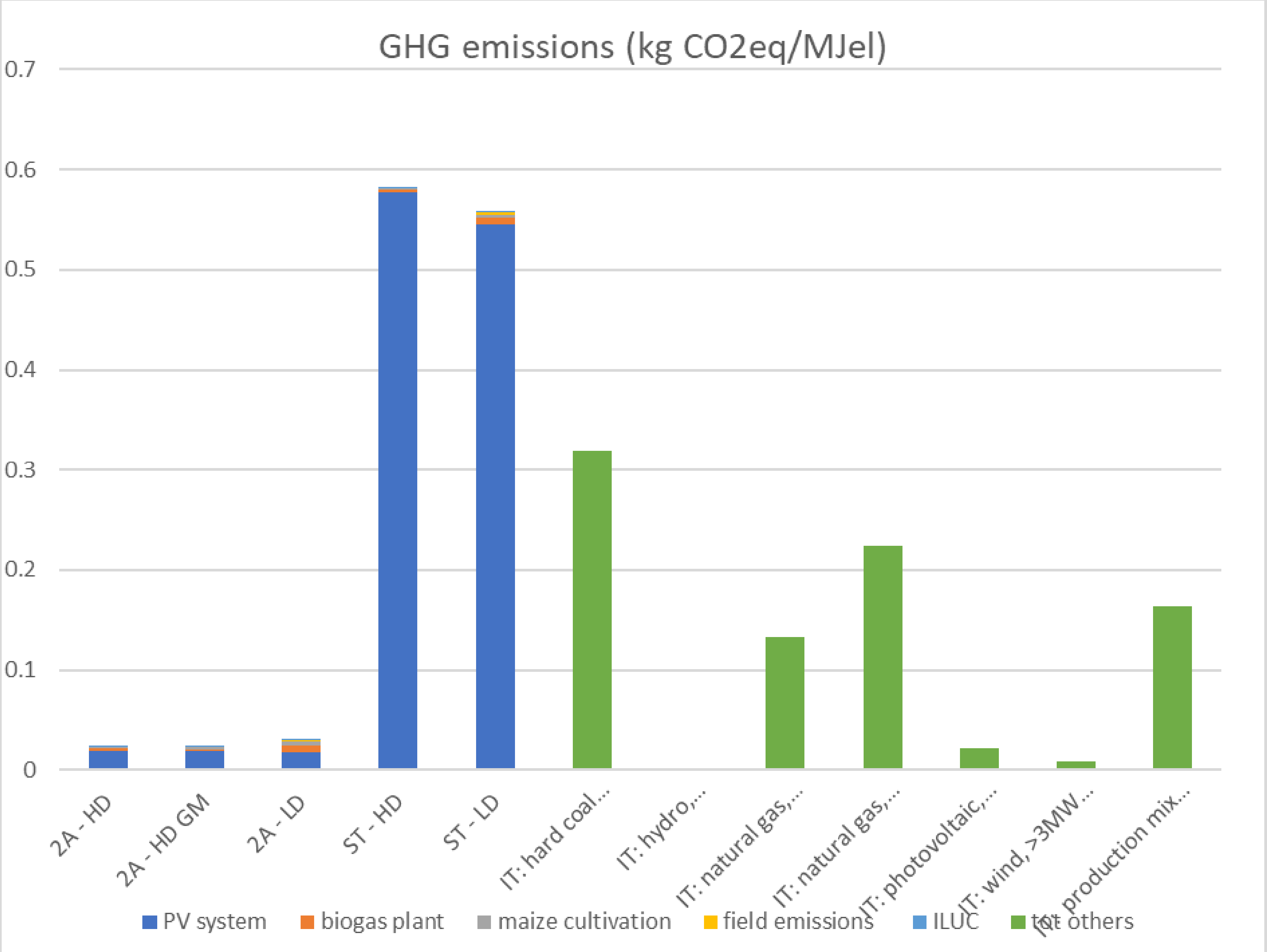
Cultivation

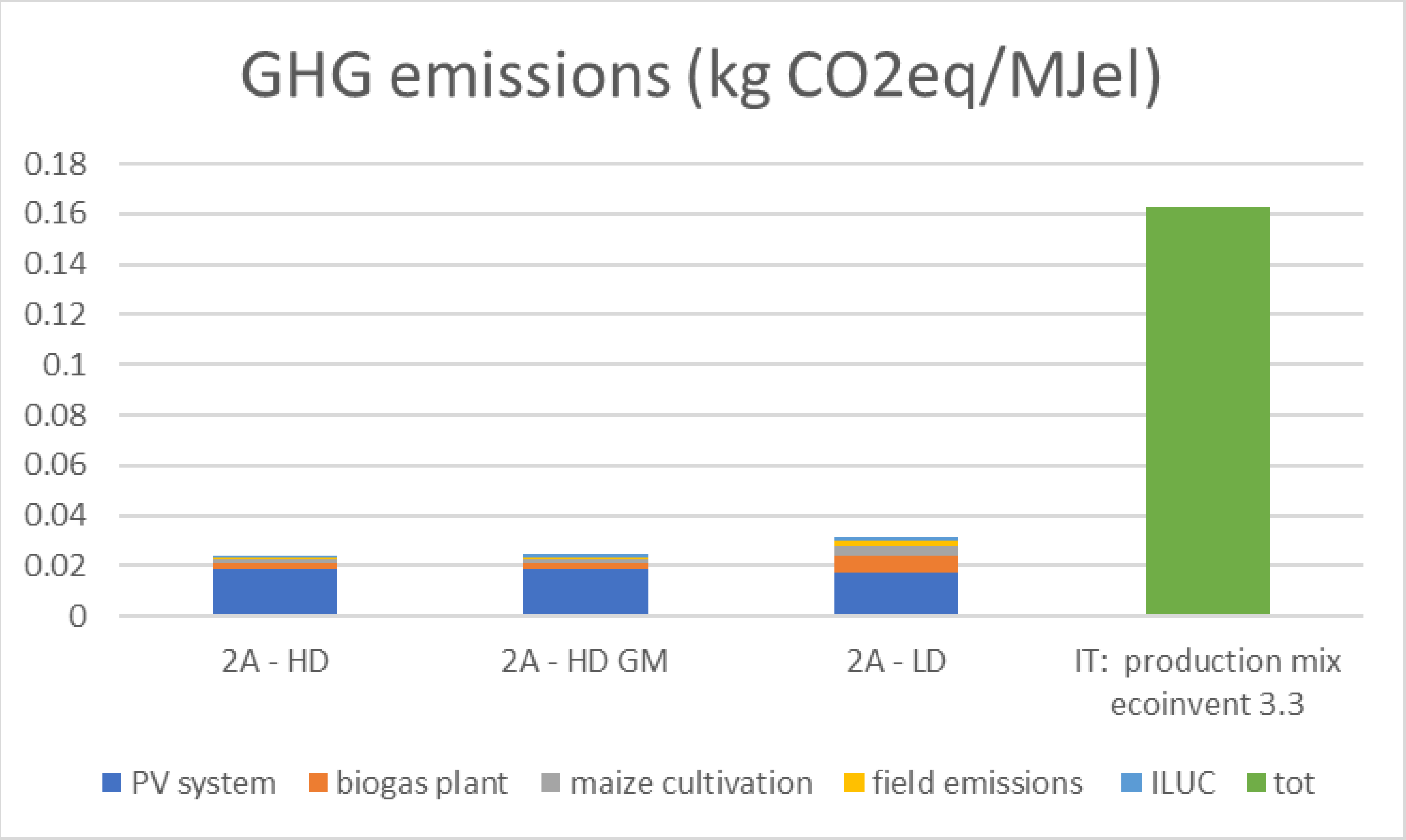
- Diesel
- Lubricating o
- Plastic wraps
- Urea as N
- Seed
- Herbicides
- Insecticides
- Machinery
- Machinery sh
- Irrigation wa





GHG emissions (kg CO2eq/MJel)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2A - HD
2A - HD GM
2A - LD
ST - HD
ST - LD
IT: hard coal...
IT: hydro,...
IT: natural gas,...
IT: natural gas,...
IT: photovoltaic,...
IT: wind, >3MW...
IT: production mix...
PV system
biogas plant
maize cultivation
field emissions
ILUC
tot others

Environmental performances of Agrovoltaico systems combined with biogas from maize



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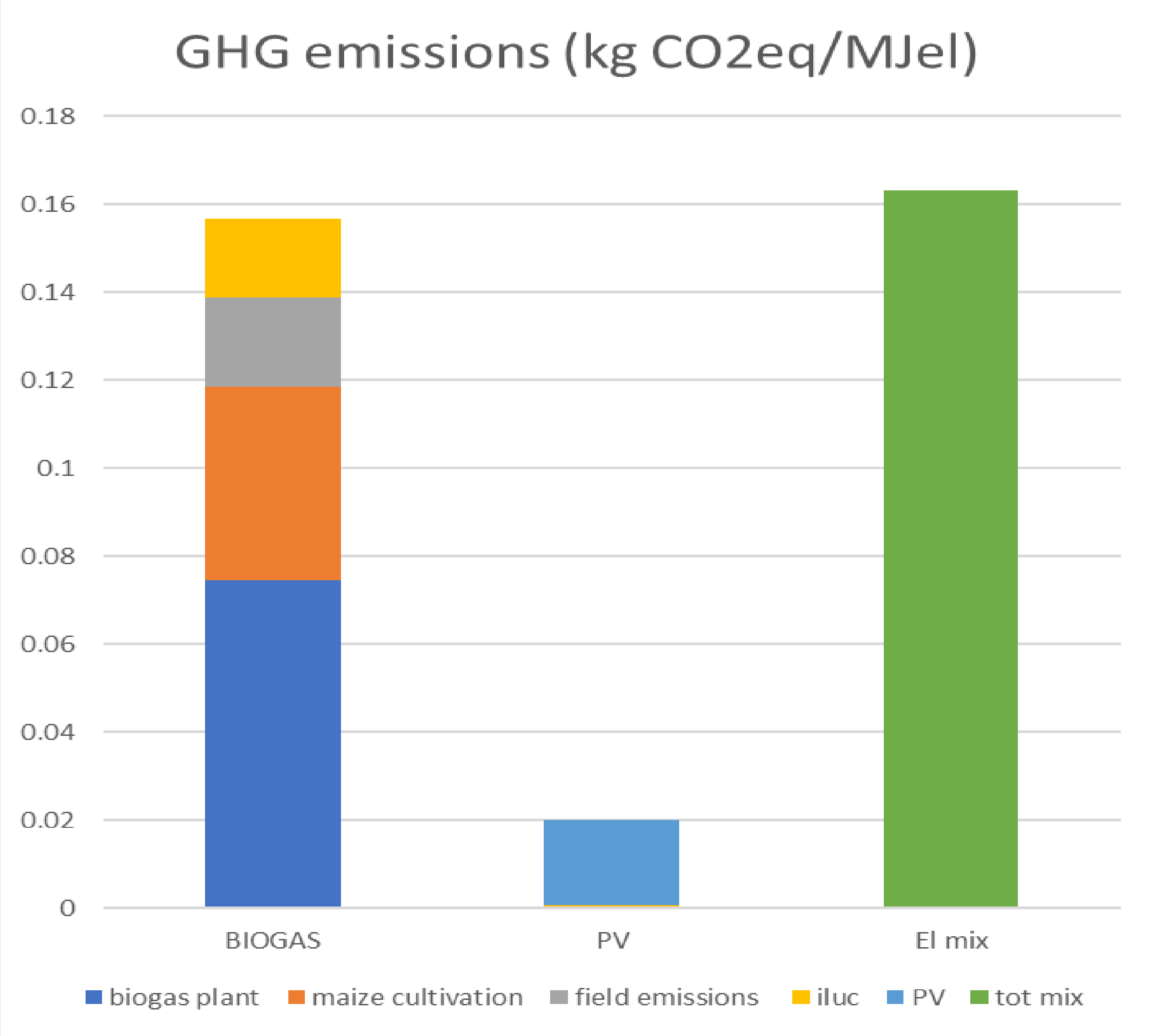

Environmental performances of Agrovoltaico systems combined with biogas from maize

Electricity production per ha

MJ/y*ha	PhotoVoltaic	Biogas	tot	Ratio
2A - LD	919750	88954	1008704	10.34
ST - LD	958750	92654	1051404	10.35
2A - HD	2547000	90655	2637655	28.10
ST - HD	2655000	93675	2748675	28.34
full light	2547000	88485	2635485	28.78

Interpretation, conclusions and future work

Conclusions

- **As mentioned:**
  - **Agrovoltaico systems can substantially contribute to reduce GHG emissions in comparison to many other sources of electricity;**
  - **The reduction of the amount of material used for the supporting infrastructure is of paramount importance;**
  - **The replacement of steel with aluminium is counterproductive**
- **Higher productivity in case of water stress -> resilience to climate change**
- **The production of electricity from anaerobic digestion of energy crops is in any case to be avoided: it generates higher GHG emissions, occupies much more land (almost 30 times more), emits more other pollutants.**

Limitations

- **Only GHG emissions are analysed**
- **Preliminary results**

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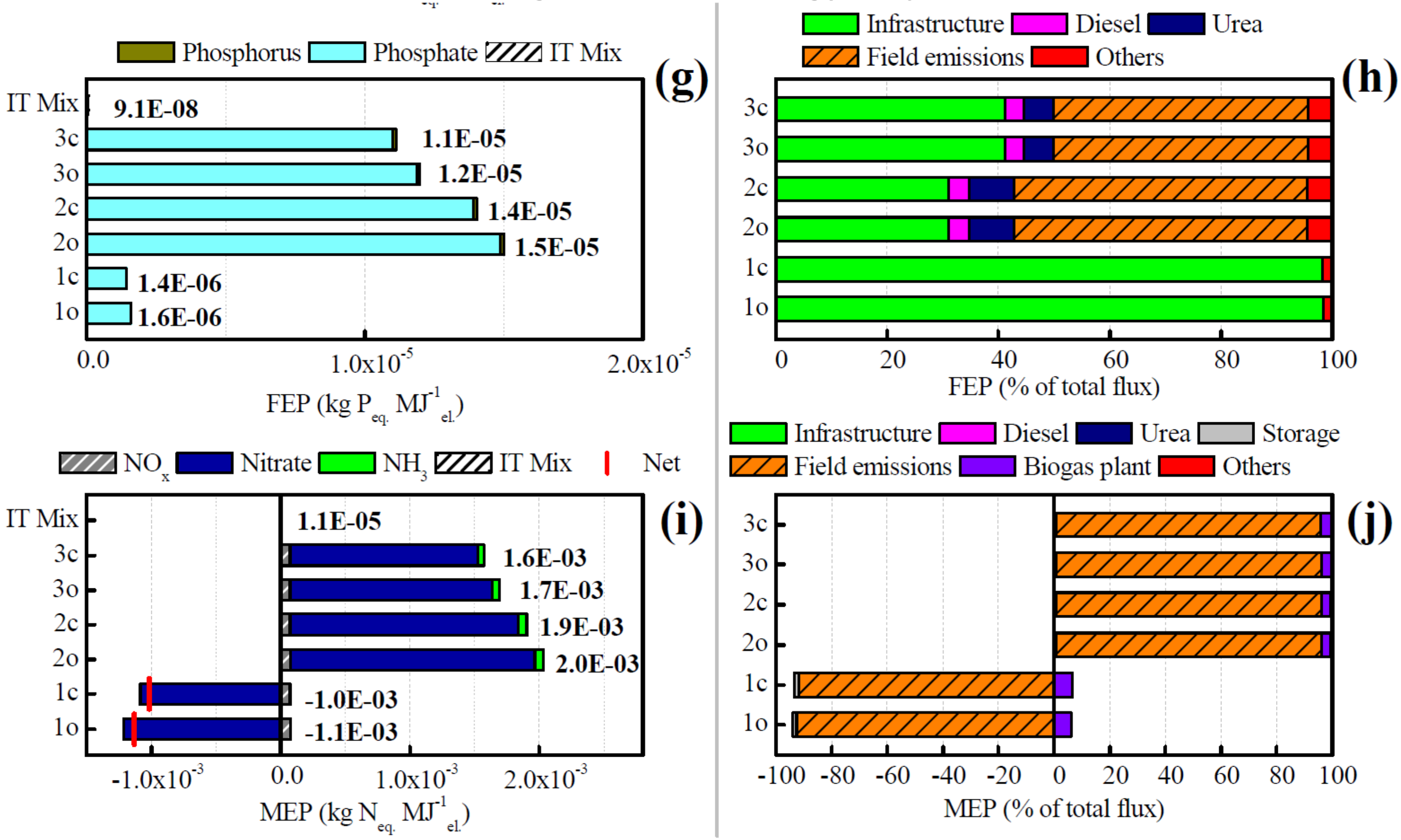
Interpretation, conclusions and future work

Future work: additional environmental impacts

Agostini et al. 2015 Environmentally Sustainable Biogas? The Key Role of Manure Co-Digestion with Energy Crops



Interpretation, conclusions and future work

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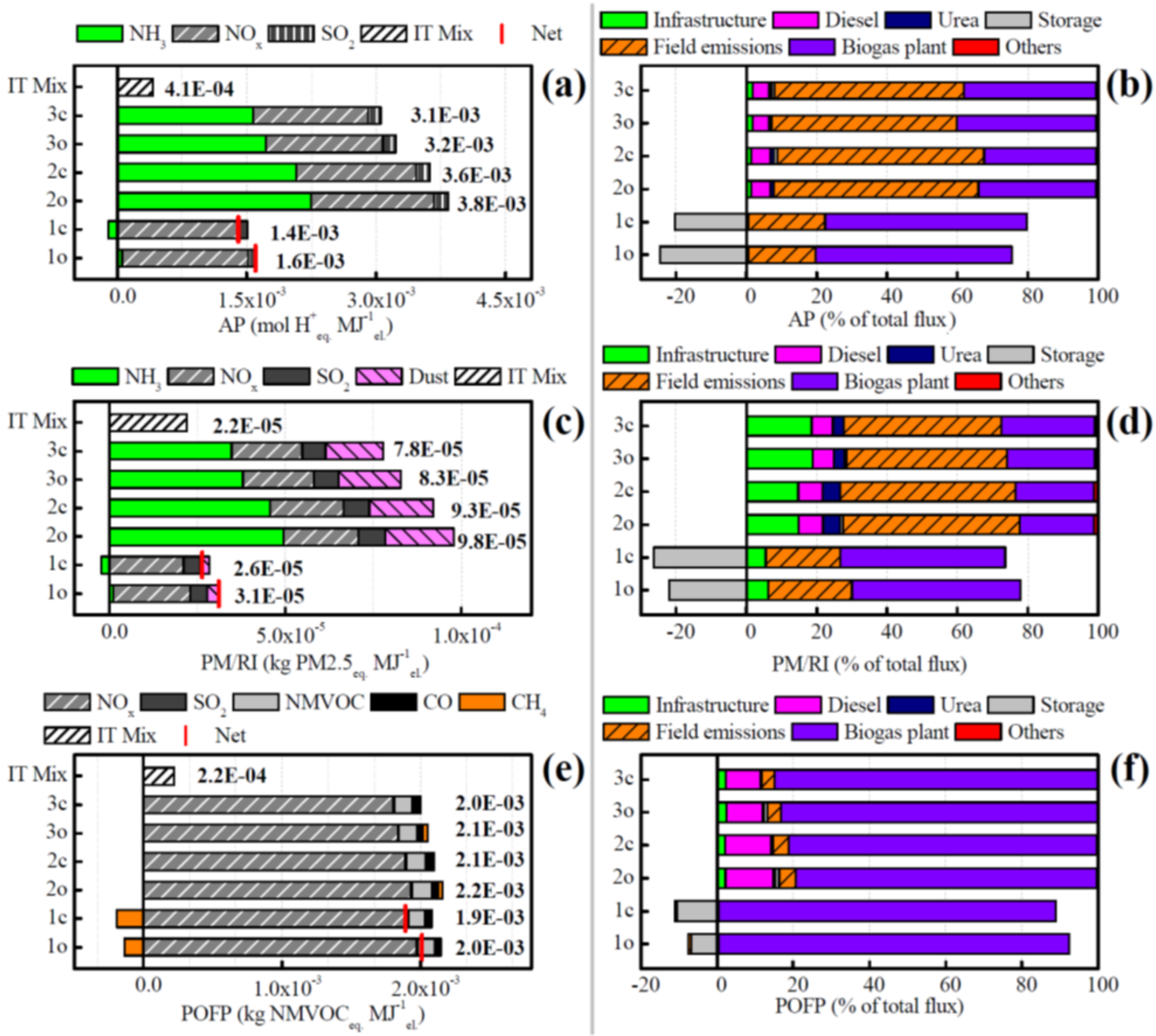
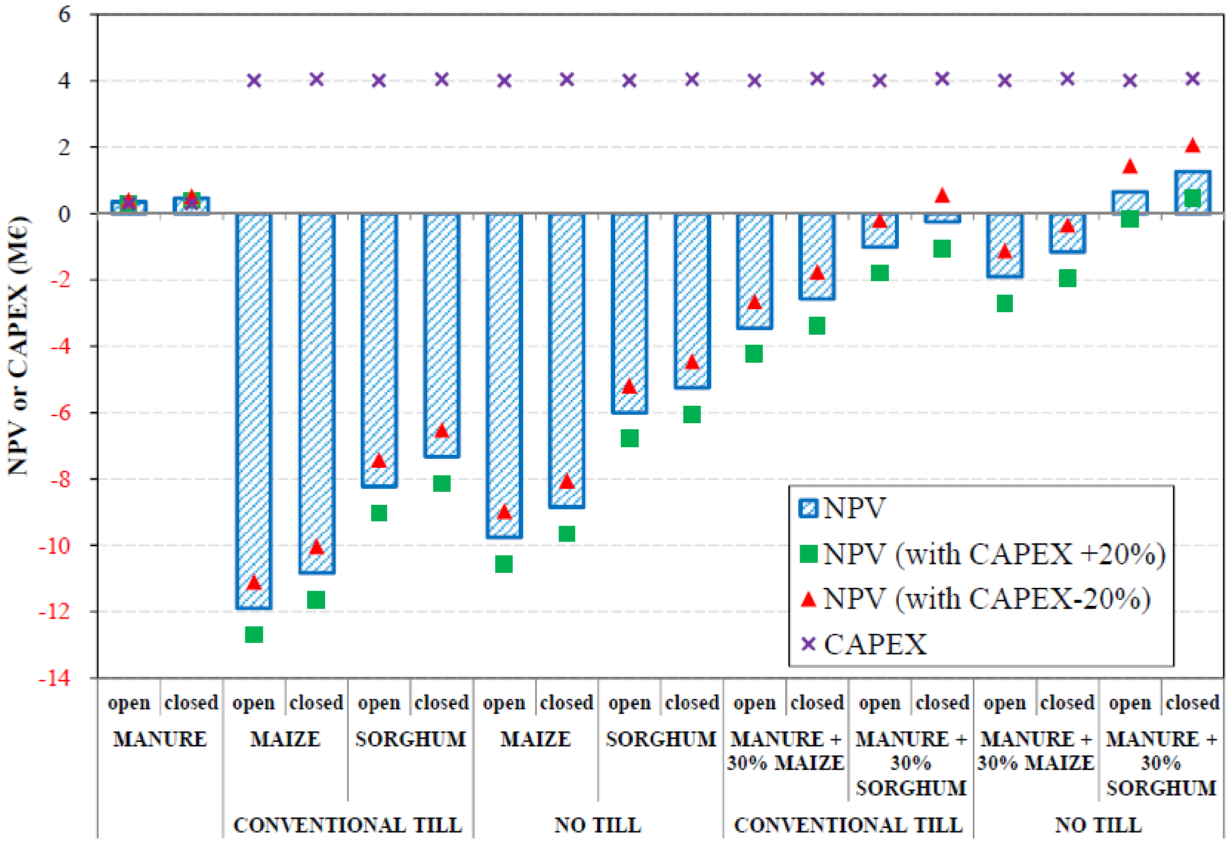


Interpretation, conclusions and future work

Future work: economic analysis

Agostini et al.
Economics of GHG emissions mitigation via biogas production from Sorghum, maize and dairy farm manure digestion in the Po valley



Future work: integration of smart PV in power grids

Thanks you for your attention

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