Impronta carbonica dei sistemi agricoli:

Dalla gestione del suolo alla produzione di biogas

Alessandro Agostini – ENEA

Piacenza, 20 Gennaio 2020

UCSC Field Crops Group

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

UNIVERSITÀ CATTOLICA del Sacro Cuore

CABIOS – Agricoltura conservativa e fasce tampone bioenergetiche

Lunedì 20 gennaio 2020 – Ore 9:45

Aula Piana – Università Cattolica del Sacro Cuore

Via Emilia Parmense, 84 - 29100 Piacenza

Il progetto Cabios - Conservation Agriculture and BIOenergy buffer Strips for water and soil quality improvement (Implementazione di tecniche di agricoltura conservativa e fasce tampone bioenergetiche per il miglioramento della qualità dell'acqua e del suolo) aveva lo scopo di monitorare l'efficienza agro-ambientale di un pacchetto innovativo di pratiche proprie dell'agricoltura conservativa abbinato all'irrigazione con ala gocciolante interrata (SDI) e alla realizzazione di fasce tampone bioenergetiche lungo i margini dei campi. Gli indicatori misurati hanno permesso di quantificare l'impronta carbonica delle varie pratiche e la riduzione del rilascio di sostanze inquinanti insieme al miglioramento della qualità delle acque e del suolo.

Le attività di progetto sono state realizzate in 4 aziende tra loro consorziate per la produzione di biogas e partner del Gruppo Operativo Cabios.

I principali risultati vengono presentati in occasione di questo convegno conclusivo.

PARTNER

Il progetto, coordinato dal Dipartimento di Scienze delle Produzioni Vegetali Sostenibili (DI.PRO.VES) dell'Università Cattolica del Sacro Cuore di Piacenza, è realizzato in collaborazione con la Società agricola Colombarone di Paraboschi e Carini, l'Azienda Agricola Eridano di Zermani F.lli S.S., l'Azienda Agricola Serena Tranquillo, l'Azienda Agricola Rossi Giorgio e Rossi Maurizio e il Centro Ricerche Produzioni Animali – CRPA SpA.

PROGRAMMA

09:45 Registrazione partecipanti

10:00 Il progetto CABIOS
Stefano Amaducci – *UCSC sede di Piacenza*

10:15 Efficienza agroambientale fasce tampone e agricoltura conservativa
Andrea Ferrarini - *UCSC sede di Piacenza*

10:45 La subirrigazione: un'alleata in agricoltura da reddito?
Sabrina Rossi – *Consorzio Agrario Terrepadane*

11:15 Impronta carbonica dei sistemi agricoli (dalla gestione del suolo alla produzione di biogas)
Alessandro Agostini – *ENEA*

11:45 Il futuro dei Gruppi Operativi per l'Innovazione
Stefano Nannetti – *Regione Emilia-Romagna*

12:00 Conclusione dei lavori e buffet

UCSC Field Crops Group

Partecipazione libera, previa **registrazione**.

Seguici su **http://cabios.crpa.it**

PARTICIPATING IN eip-agri

Programma di Sviluppo Rurale dell'Emilia-Romagna 2014-2020

UNIONE EUROPEA – RegioneEmiliaRomagna – L'Europa investe nelle zone rurali

Divulgazione a cura di C.R.P.A. S.p.a. - Autorità di Gestione: Direzione Agricoltura, caccia e pesca della Regione Emilia-Romagna Iniziativa realizzata nell'ambito del Programma regionale di sviluppo rurale 2014-2020 - Tipo di operazione 16.1.01 - Gruppi operativi del partenariato europeo per l'innovazione: "Produttività e sostenibilità dell'agricoltura" - Focus Area 4B – Qualità delle acque - Progetto "Implementazione di tecniche di agricoltura conservativa e fasce tampone bioenergetiche per il miglioramento della qualità dell'acqua e del suolo".

Informazioni e segreteria

CRPA

Centro Ricerche Produzioni Animali - CRPA SpA.
Andrea Poluzzi, a.poluzzi@crpa.it, Tel. 0522 436999

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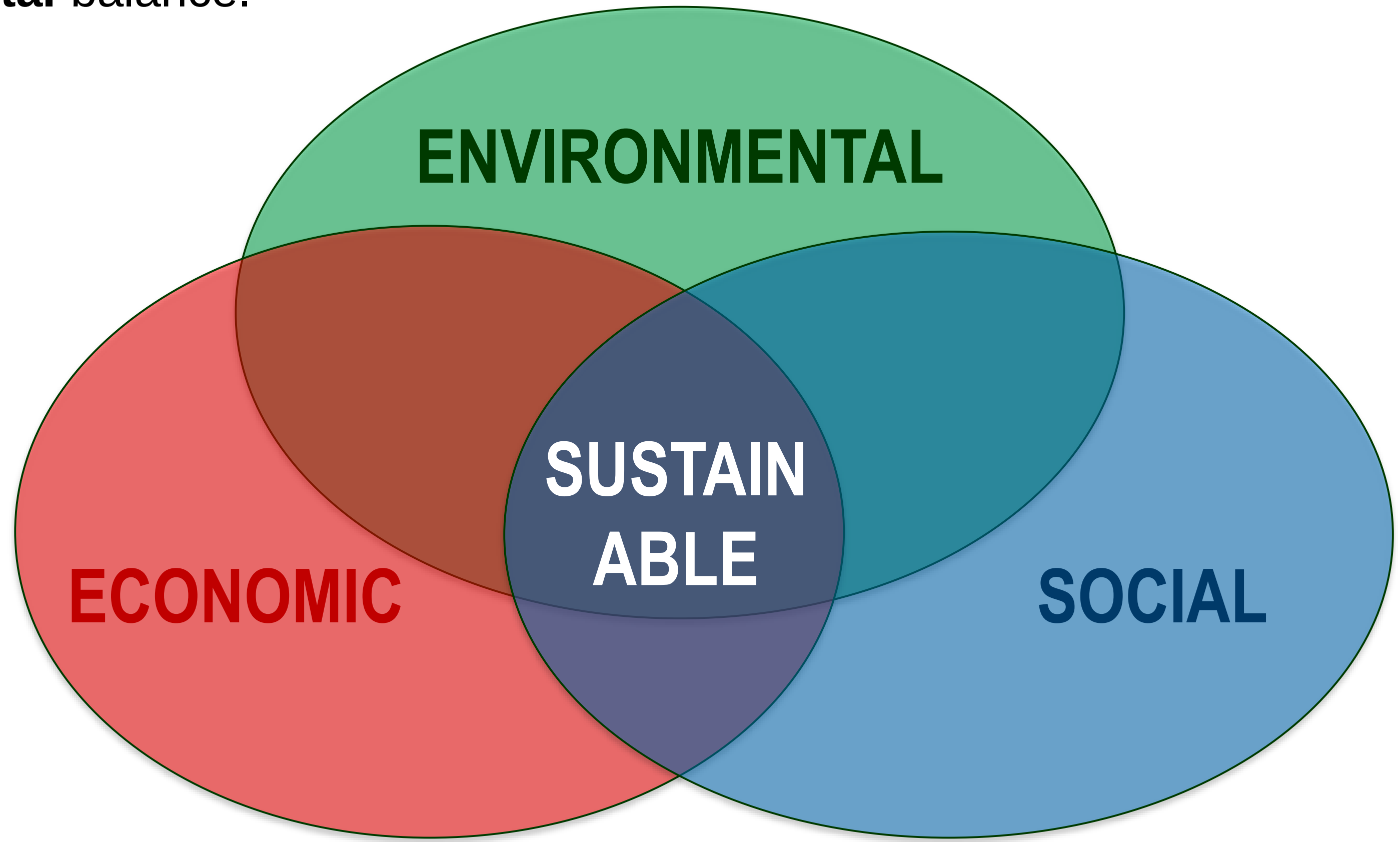
Sommario

1. *Sostenibilità e LCA*
2. *Le fasce tampone*
3. *L'agricoltura conservativa, la sub-irrigazione e il biogas*
4. *Il biogas: analisi economica*
5. *Conclusioni*

Sustainability: definition

Sustainable development: ‘development that meets the needs of the present without compromising the ability of future generations to meet their own needs’.
It seeks to reconcile **economic** development with the protection of **social** and **environmental** balance.



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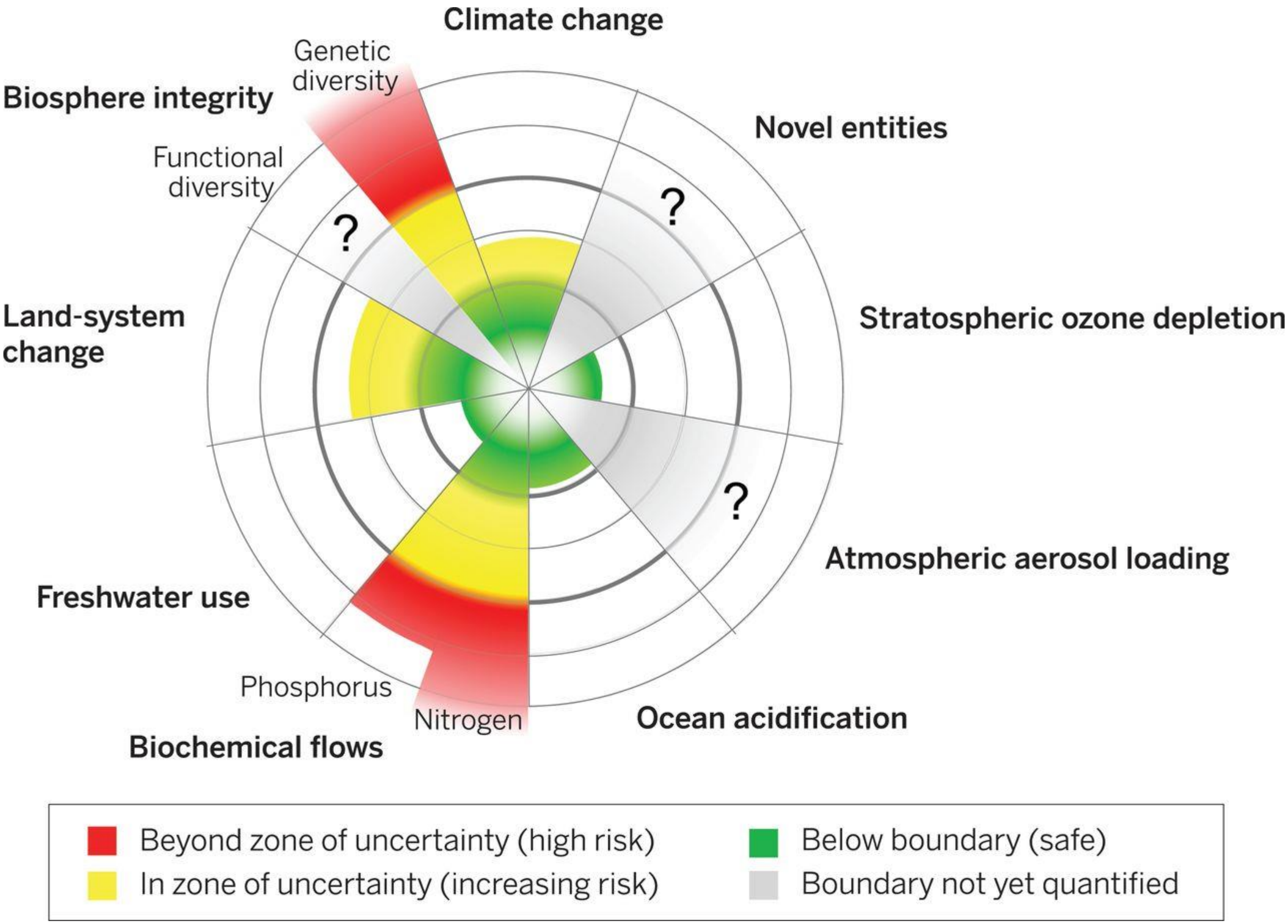
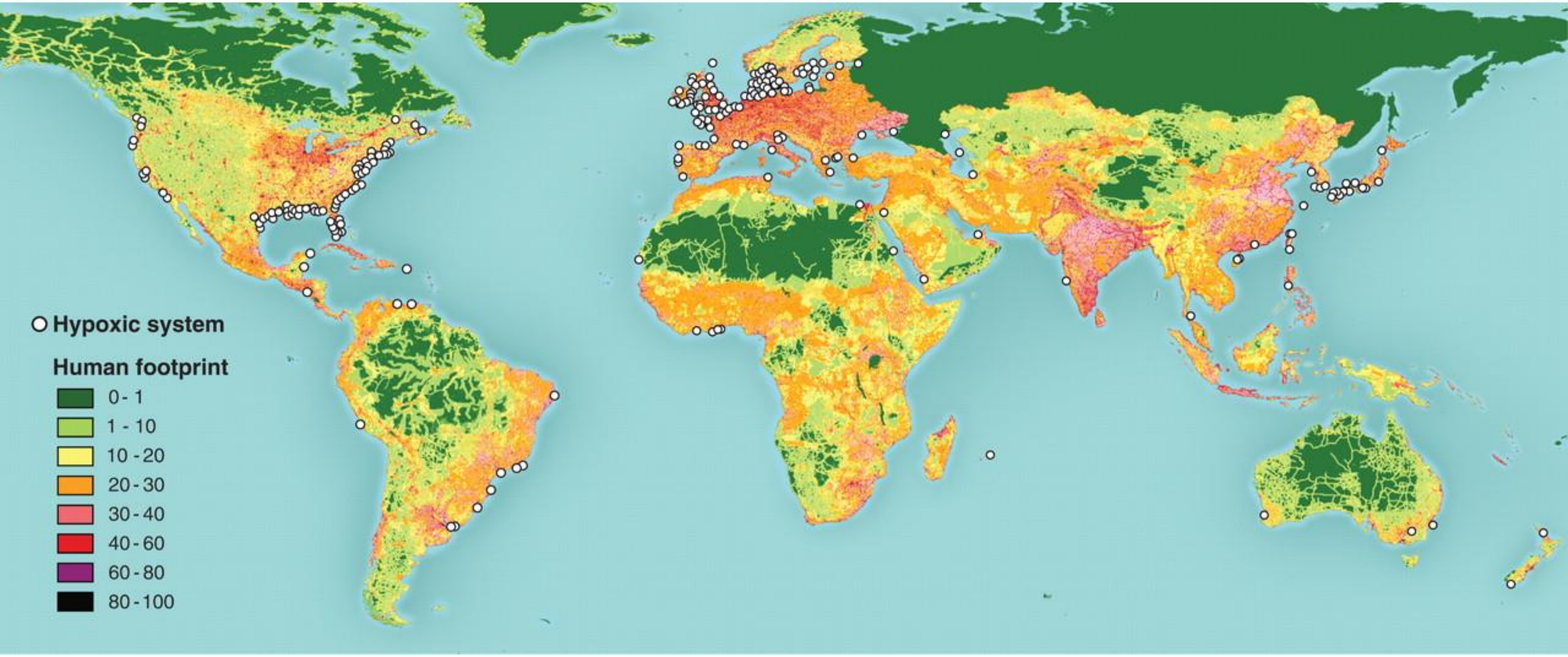
Planet boundaries concept



Eutrophication



Global distribution of 400-plus systems that have scientifically reported accounts of being eutrophication-associated dead zones.

Air quality

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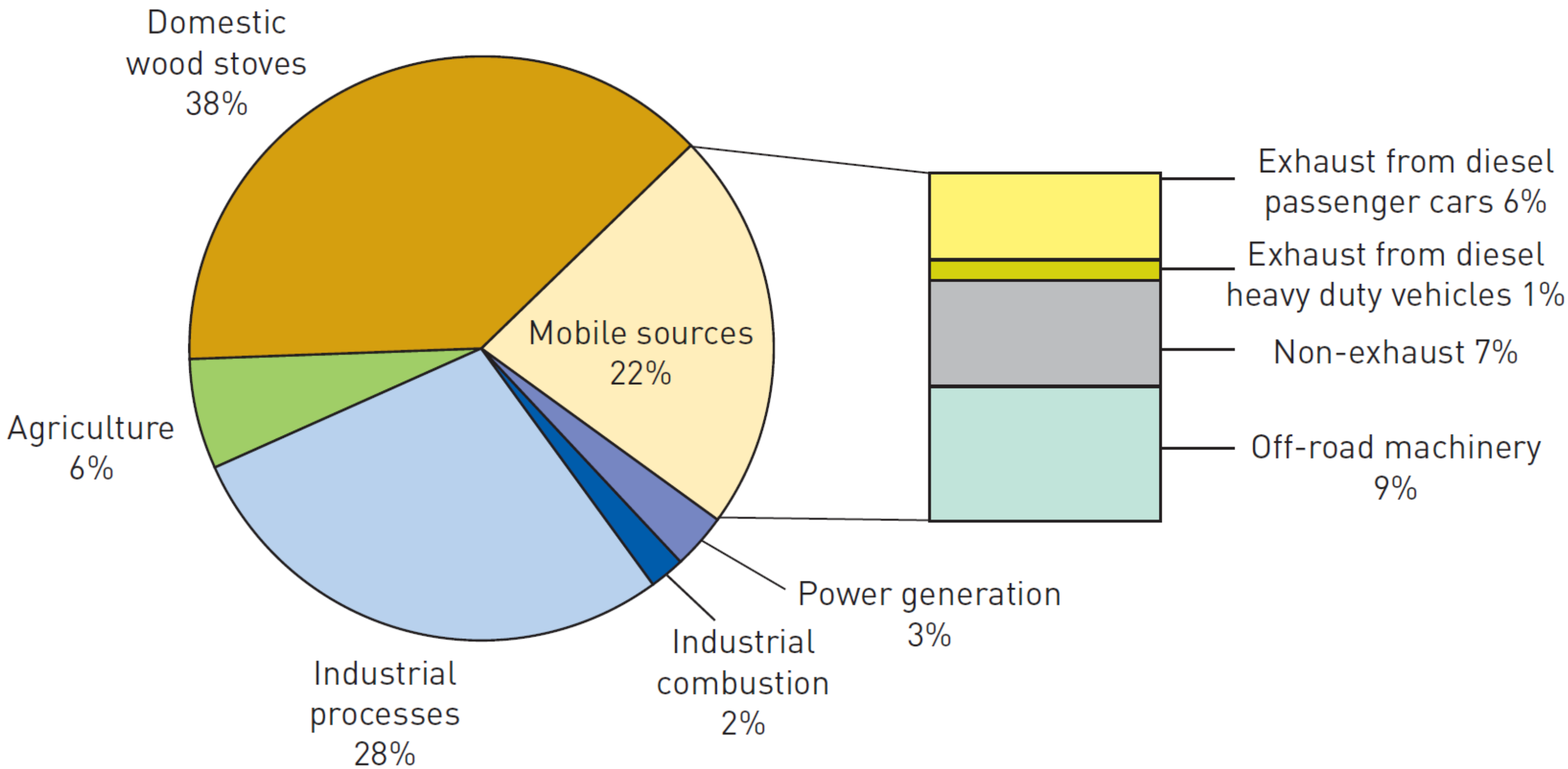

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EEA's 2019 EU air

MyERS

Membership

Publications

e-learning

ERS Vision

Healthy Lungs For Life

25 October, 2019

Europe's air is getting cleaner, but persistent pollution, especially in cities, is continuing to damage people's health. The latest reports are based on the European Environment Agency's (EEA) newest analysis on air quality, which shows that exposure to air pollution caused approximately 400,000 premature deaths in the European Union (EU) in 2016.

The EEA's Air quality in Europe – 2019 report includes the latest official air quality data from more than 4,000 monitoring stations across Europe in 2017. The analysis showed that poor air quality continues to damage Europeans' health, especially in urban areas, with particulate matter (PM), nitrogen dioxide (NO_2) and ground-level ozone (O_3) causing the biggest harm.

According to the EEA analysis, fine particulate matter ($PM_{2.5}$) alone caused around 412,000 premature deaths in 41 European countries in 2016. Approximately 374,000 of those deaths occurred in the EU.

Despite persisting pollution, the EEA data confirms that regulations and local measures intended to reduce air pollution across the EU are improving Europe's air quality with positive health effects. For example, the EEA reports that fine particulate matter caused about 17,000 fewer premature deaths in the EU in 2016, compared with 2015.

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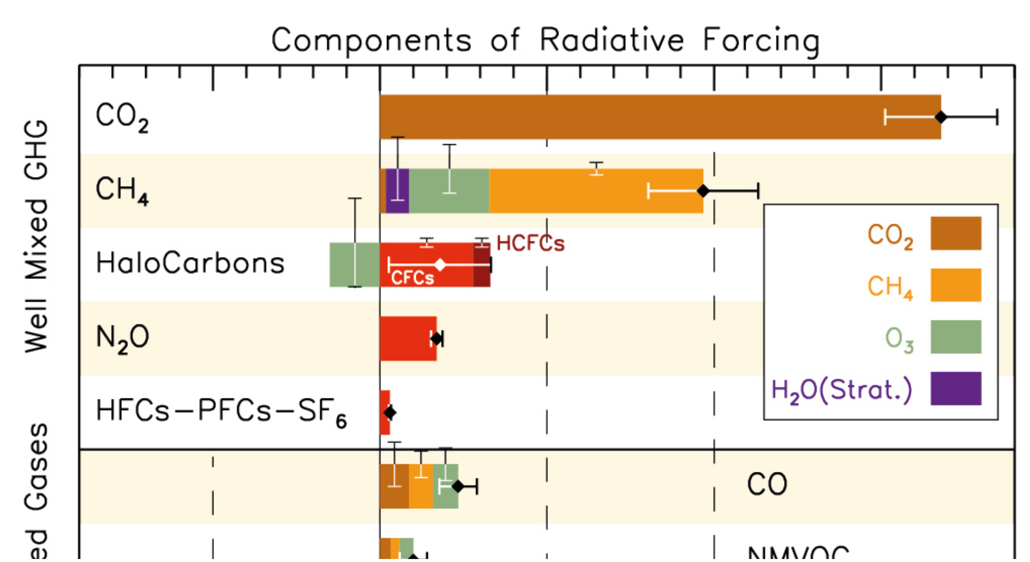

Table 8.7 | GWP and GTP with and without inclusion of climate–carbon feedbacks (cc fb) in response to emissions of the indicated non-CO_2 gases (climate-carbon feedbacks in response to the reference gas CO_2 are always included).

	Lifetime (years)		GWP_{20}	GWP_{100}	GTP_{20}	GTP_{100}
CH_4[b]	12.4[a]	No cc fb	84	28	67	4
		With cc fb	86	34	70	11
HFC-134a	13.4	No cc fb	3710	1300	3050	201
		With cc fb	3790	1550	3170	530
CFC-11	45.0	No cc fb	6900	4660	6890	2340
		With cc fb	7020	5350	7080	3490
N_2O	121.0[a]	No cc fb	264	265	277	234
		With cc fb	268	298	284	297
CF_4	50,000.0	No cc fb	4880	6630	5270	8040
		With cc fb	4950	7350	5400	9560

Notes:

Uncertainties related to the climate–carbon feedback are large, comparable in magnitude to the strength of the feedback for a single gas.

[a] Perturbation lifetime is used in the calculation of metrics.

[b] These values do not include CO_2 from methane oxidation. Values for fossil methane are higher by 1 and 2 for the 20 and 100 year metrics, respectively (Table 8.A.1).

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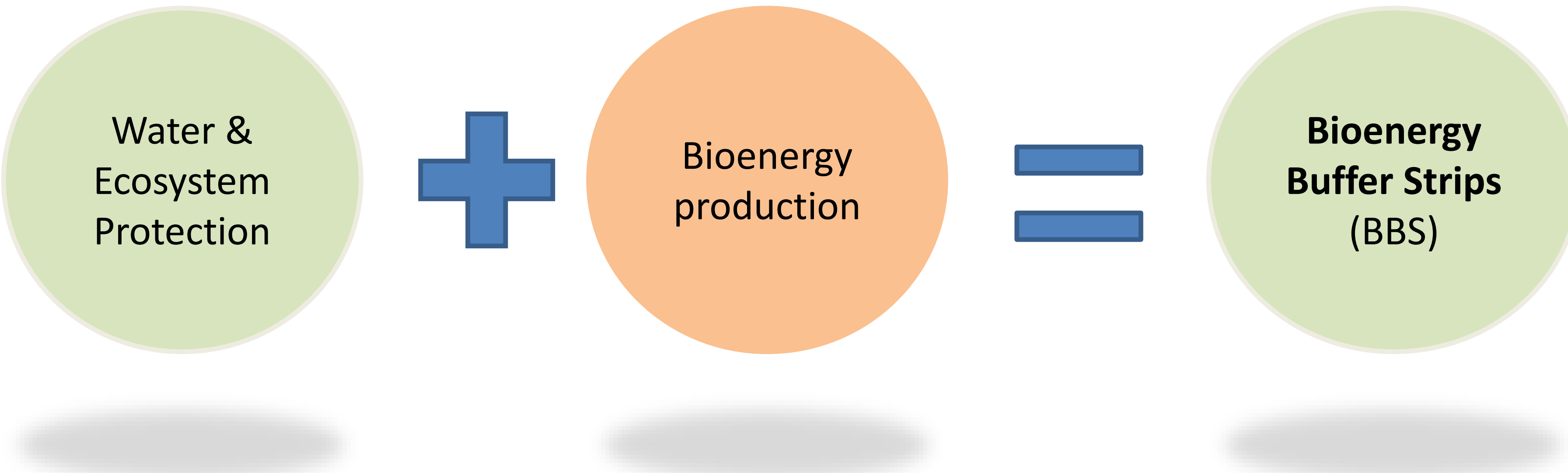
L’innovazione in CABIOS

Plant Soil Water

Il Gruppo Operativo CABIOS si propone di integrare le tecniche di **agricoltura conservativa** combinandole con la distribuzione del **digestato**, con un sistema di **irrigazione sotterranea** e con la realizzazione di **fasce tampone** bioenergetiche lungo i margini dei campi

Introduction: context

- **Water:** The EU Water Framework Directive [1] has set specific guidelines for the protection and improvement of water quality in EU: in Italy, the realization of buffer strips along watercourses is mandatory[2]
- **Bioenergy:** EU Renewable Energy Directive[3]: Renewable Energy Targets: sustainability criteria and GHG saving thresholds



Biofuels from perennial energy crops on buffer strips: a win-win strategy.

Authors: A. Agostini[1, 2], P. Serra[2], J. Giuntoli[3], A. Ferrarini[2], S. Amaducci[2]

1) ENEA–Italian National Agency for New Technologies, Energy and the Environment, Via Anguillarese 301, Rome, Italy
2) Department of Sustainable Crop Production, Università Cattolica del Sacro Cuore, 29122 Piacenza, Italy
3) Independent researcher, Montecatini Terme, Italy

Perennial crops

Two perennial crops were chosen:

- Miscanthus (*Miscanthus x giganteus* Greef et Deuter)

Lifespan 20 y (Iqbal *et al.*, 2015)

- Willow (*Salix spp* L.) managed in SRCs

Lifespan 20 y (Kryzaniak *et al*., 2016)

Systems compared:

Miscanthus in buffer strips	(M BBS)
Miscanthus in open field	(M OF)
Miscanthus in buffer strips with border effect	(M BBS BE)
Willow in buffer strips	(M BBS)
Willow in open field	(M OF)
Willow in buffer strips with border effect	(M BBS BE)
Battery Electric Vehicles running on the IT electricity mix	(BEV)
Battery Electric Vehicles running on renewable electricity	(BEV REN)
Conventional ICE vehicle running on fossil gasoline	(GAS)

Impact categories analysed

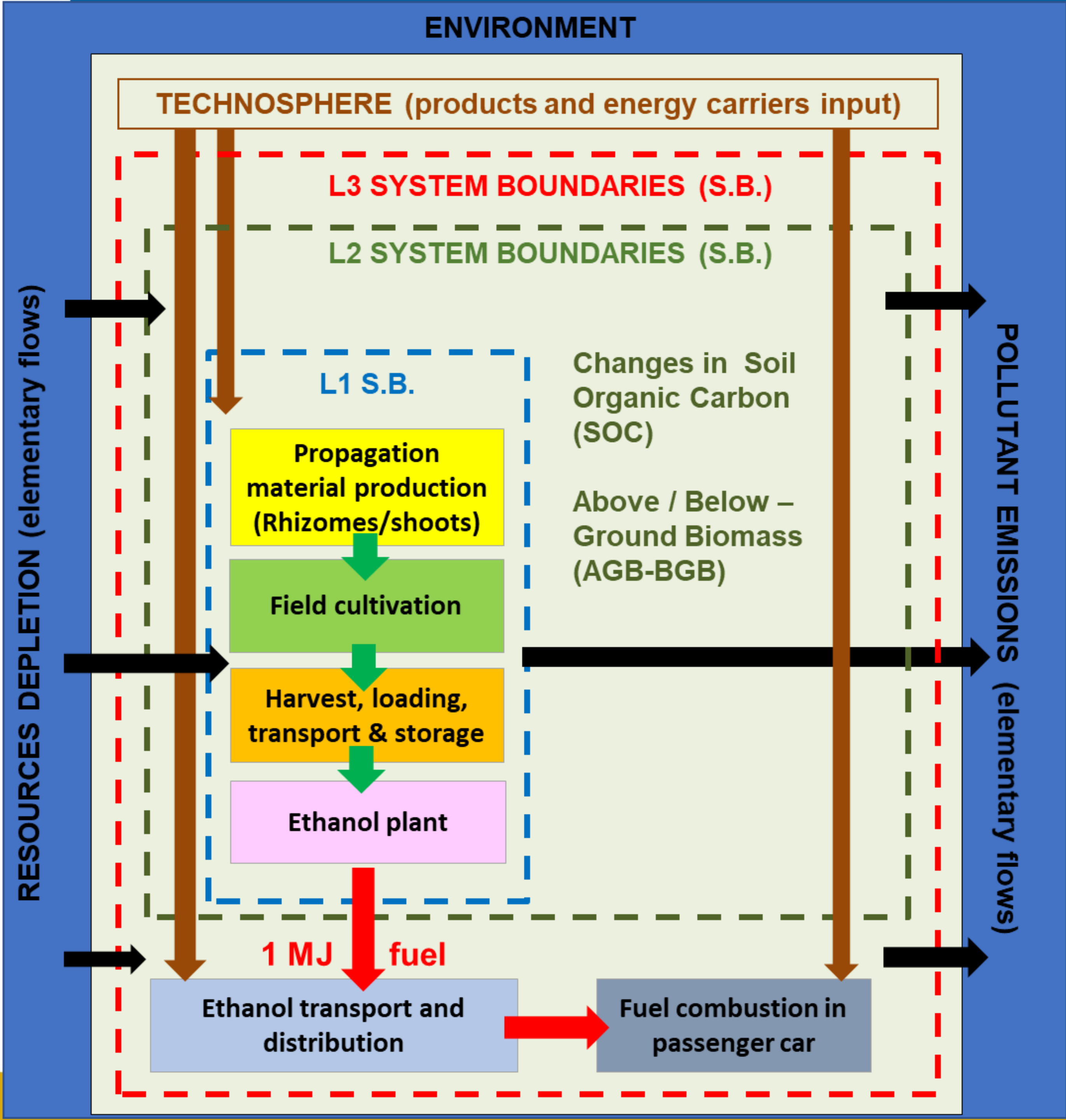
- Climate change
- Acidification
- Freshwater and Marine eutrophication
- Respiratory inorganic
- Photochemical ozone formation
- Resources use, mineral and metals
- Resources use, energy carriers

System boundaries for the three levels of analysis

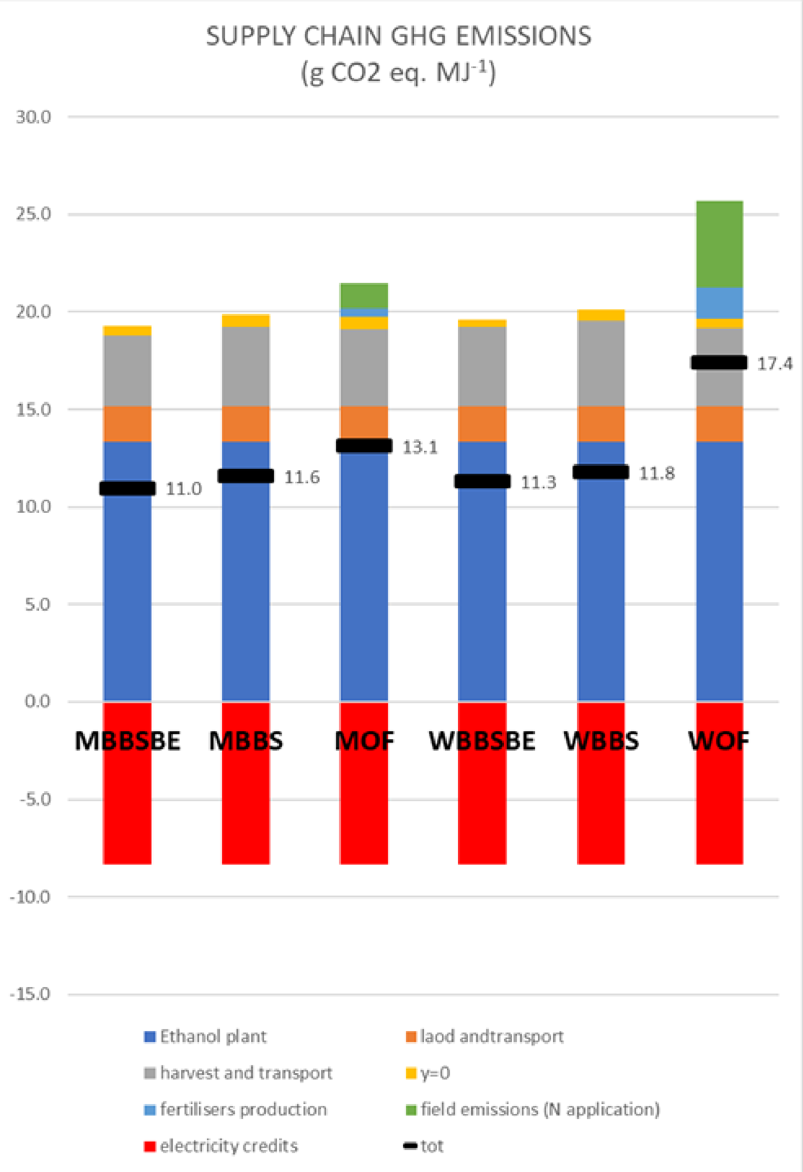
L1: supply chain

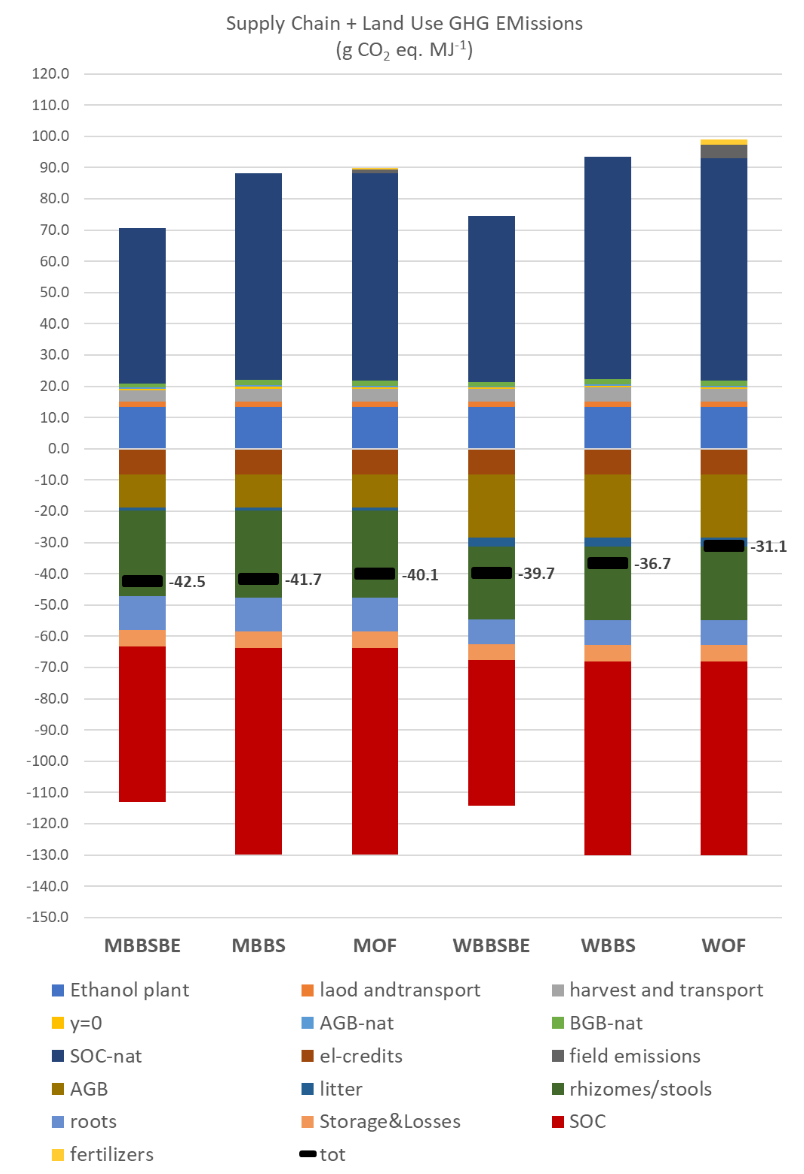
L2: supply chain + biogenic carbon

L3: cradle to grave

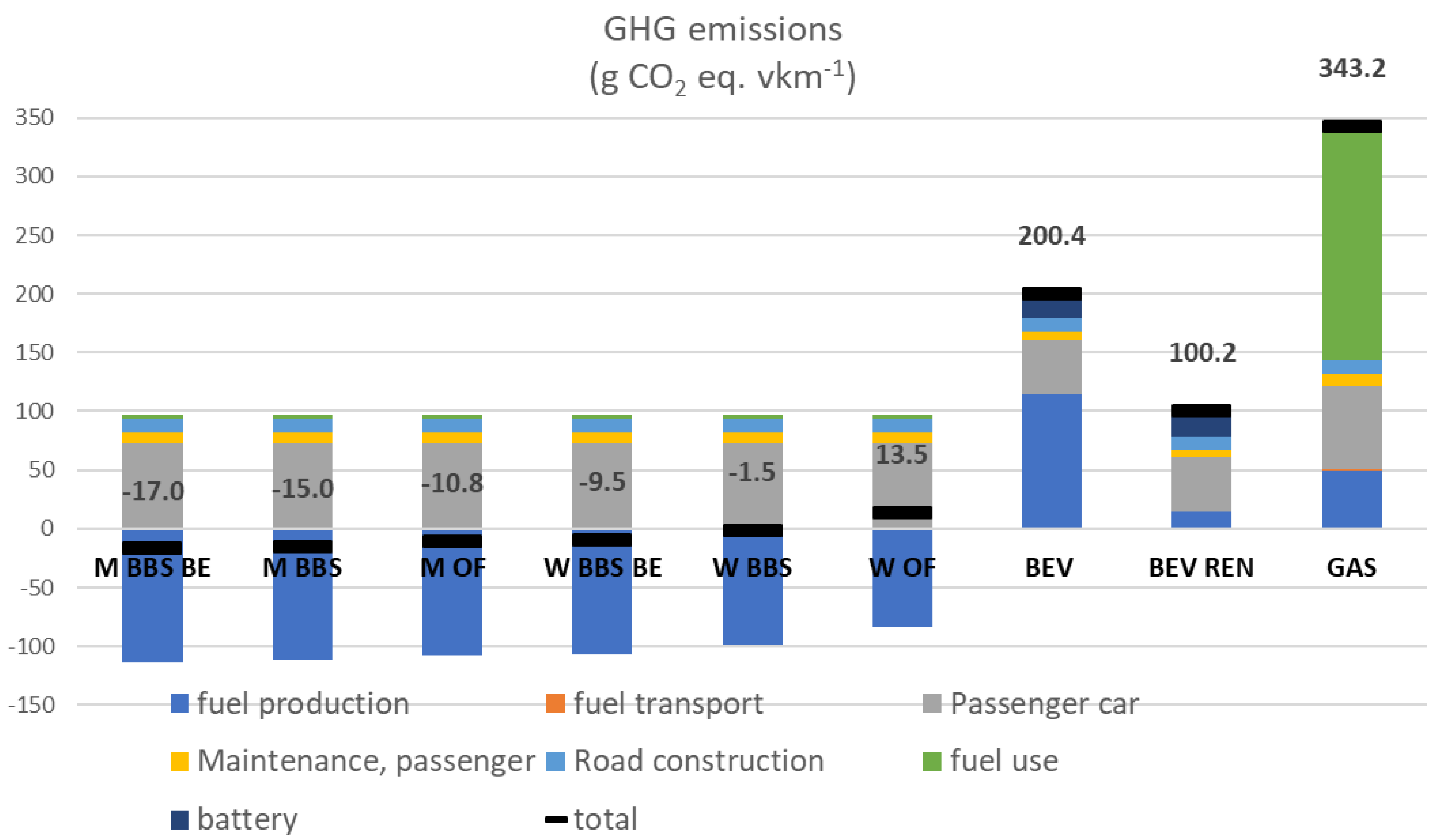


GHG emissions: cradle to gate

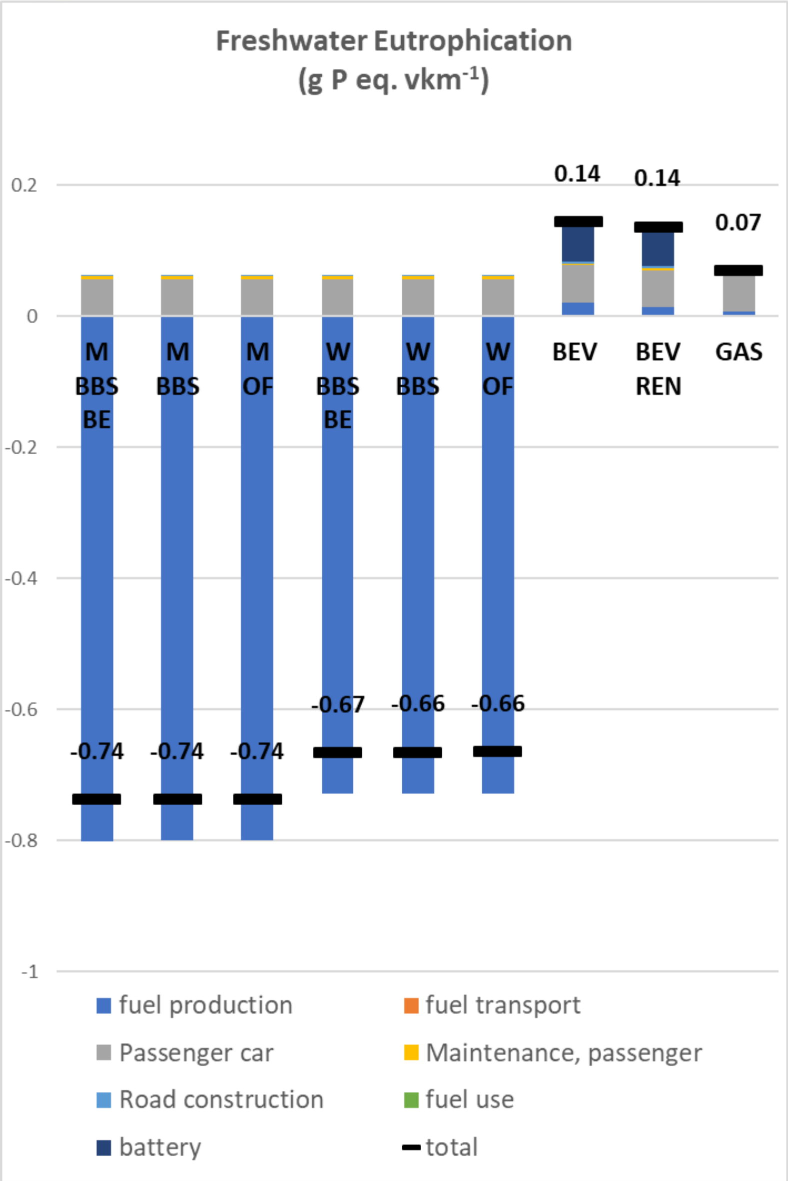


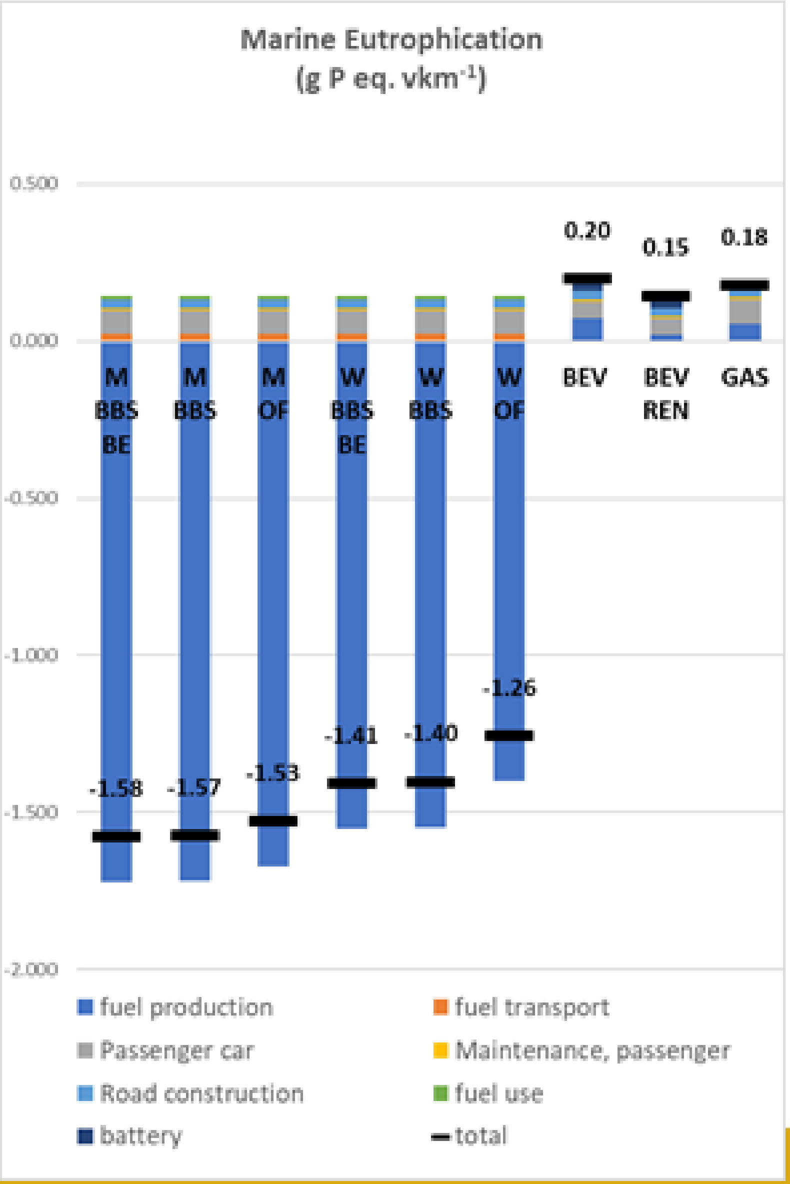


GHG emissions: cradle to grave

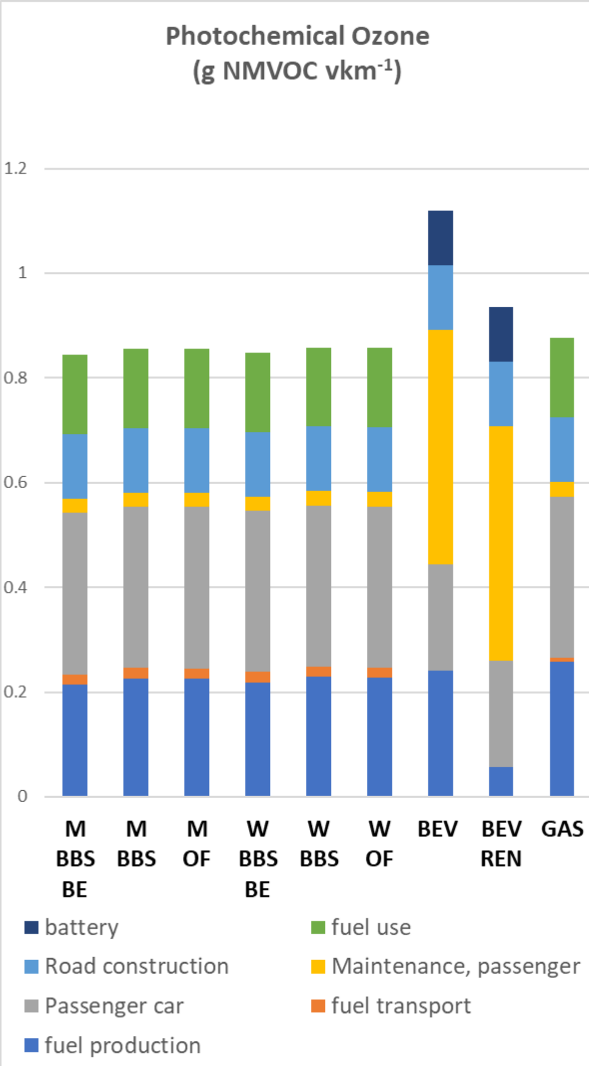


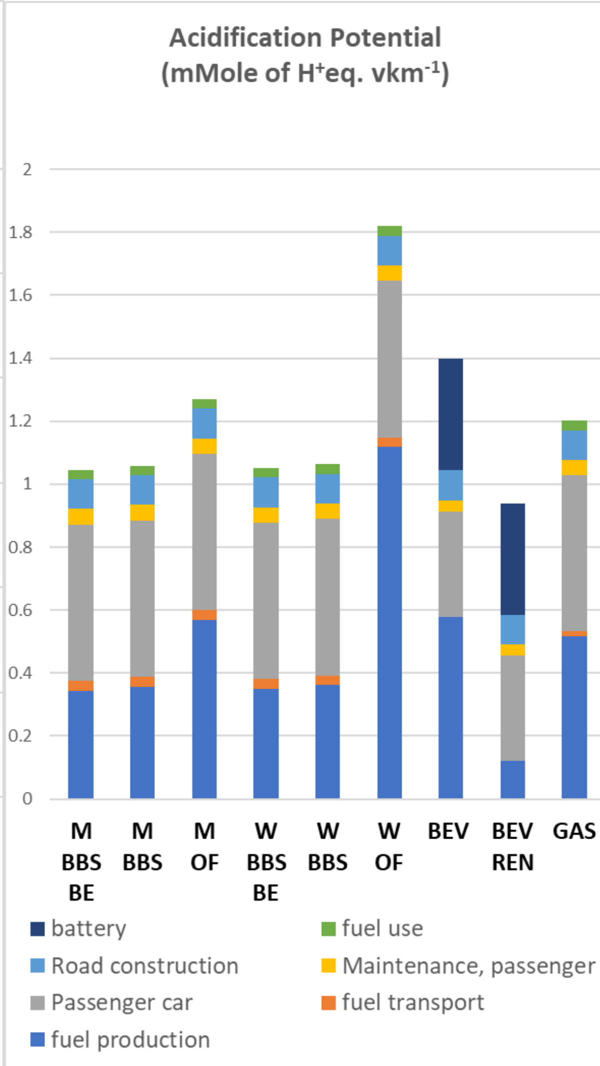
Marine Eutrophication

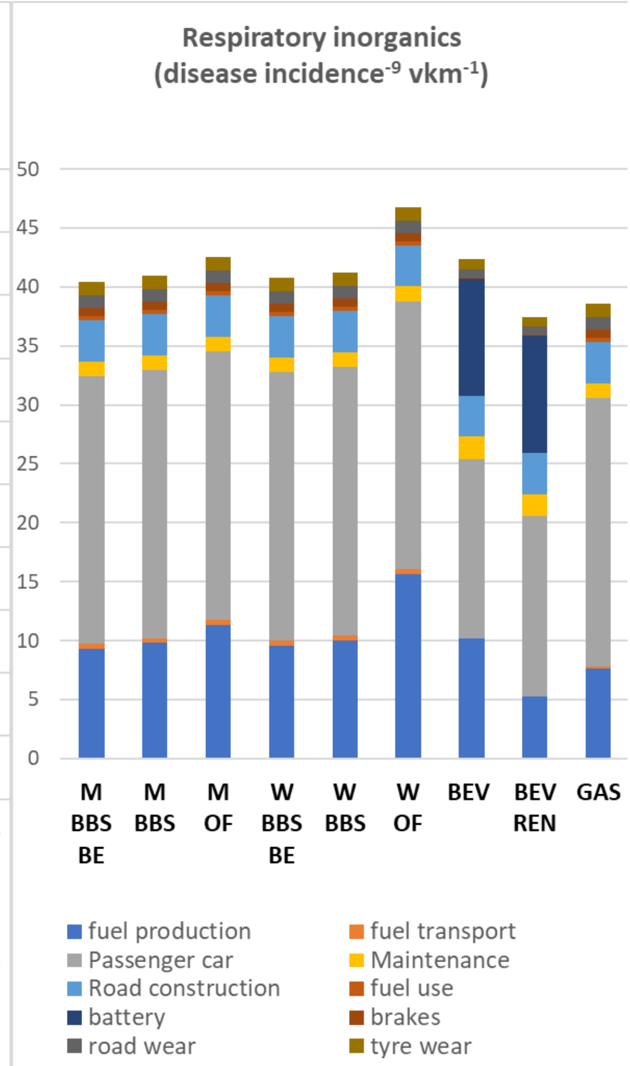




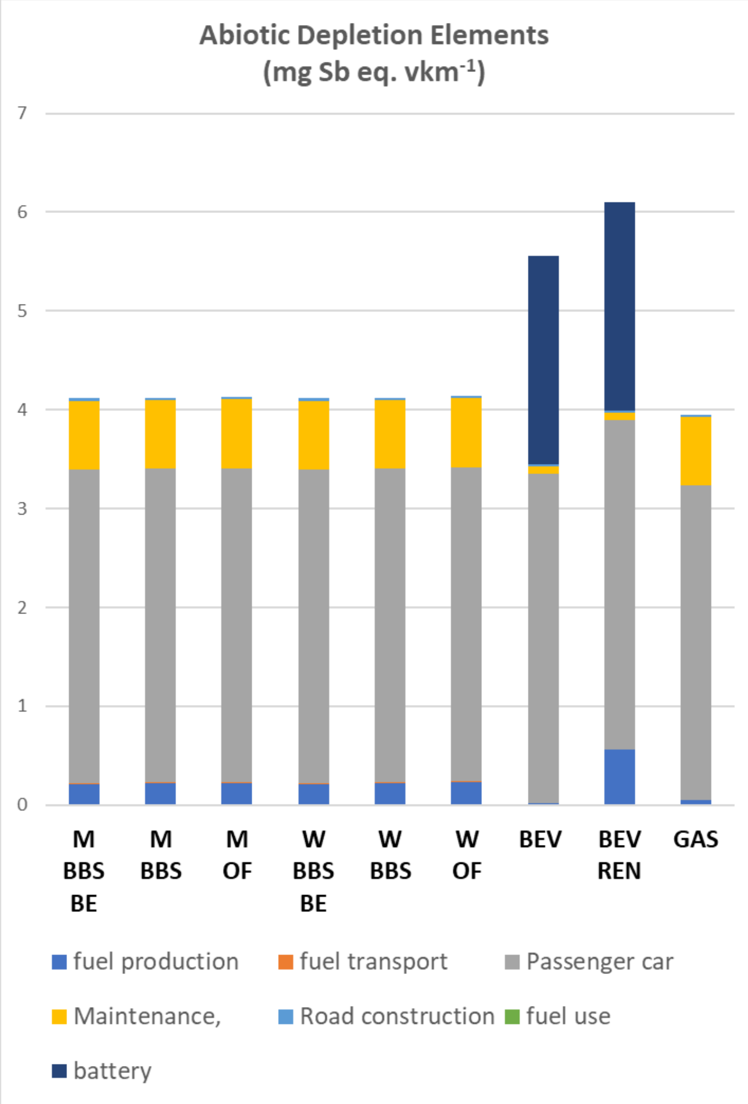
Airborne pollutants

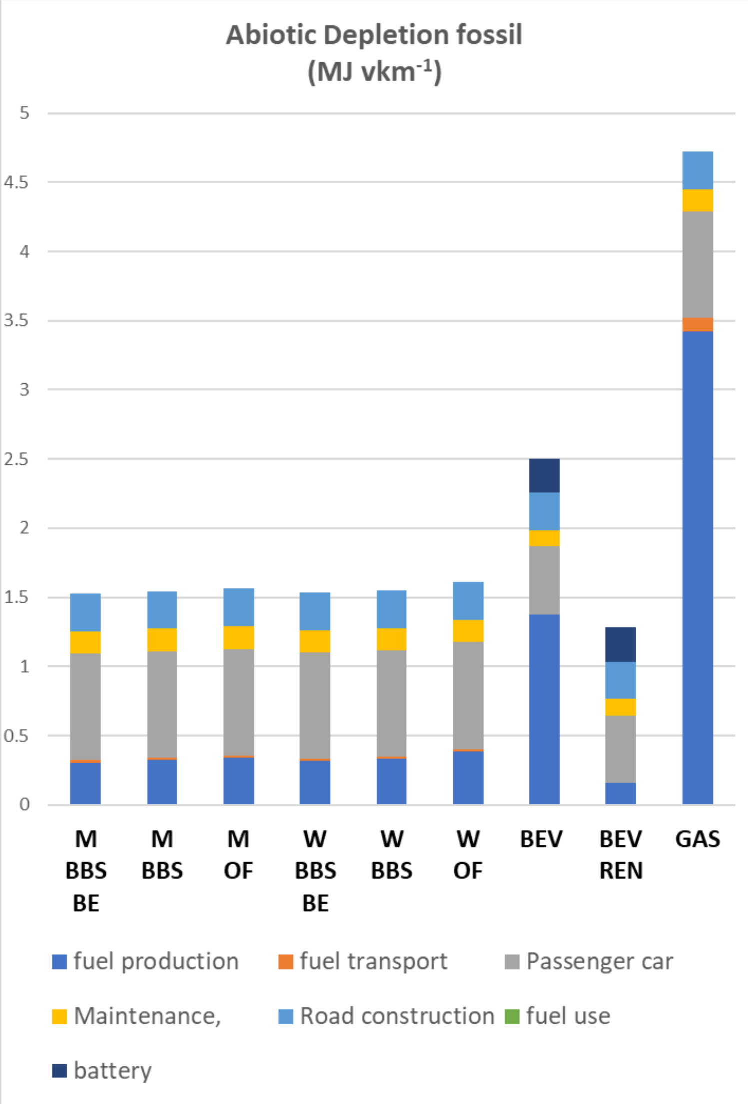






Resources depletion





Conclusions

Methodological aspects fundamental for biofuel environmental impacts assessment:

- The inclusion of the biogenic carbon pools, nutrients cycles and the infrastructures
- Expansion of the life cycle to include the fuel use
- All relevant impact categories

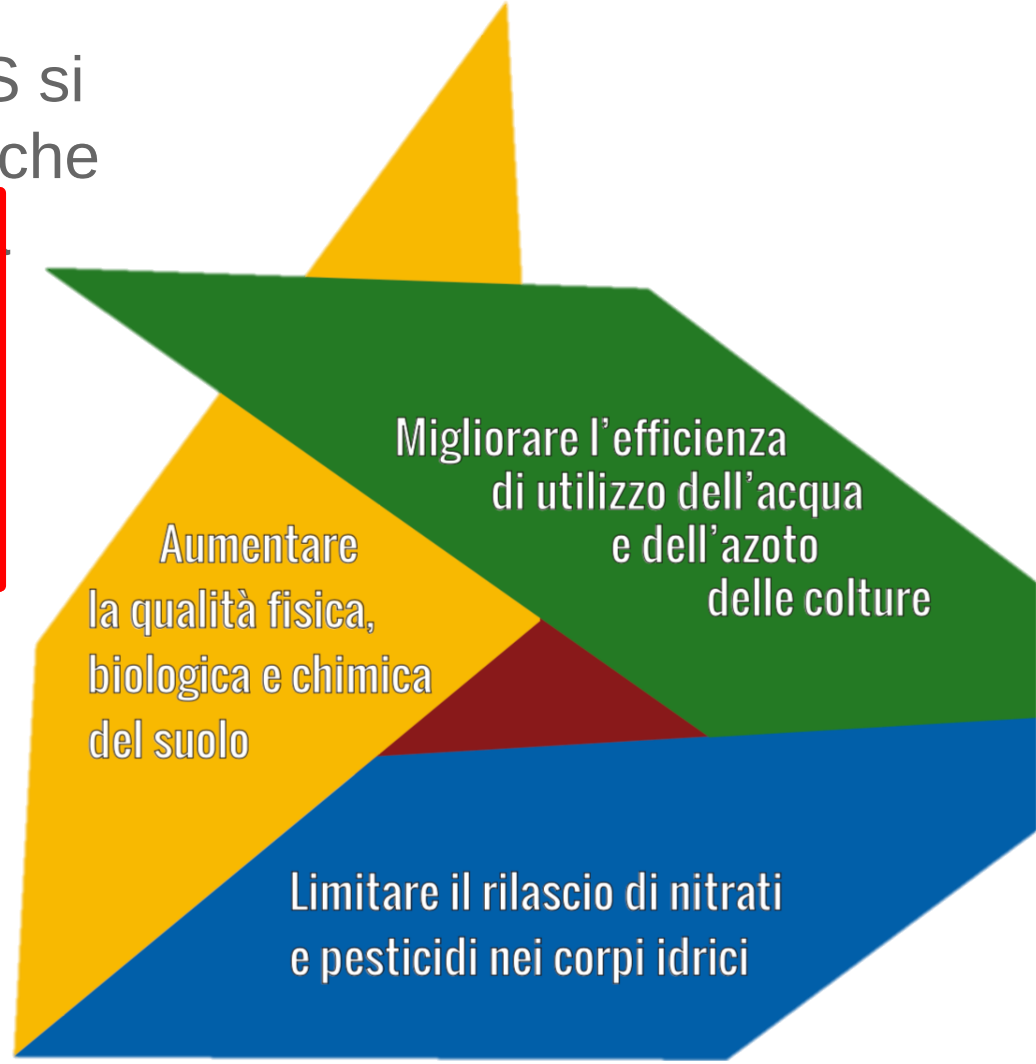
Conclusions

The production of bioethanol from perennial energy crops is a win-win option for reducing the environmental impacts deriving from private mobility.

- It enables both the **removal of nutrients** from the environment and the **removal of carbon from the atmosphere**, reducing the anthropic burden on two critical planetary boundaries, climate change and nutrients cycle.
- If the cultivation takes places in agricultural land not cultivated anymore because either cultivation is not allowed (such as in buffer strips) or not convenient (abandoned or degraded land), **the impact on biodiversity and land system change,** the remaining planet boundaries which have already been exceeded, is positive.
- As regards **resources depletion and air pollution**, the use of bioethanol from perennial energy crops cultivated in bioenergy buffer strips does not show any significant trade off.
- The use of **fertilisers** worsens all the environmental aspects of biofuel production.
- Future work will include the **dismission** of the plantation and an analysis of the impact of the dismission on SOC.

L’innovazione in CABIOS

Il Gruppo Operativo CABIOS si propone di integrare le tecniche di **agricoltura conservativa** combinandole con la distribuzione del **digestato**, con un sistema di **irrigazione sotterranea** e con la realizzazione di **fasce tampone** bioenergetiche lungo i margini dei campi



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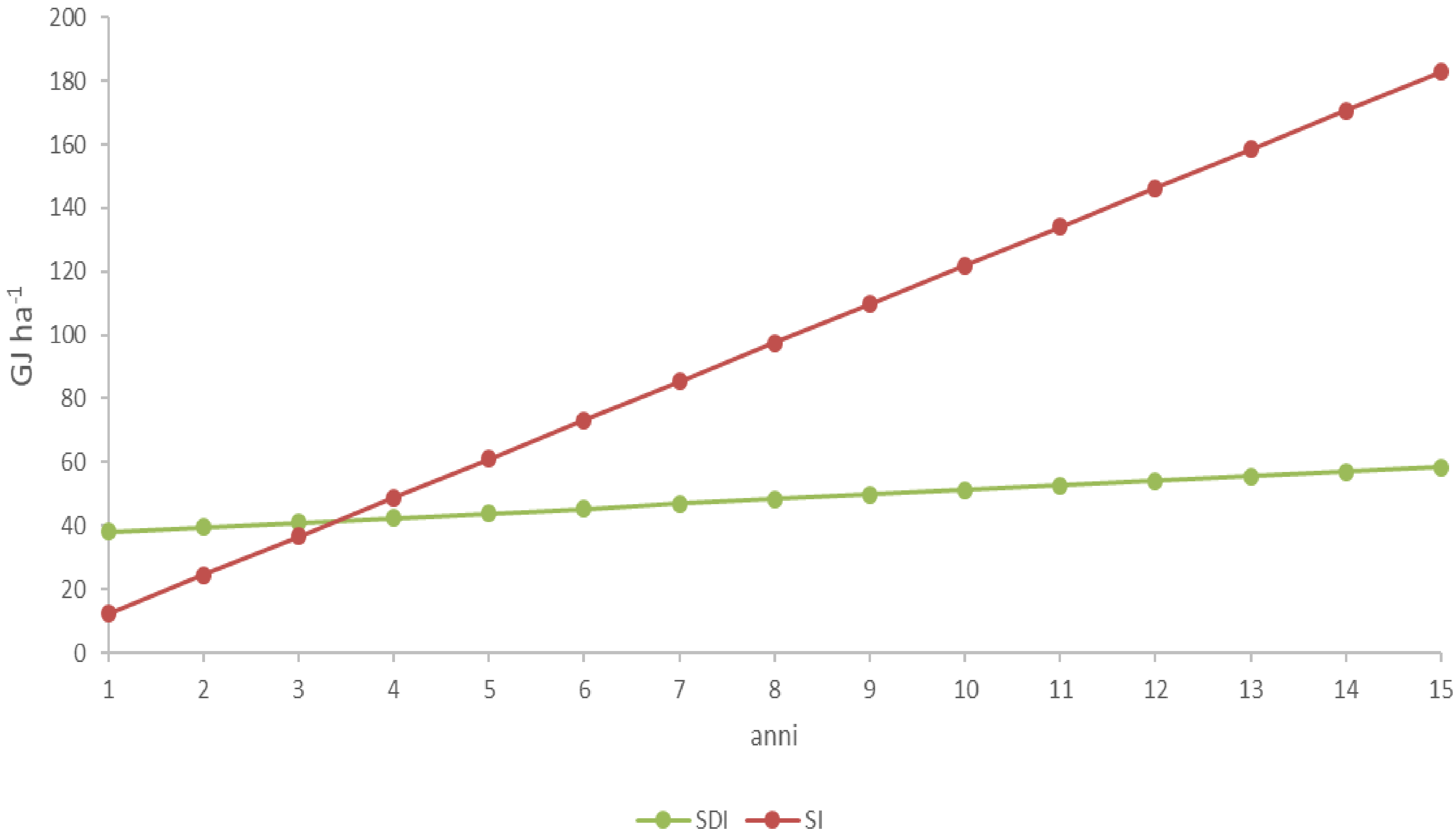
L'innovazione in CABIOS



L'agricoltura conservativa:

Bilancio energetico con risultati contrastanti:

- risparmio fino al 15% di gasolio e lubrificanti
- aumentato del costo energetico (+23%) di erbicidi (terminazione delle cover crop).

Agricoltura conservativa + sub irrigazione:

- Emissioni totali di GHG nella fase di coltivazione inferiori del 7 – 11% (mais e frumento rispettivamente) rispetto alle pratiche convenzionali

- Considerando l'intera filiera, fino alla trasformazione del biogas prodotto in energia elettrica, dimunuzione del 4% nelle emissioni totali di GHG.

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Article

Environmentally Sustainable Biogas? The Key Role of Manure Co-Digestion with Energy Crops

Alessandro Agostini [1,2,*], Ferdinando Battini [3], Jacopo Giuntoli [1], Vincenzo Tabaglio [3], Monica Padella [1], David Baxter [1], Luisa Marelli [1] and Stefano Amaducci [3]

[1] European Commission, Joint Research Centre (JRC), Institute for Energy and Transport (IET), Sustainable Transport Unit, Westerduinweg 3, 1755LE Petten, The Netherlands; E-Mails: jacopo.giuntoli@ec.europa.eu (J.G.); monica.padella@jrc.ec.europa.eu (M.P.); david.baxter@ec.europa.eu (D.B.); luisa.marelli@jrc.ec.europa.eu (L.M.)

[2] ENEA–Italian National Agency for New Technologies, Energy and the Environment,

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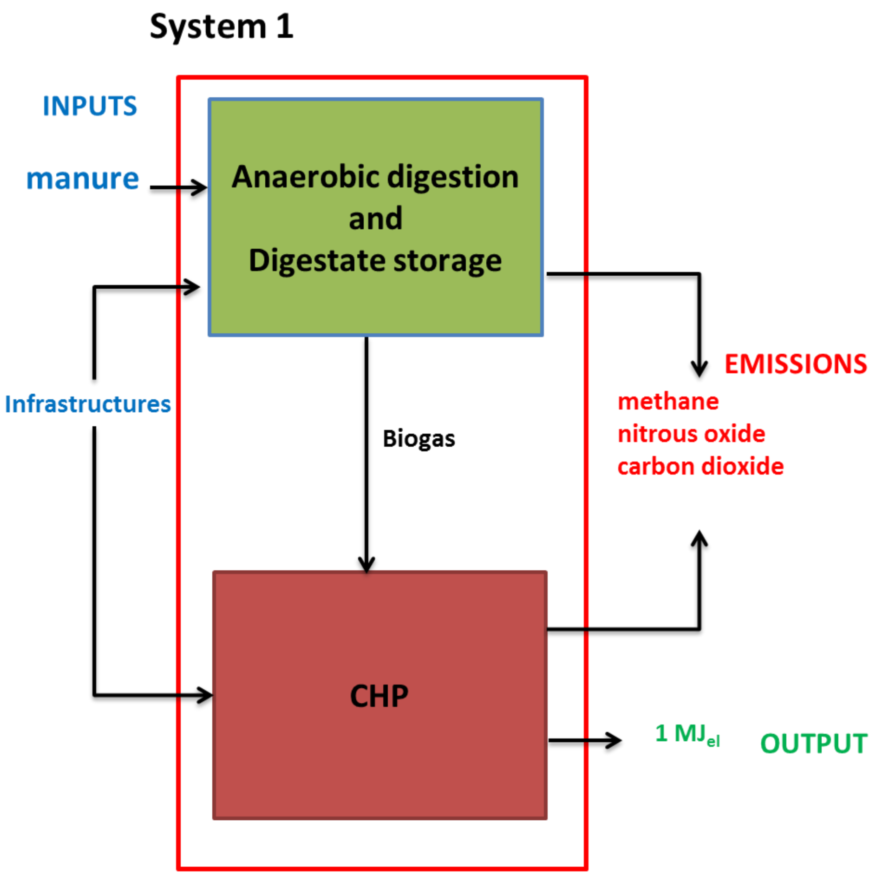
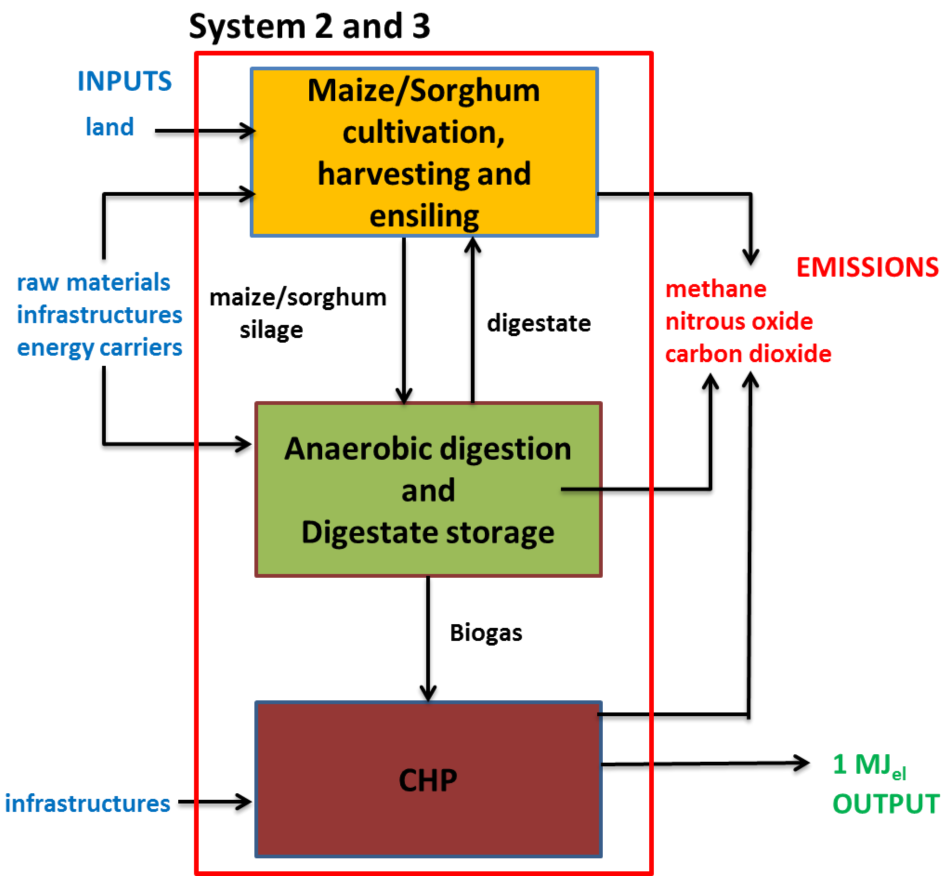
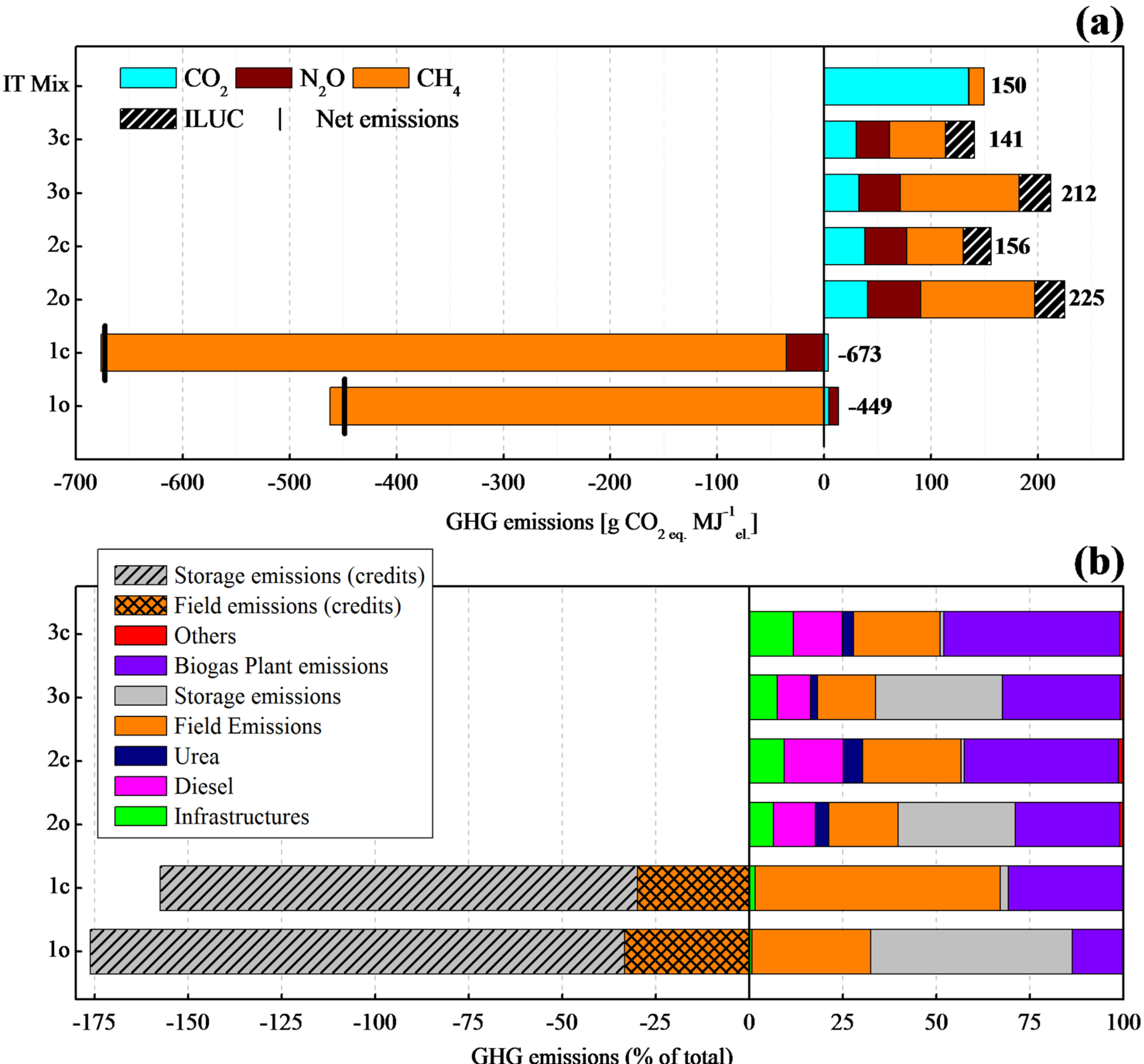
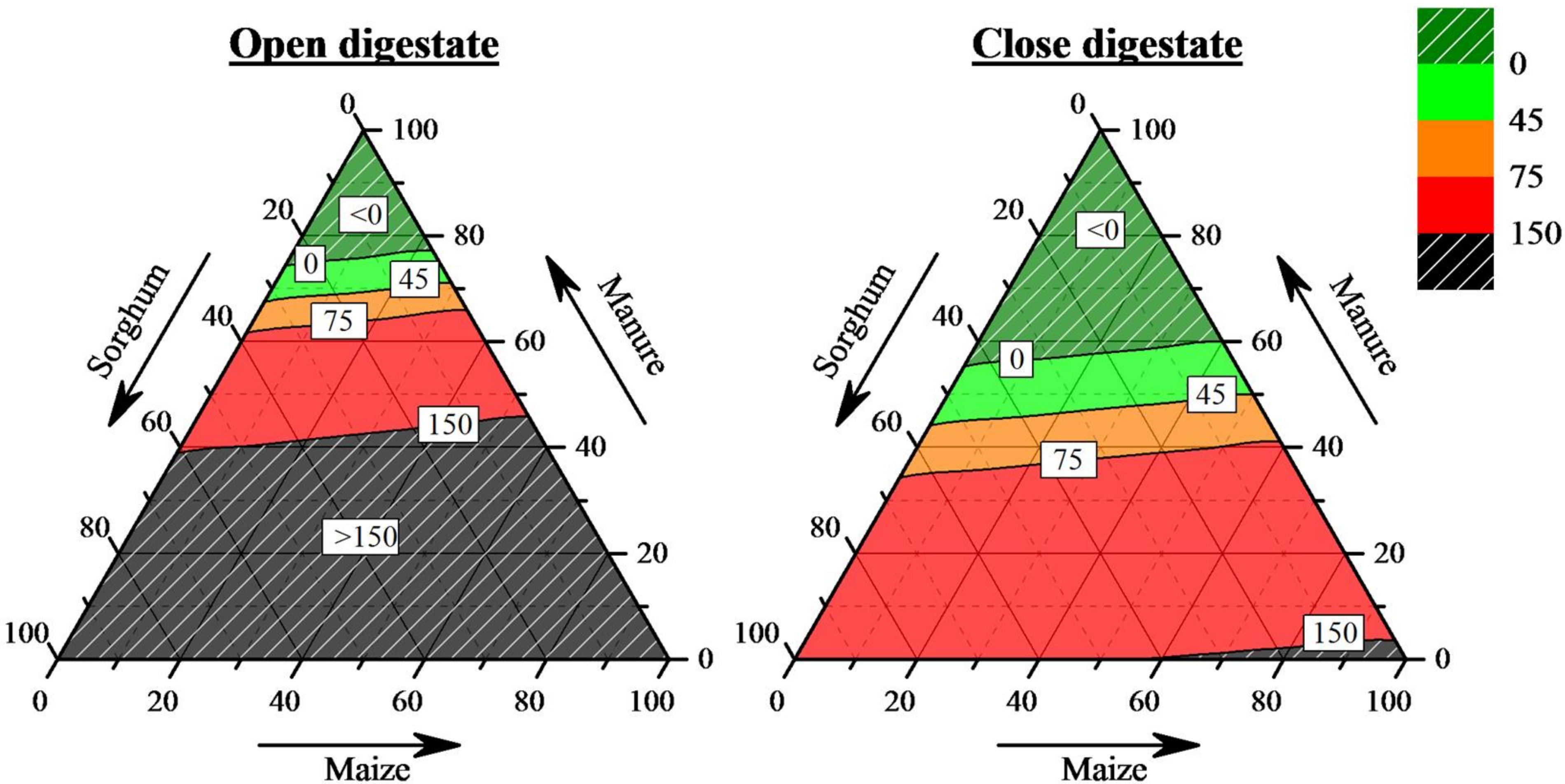






(a)
CO$_2$
N$_2$O
CH$_4$
ILUC
Net emissions
IT Mix
3c
3o
2c
2o
1c
1o
150
141
212
156
225
-673
-449
-700
-600
-500
-400
-300
-200
-100
0
100
200
GHG emissions [g CO$_{2\,eq.}$ MJ$^{-1}_{el.}$]
(b)
Storage emissions (credits)
Field emissions (credits)
Others
Biogas Plant emissions
Storage emissions
Field Emissions
Urea
Diesel
Infrastructures
3c
3o
2c
2o
1c
1o
-175
-150
-125
-100
-75
-50
-25
0
25
50
75
100
GHG emissions (% of total)



Open digestate
Close digestate
Sorghum
Manure
Maize
<0
0
45
75
150
>150
0
45
75
150

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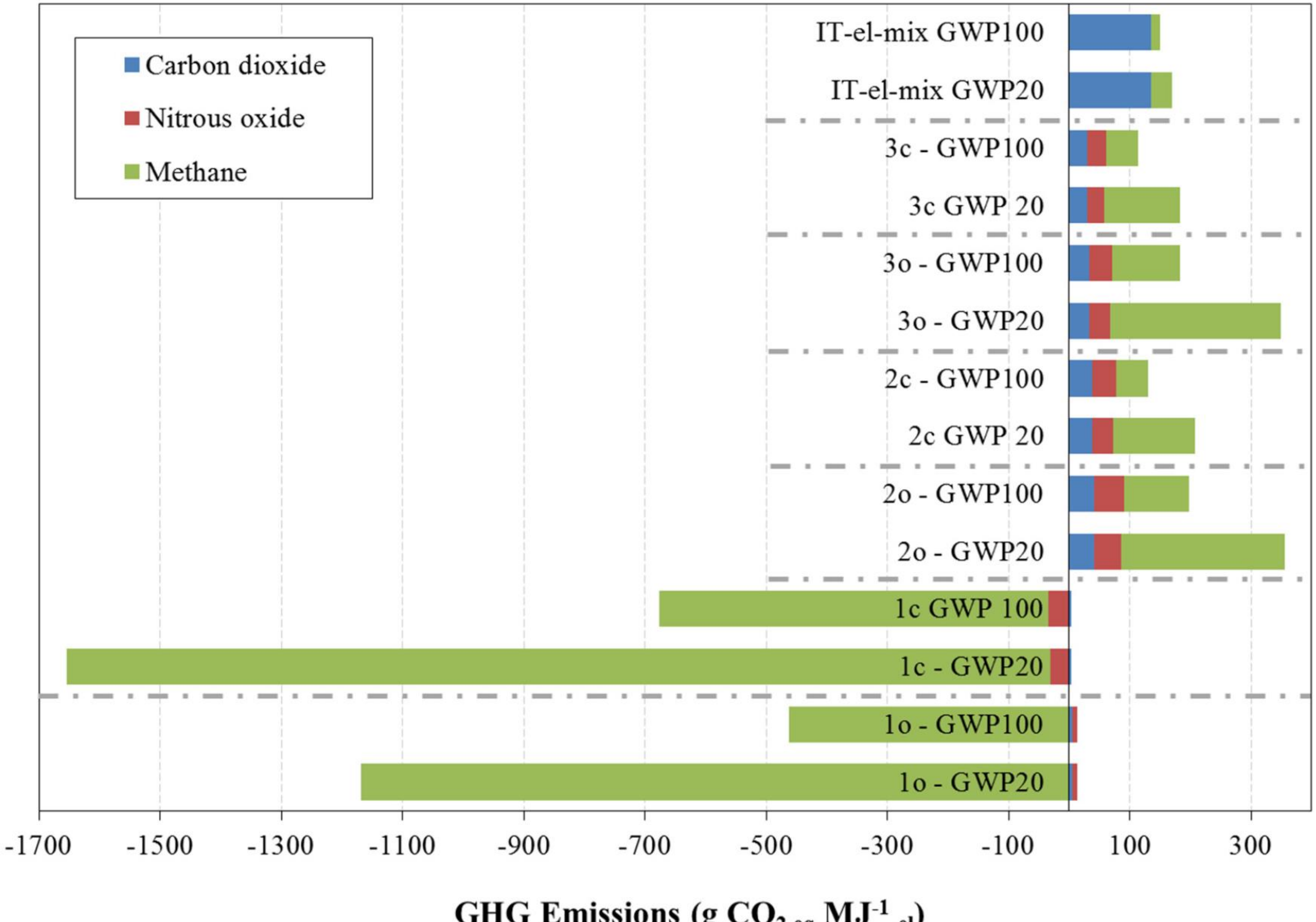

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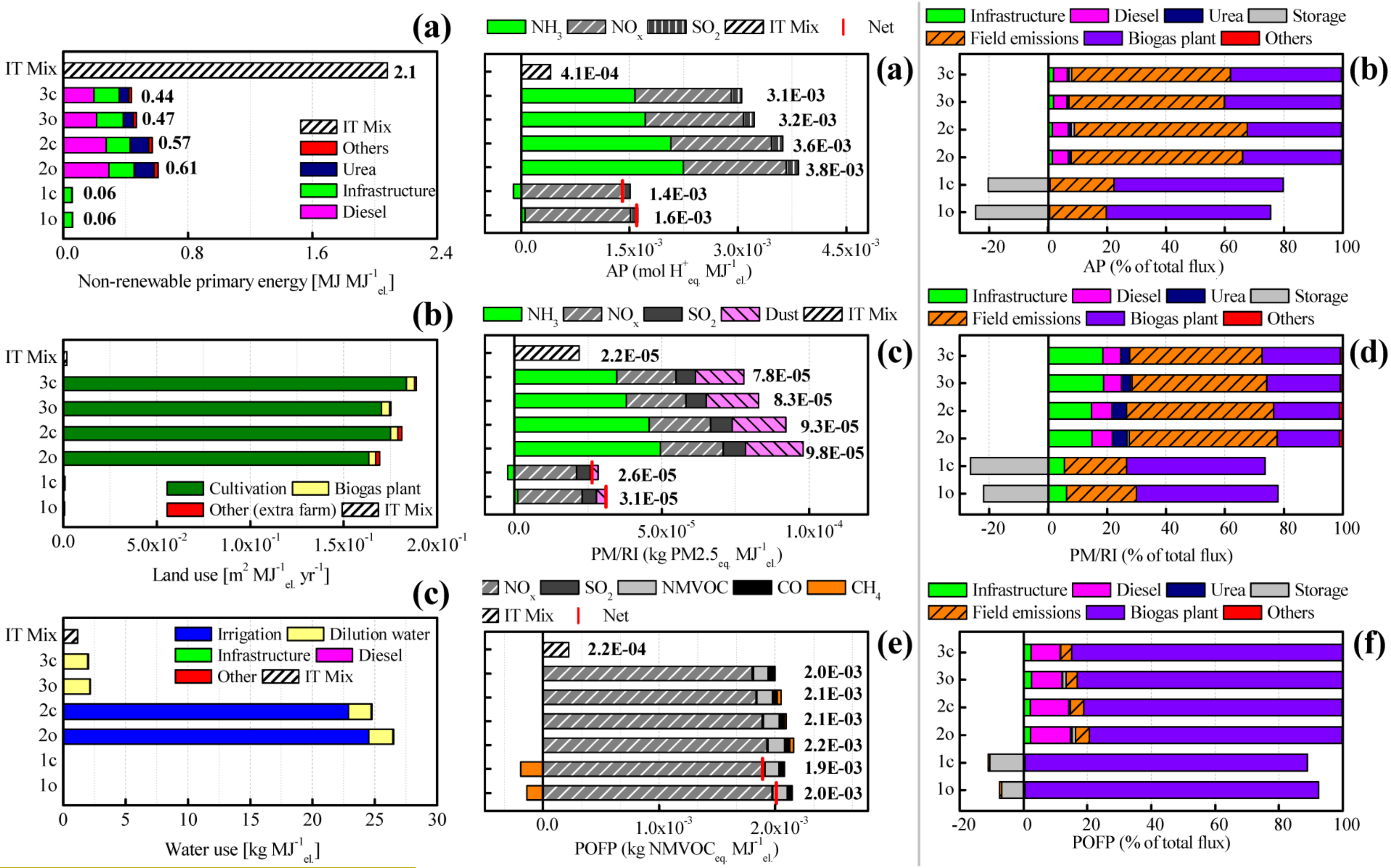

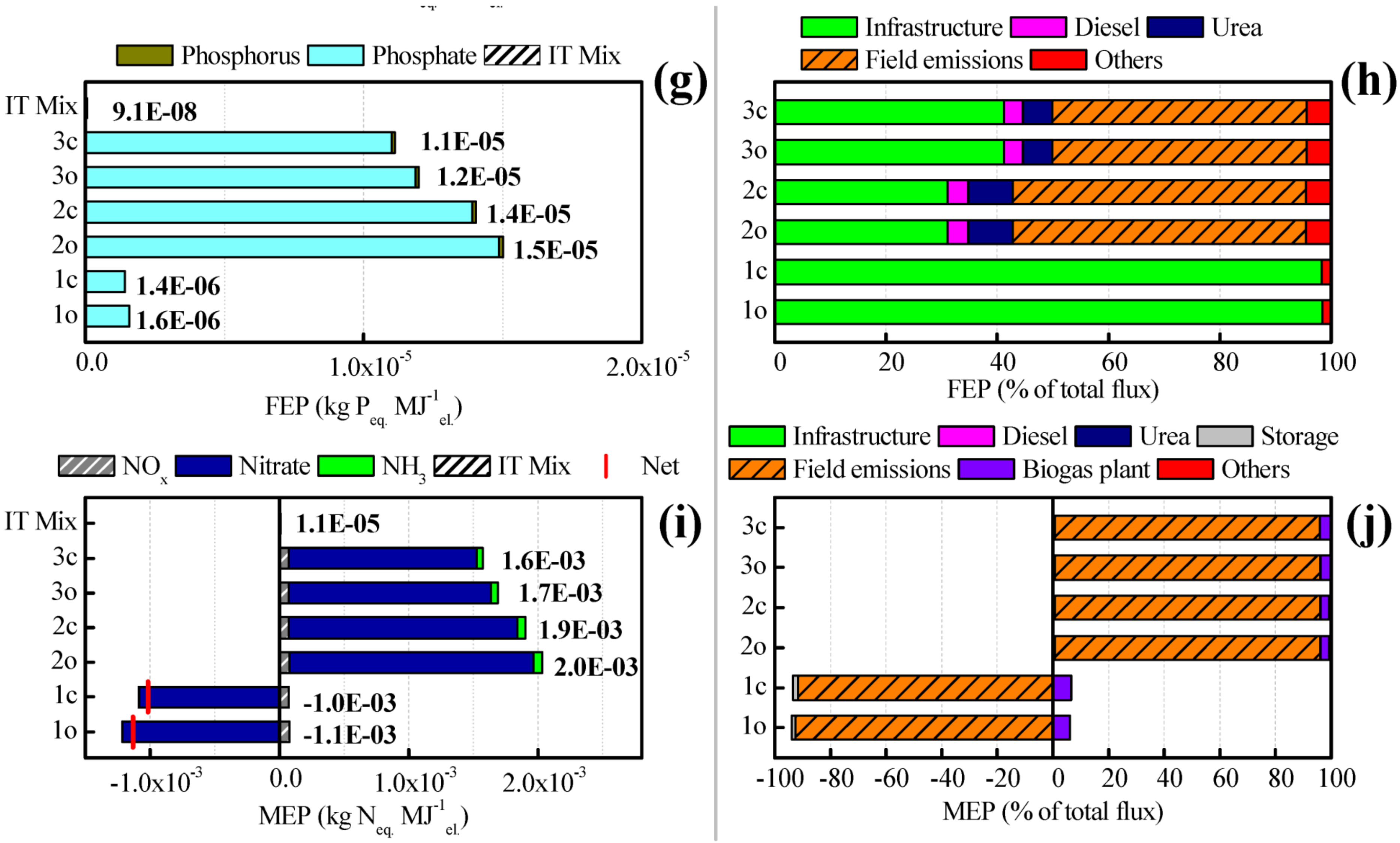

Phosphorus
Phosphate
IT Mix
(g)
IT Mix
3c
3o
2c
2o
1c
1o
9.1E-08
1.1E-05
1.2E-05
1.4E-05
1.5E-05
1.4E-06
1.6E-06
0.0
1.0x10^-5
2.0x10^-5
FEP (kg P eq. MJ^-1 el.)
Infrastructure
Diesel
Urea
Field emissions
Others
(h)
0
20
40
60
80
100
FEP (% of total flux)
NOx
Nitrate
NH3
IT Mix
Net
(i)
1.1E-05
1.6E-03
1.7E-03
1.9E-03
2.0E-03
-1.0E-03
-1.1E-03
-1.0x10^-3
0.0
1.0x10^-3
2.0x10^-3
MEP (kg N eq. MJ^-1 el.)
Storage
Biogas plant
(j)
-100
-80
-60
-40
-20
MEP (% of total flux)

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Table A1. Input data considered for the cultivation of 1 ha maize and sorghum silage under conventional tillage (CT) and no-tillage (NT).

Input	Unit	Maize (CT)	Sorghum (CT)	Maize (NT)	Sorghum (NT)	Notes	Sources
Diesel	$kg \cdot yr^{-1}$	327.8	227.0	287.7	186.9	See Table 2 for values disaggregated by operation	-
Lubricating oil	$kg \cdot yr^{-1}$	1.87	1.30	1.64	1.07	0.008 per kWh - Included disposal and treatment of waste	Elaborated from [8]
Plastic wraps	$kg \cdot yr^{-11}$	2.5	2.5	2.5	2.5	0.11 kg/m^2 for baling	[75]
Urea as N	$kg \cdot yr^{-1}$	120	60	120	60	-	Field trials
Seed	$kg \cdot yr^{-1}$	25	8	25	8	-	Field trials
Herbicides	$kg\ yr^{-1}$ a.s.*	2.5	1,5	3.1	2.1	S-metolaclor + Terbutilazine Glyphosate only for NT	Field trials
Insecticides	$kg \cdot yr^{-1}$ a.s.*	1.13	1.13	1.13	1.13	Against soil insects	Field trials
Machinery	$kg \cdot yr^{-1}$	39.65	32.35	35.80	28.49	Average lifetime 12 years	[42]
Machinery shed	$m^2 \cdot yr^{-1}$	0.087	0.081	0.068	0.062	Average lifetime 40 years	[42]
Irrigation water	$m^3 \cdot yr^{-1}$	1400	0	1400	0	Distributed over three times for maize	Field trials

Note: * Values given in kg of active substance (a.s.).

Conventional versus no-tillage cultivation

- With NT management, the GHG emissions for cultivation per hectare decreased by 9% for maize and by 13 % for sorghum.

- As cultivation accounted for less than one fourth of the total GHG emissions limited GHG savings could be achieved by adopting the NT instead of the CT management;

- The total GHG emissions decreased by only about 2%

- These results however have limitations because of missed accounting of soil organic carbon accumulation and the additional N_2O emissions due to the higher soil microbial activity under NT management.

Conclusions – biogas env. sust.

- Manure: GHG emissions reduction per se; trade offs with other impacts.
- Energy crops: GHG similar to electricity mix; but the impacts on all the other environmental categories (including land use, water and primary energy consumption) are much higher.
- Energy crops codigestion with manure negative GHG emissions if only a limited fraction is allowed (30%)
- In the case of energy crops co-digestion, the impact of agronomic practices (i.e., choice of crop, fertilization, irrigation, no-tillage) has minor effects, especially if compared to the major positive effect achieved by increasing the share of manure or by covering the digestate storage with gas tight membranes.

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Biomass and Bioenergy 89 (2016) 58–66

Contents lists available at ScienceDirect

Biomass and Bioenergy

journal homepage: http://www.elsevier.com/locate/biombioe

Research paper

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

Alessandro Agostini [a, b, *], Ferdinando Battini [c], Monica Padella [a], Jacopo Giuntoli [a], David Baxter [a], Luisa Marelli [a], Stefano Amaducci [c]

[a] *European Commission, Joint Research Centre (JRC), Institute for Energy and Transport (IET), Sustainable Transport Unit, Westerduinweg 3, 1755LE Petten, The Netherlands*

[b] *ENEA—Italian National Agency for New Technologies, Energy and the Environment, Via Anguillarese 301, Rome, Italy*

[c] *Department of Sustainable Crop Production, Università Cattolica del Sacro Cuore, 29122 Piacenza, Italy*

Aim of the work

To explore how the use of different feedstocks, agricultural practices and digestate storage technologies affect the environmental and economic performances of biogas

Economic perfomance

- ✓ Costs (CAPEX, OPEX)
- ✓ Revenues
- ✓ Break-even tariff
- ✓ Net present value (NPV)
- ✓ IRR (Internal Rate of Return)

Environmental impact

- ✓ GHG savings

Cost per t $CO2_{eq}$ saved

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20 SYSTEMS ANALYSED

FEEDSTOCK	AGRICULTURAL PRACTICE	DIGESTATE STORAGE
MANURE (1)	NO TILL (NT)	OPEN
MAIZE (2)	CONVENTIONAL TILL (CT)	CLOSED
SORGHUM (3)		
MANURE +30% SORGHUM (4)		
MANURE +30% MAIZE (5)		

SYSTEMS DESCRIPTION

MANURE :

- ✓ typical dairy farm in the Po valley
- ✓ 50 kW_{el}
- ✓ credits from avoided emissions from manure storage
- ✓ substrate no cost

(more details in Battini et al., 2014, Mitigating the environmental impacts of milk production via anaerobic digestion of manure: Case study of a dairy farm in the Po Valley; Science of The Total Environment, 2014)

MAIZE & SORGHUM:

- ✓ typical cultivation conditions and practices of the Po valley
- ✓ 1 MW_{el}
- ✓ all operations from contractors

- MAIZE: yield = 55.2 t/ha; irrigated; 120 kg N
- SORGHUM: yield = 58.0 t/ha; rainfed; 60 kg N

CONVENTIONAL TILL: ploughing at 40 cm, harrowing and sowing

NO TILL: direct sowing after herbicide treatment (Glyphosate)

(more details in Agostini et al., 2015, Environmentally sustainable biogas? The key role of manure co-digestion with energy crops; Energies, 2015)

REVENUES

- ✓ Italian biogas subsidy schemes: feed-in tariff (for renewable electricity and heat)
- ✓ It depends on the size of the plant and on the feedstock used

Annex I, DM 2012

Maize; Sorghum

Manure

Manure+30% crops

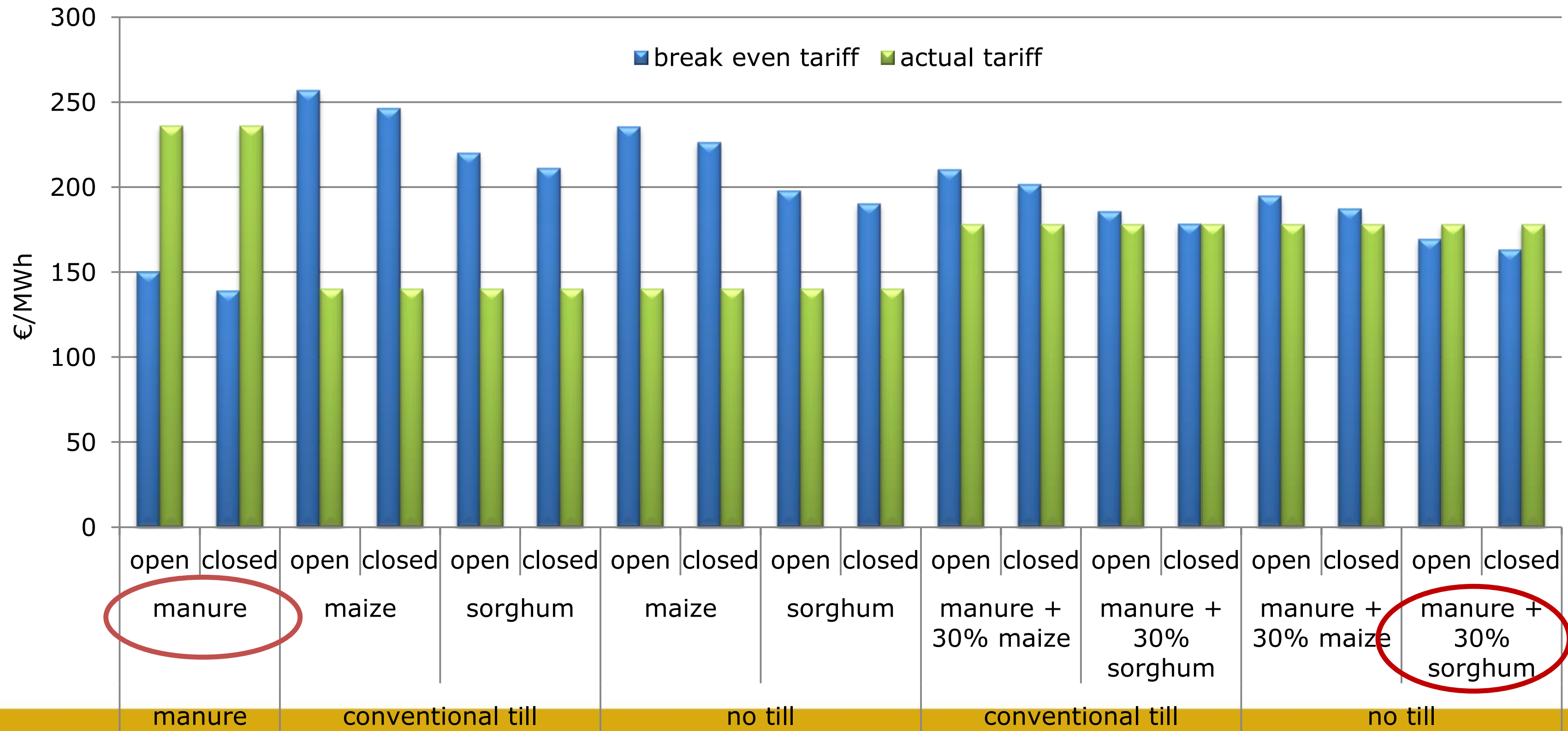
		Capacity	Useful life time (ys)	€/MWh
Biogas	a) prodotti di origine biologica	1<P≤300	20	180
		300<P≤600	20	160
		600<P≤1000	20	140
		1000<P≤5000	20	104
		P>5000	20	91
	b) sottoprodotti di origine biologi… cui alla Tabella 1 –A; d) rifiuti non provenienti da r… diversi da quelli di cui alla lettera c)	1<P≤300	20	236
		300<P≤600	20	206
		600<P≤1000	20	178
		1000<P≤5000	20	125
		P>5000	20	101
	c) rifiuti per i quali la frazione biodegradabile è determinata forfettariamente con le modalità di cui all'Allegato 2	1<P≤1000	20	216
		1000<P≤5000	20	109
		P>5000	20	85

Art. 8(5), DM 2012

c) per i soli impianti a biomasse e biogas di potenza non superiore a 1 MW e nel solo caso in cui dall'autorizzazione risulti che per l'alimentazione vengono utilizzate biomasse della tipologia di cui alla lettera b) del comma 4, congiuntamente a biomasse rientranti nella tipologia di cui alla lettera a), con una percentuale di queste ultime non superiore al 30% in peso, il GSE attribuisce all'intera produzione la tariffa incentivante di cui alla lettera b) del medesimo comma 4.

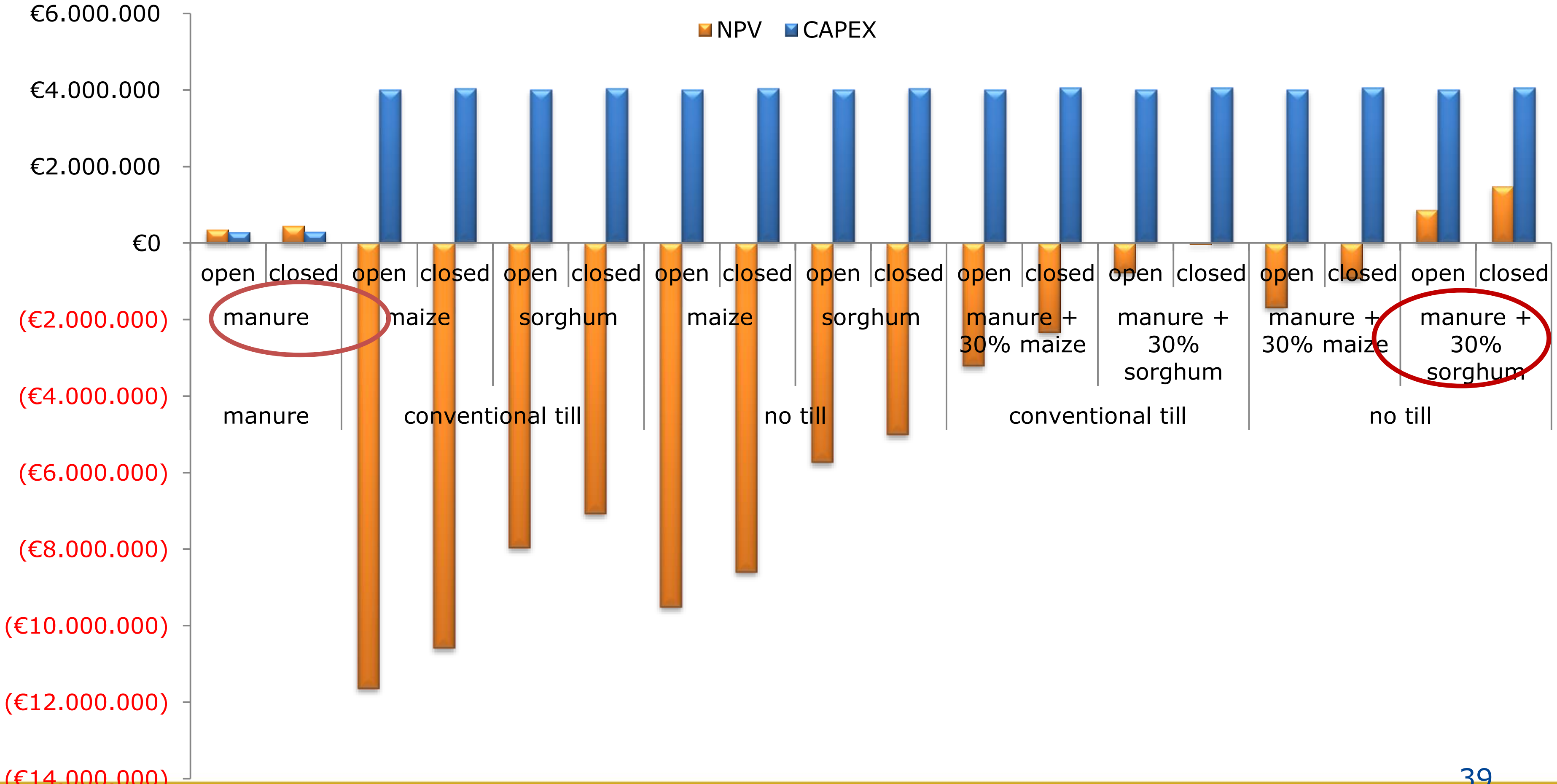
BREAK EVEN ANALYSIS

- ✓ The break-even point (BEP) is the point at which total cost equals total revenue and the profit margin is equals to zero.
- ✓ For all systems, we calculate the feed-in tariff (for electric energy) which corresponds to the BEP (break even tariff).



NET PRESENT VALUE (NPV)

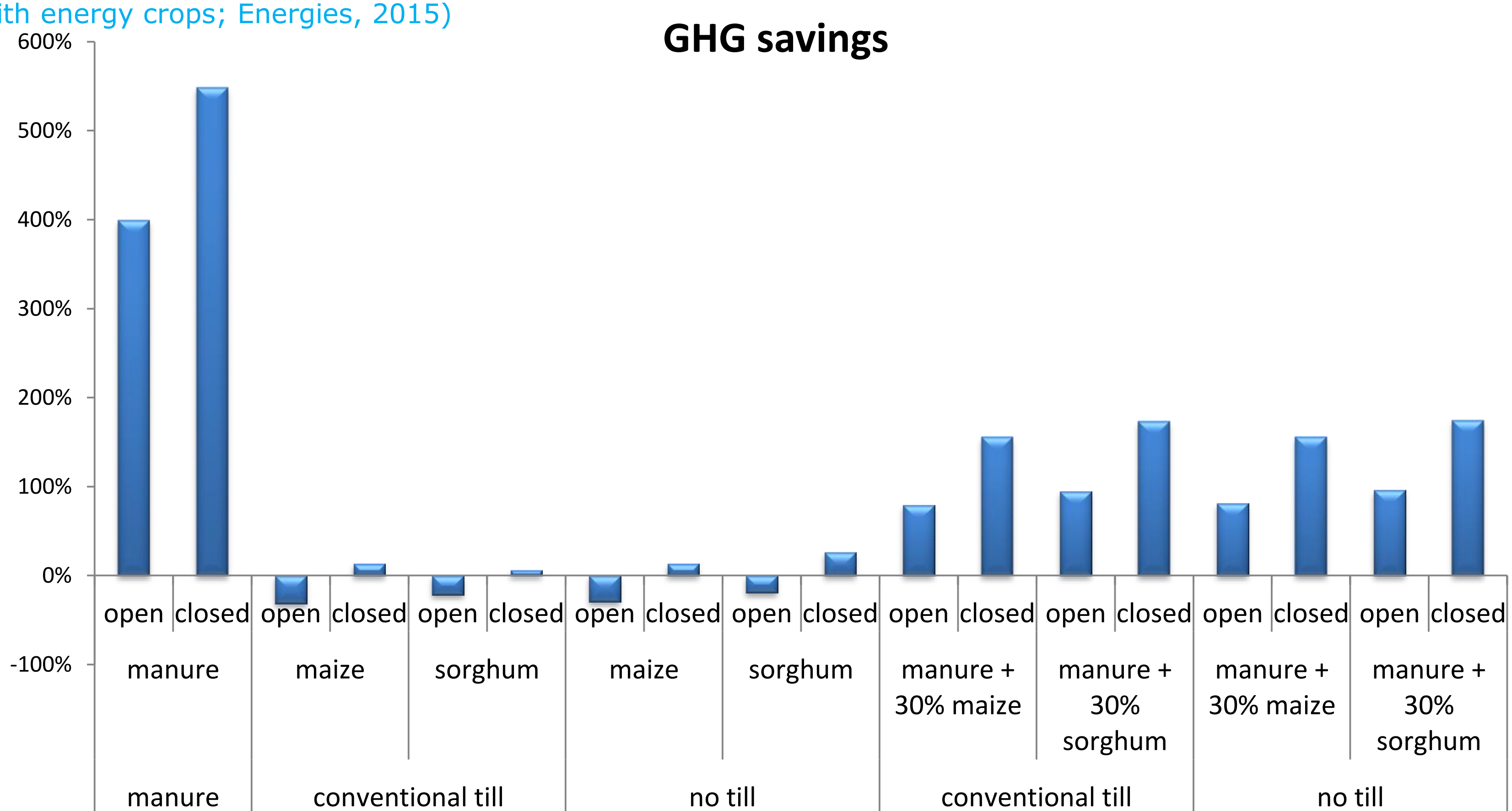
The **Net present value (NPV)** is defined as the sum of the present values of the individual (yearly) cash flows.



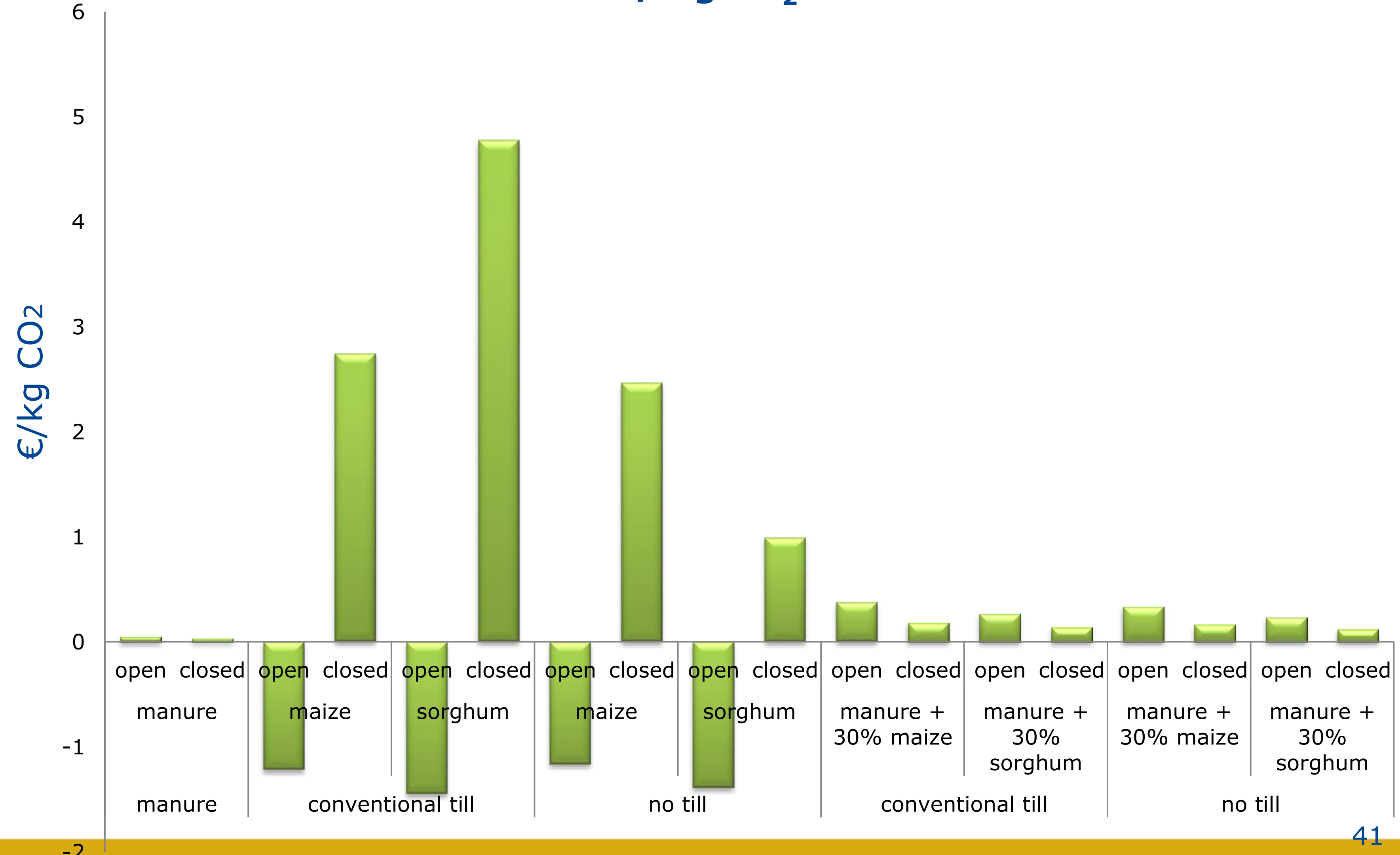
Environmental assessment

- Only Global Warming assessed; GWP from IPCC AR5
- Reference: Italian electricity mix (from PE international)

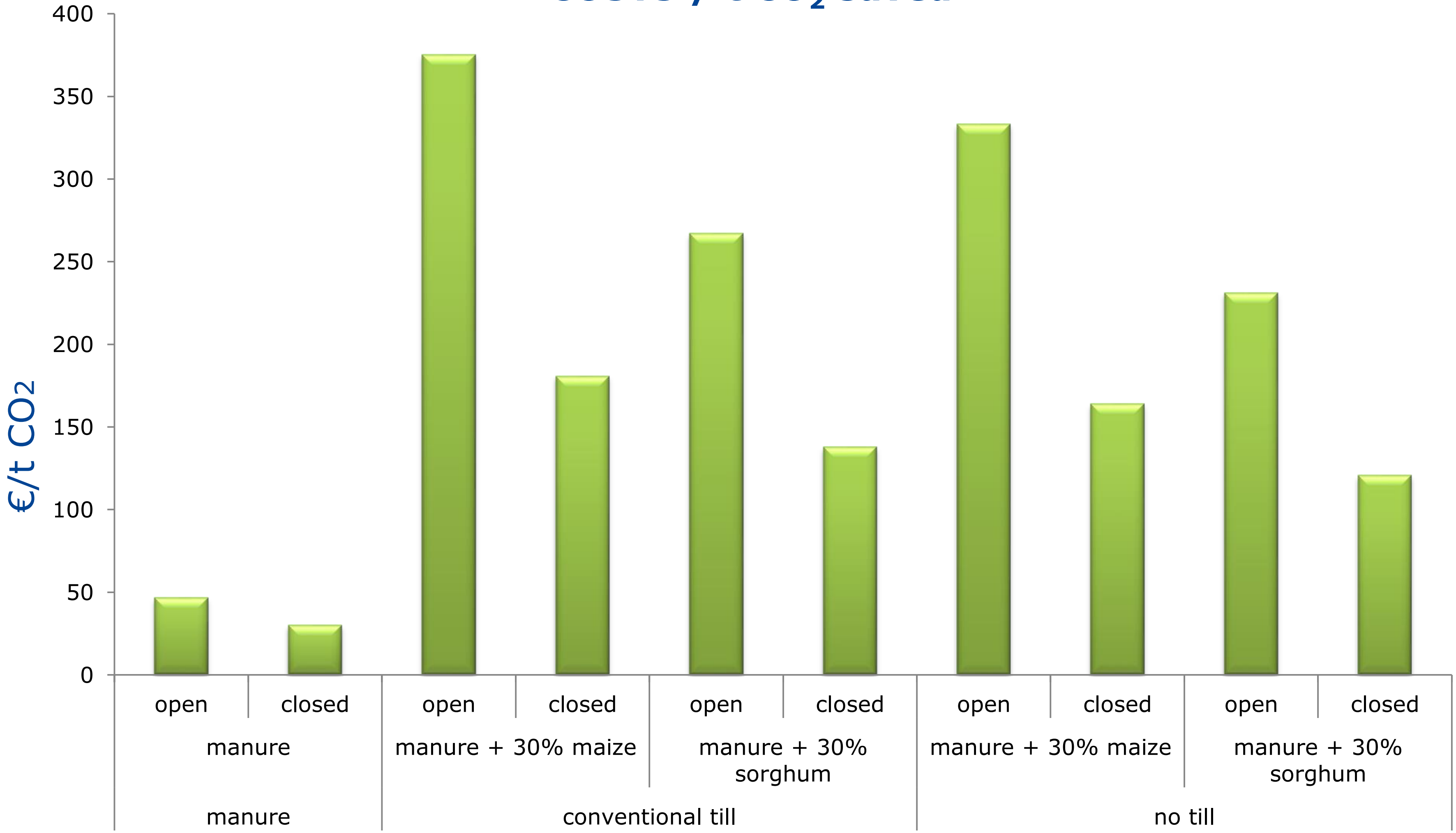
(more details in Agostini et al., 2015, Environmentally sustainable biogas? The key role of manure co-digestion with energy crops; Energies, 2015)



COSTS/ kg CO_2 saved



COSTS / t CO_2 saved



Conclusions

- ✓ **Manure** and co-digestion of manure with at most 30% sorghum (no till) provides GHG savings (in comparison to the Italian electricity mix) and profit to the economic operators
- ✓ **Energy crops** alone, instead, provides no (or very limited) GHG savings, and, with the current feed-in tariffs, does generate economic losses.
- ✓ **Sorghum** performs better than maize both economically and environmentally
- ✓ The gas-tight **cover** of the **digestate**, with recovering of the additional biogas produced, improves both the economics and environmental performances.
- ✓ The **No Till** agricultural practice as well improves both the economics and environmental performances

Conclusioni generali

- ✓ **Le fasce tampone** energetiche sono una strategia vincente, riducono le emissioni di gas serra e nutrienti, se in buffer strips impattano positivamete il consumo di suolo e la biodiversità senza effetti negativi sugli altri aspetti ambientali.

- ✓ L'**agricoltura conservativa** permette un risparmio di emissioni di gas serra del 9-13% nella fase di coltivazione, ma sul totale delle emissioni per kWh di elettricità da biogas, diventa circa il 2%

- ✓ La **sub-irrigazione,** accoppiata all'agricoltura conservativa, permette un risparmio energetico e di acqua del 30%, che corrisponde, sul totale delle emissioni di gas serra ad un risparmio del 7 % per la coltivazione del mais (11% per il frumento) che però rappresenta circa il 4% delle emission totali della filiera biogas

alessandro.agostini@enea.it

Impronta carbonica dei sistemi agricoli:
dalla gestione del suolo alla produzione di biogas

Piacenza, 20 Gennaio 2020

CAPEX

The initial investment includes the capital costs of all the fixed assets (e.g. constructions buildings, plant and machinery) and non-fixed assets (e.g. start up and technical costs such as design/planning)

Assumptions:

- ✓ Life time of investment is 20 years (which equals the economically useful life of the plant and the duration of the Italian feed-in tariff);
- ✓ No residual value (time horizon equals the economic lifetime of the plant) and no decommissioning costs
- ✓ The depreciation charge was calculated assuming an interest rate of 5% and 20 years for the pay-back time.

Investment costs	€/kW
50 kW	5,700
1000 kW	4,000

\+

Scenarios with Closed storage

Digestate cover	60 €/m^2

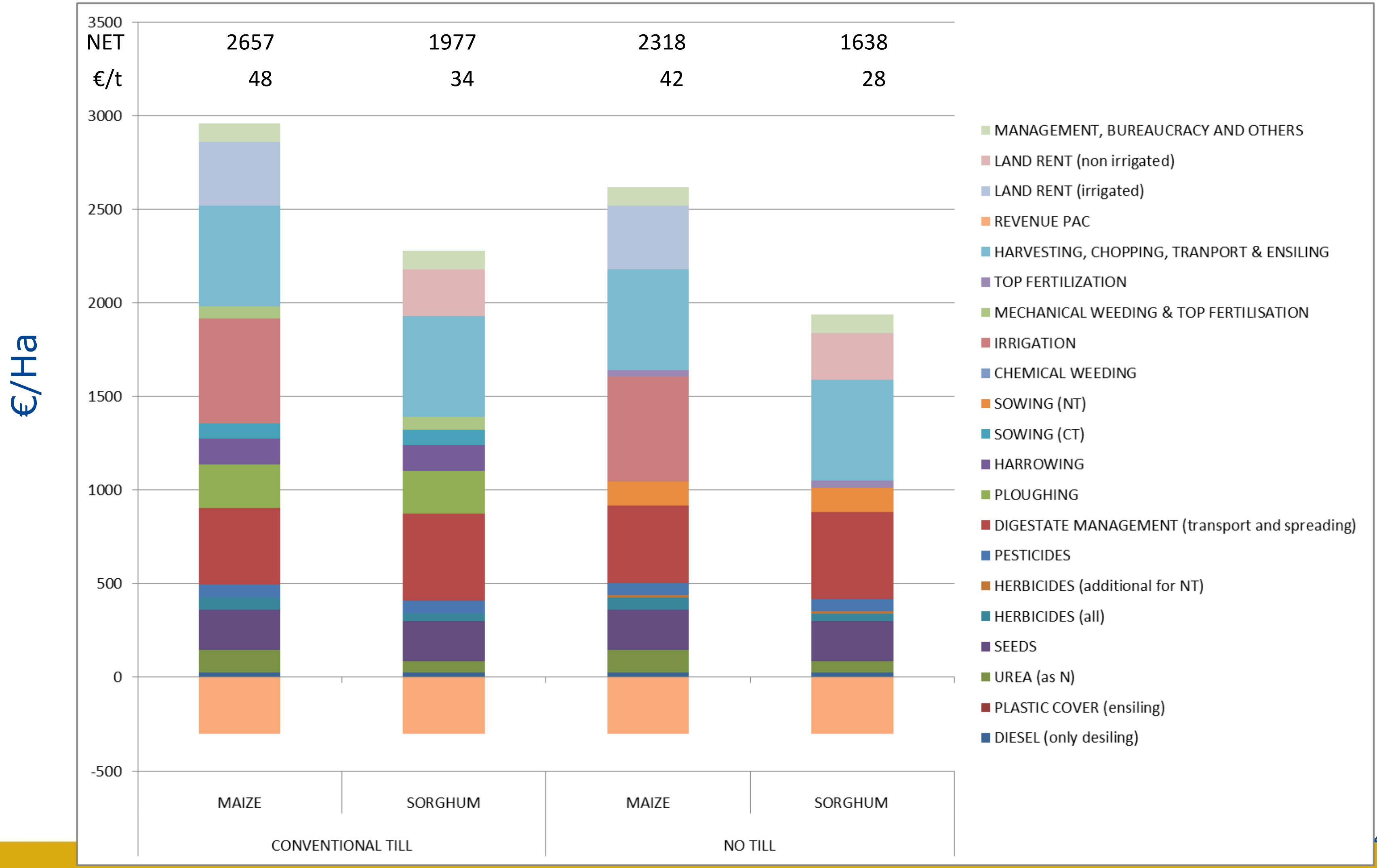
OPEX

- ✓ Operating costs include all the costs to operate and maintain (O&M) the plant:
  - ✓ labour costs
  - ✓ maintenance and repair of assets;
  - ✓ Cost of the substrate
  - ✓ insurance cost

O&M costs (€/year)	50 Kw	1,000 kW
Personnel*	9,125	36,500
Maintenance**	15,000	301,500
Insurance***	2,500	50,000
Feedstock	0	SEE NEXT SLIDE

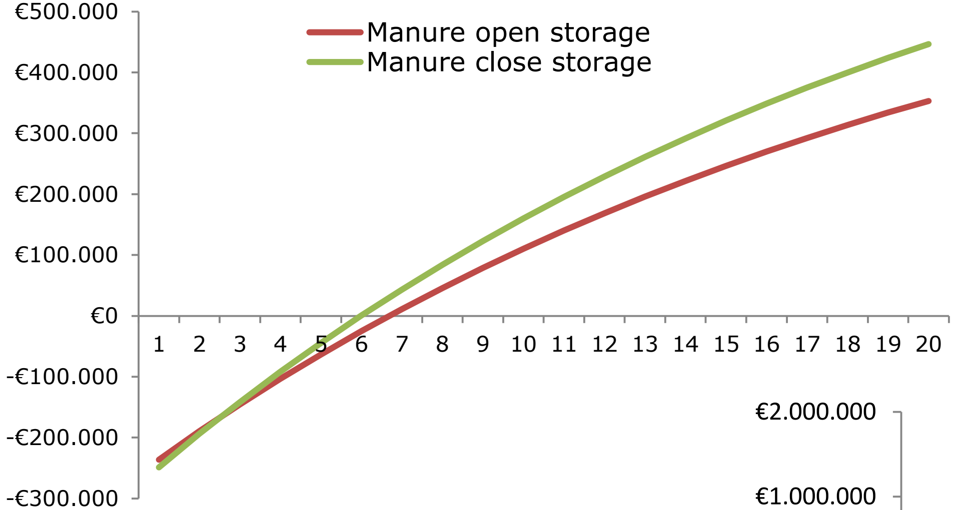
* 1h/d 50 kW, 4h/d 1MW (@25 €/h)
** 300 €/kW, Maintenance for desilaging machine is included in 1 MW plant scenarios
*** 50 €/kW

FEEDSTOCKS COSTS

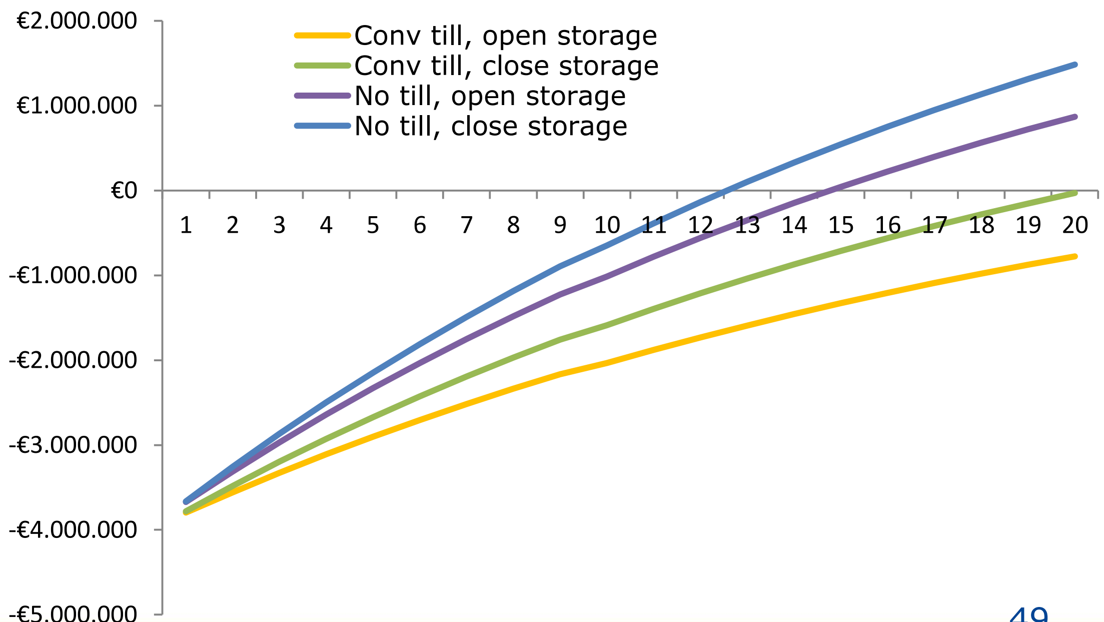


NET PRESENT VALUE (NPV)

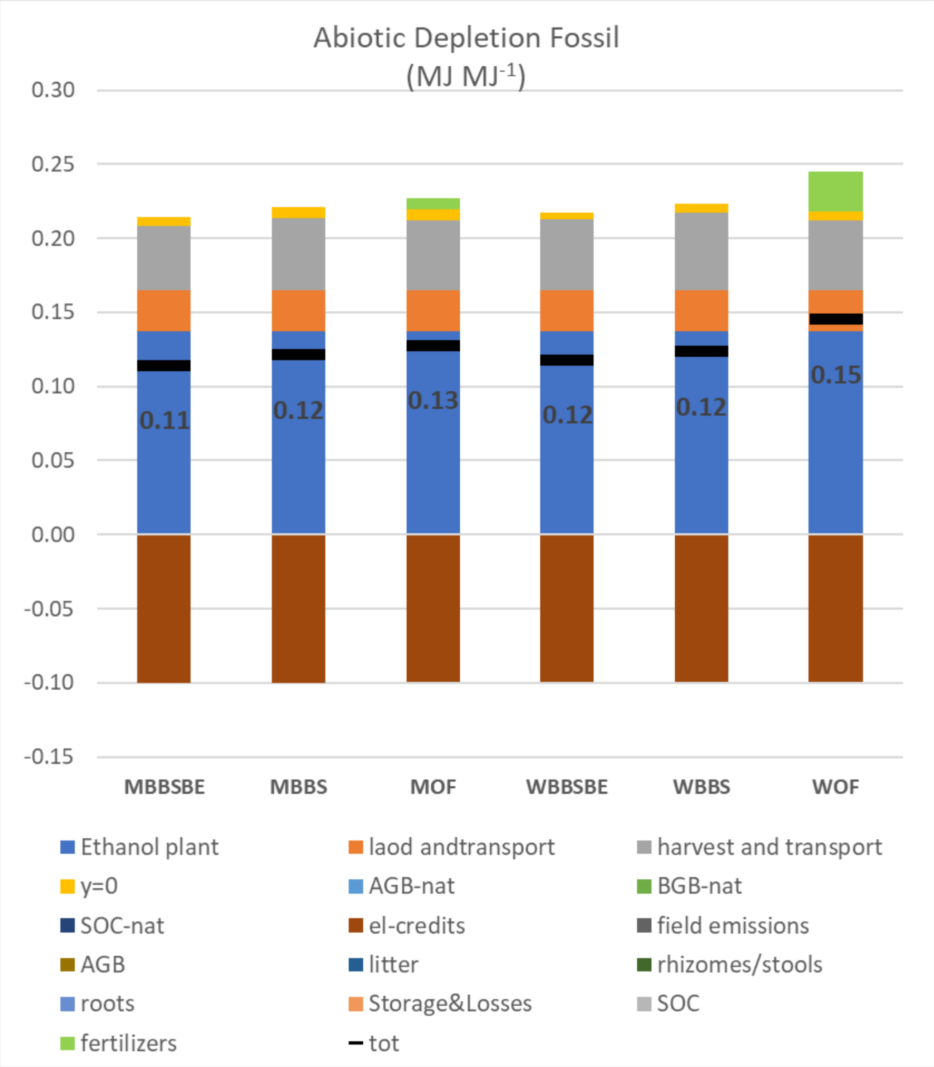
Manure

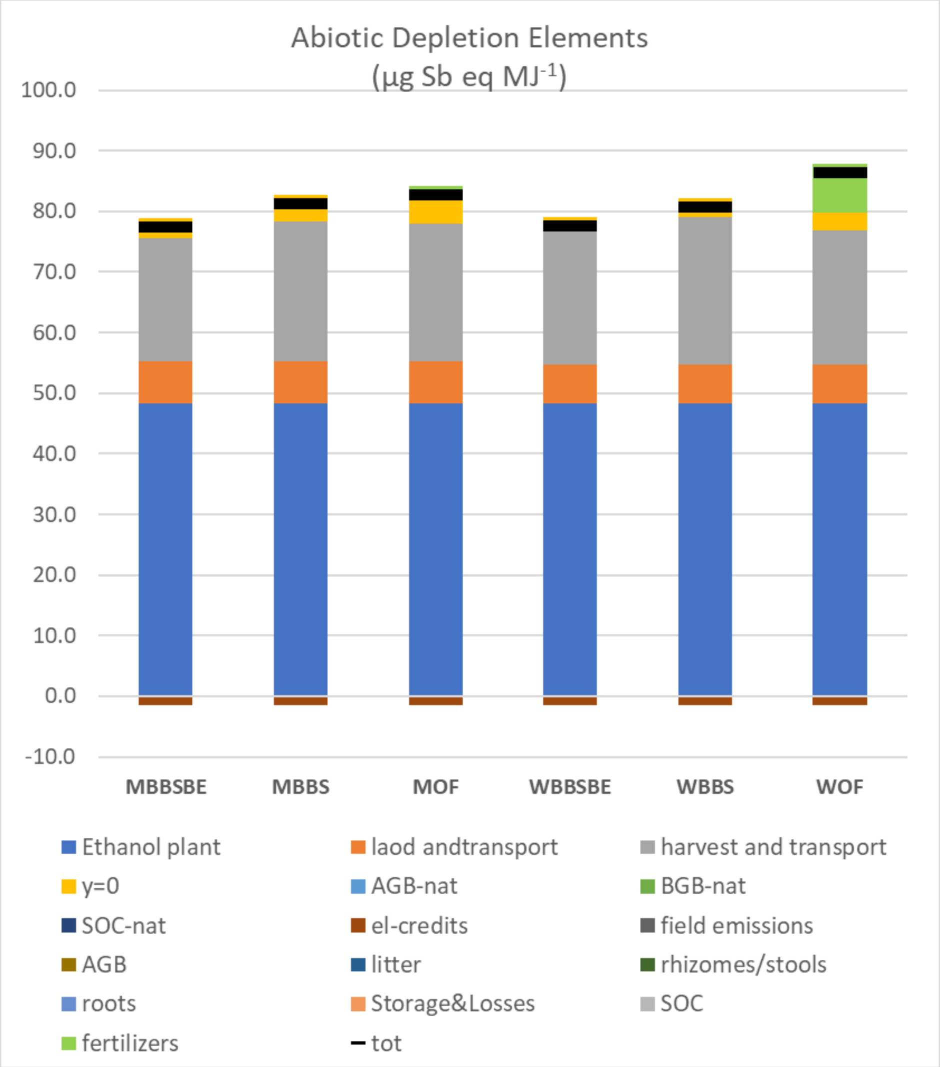


Manure + 30% Sorghum

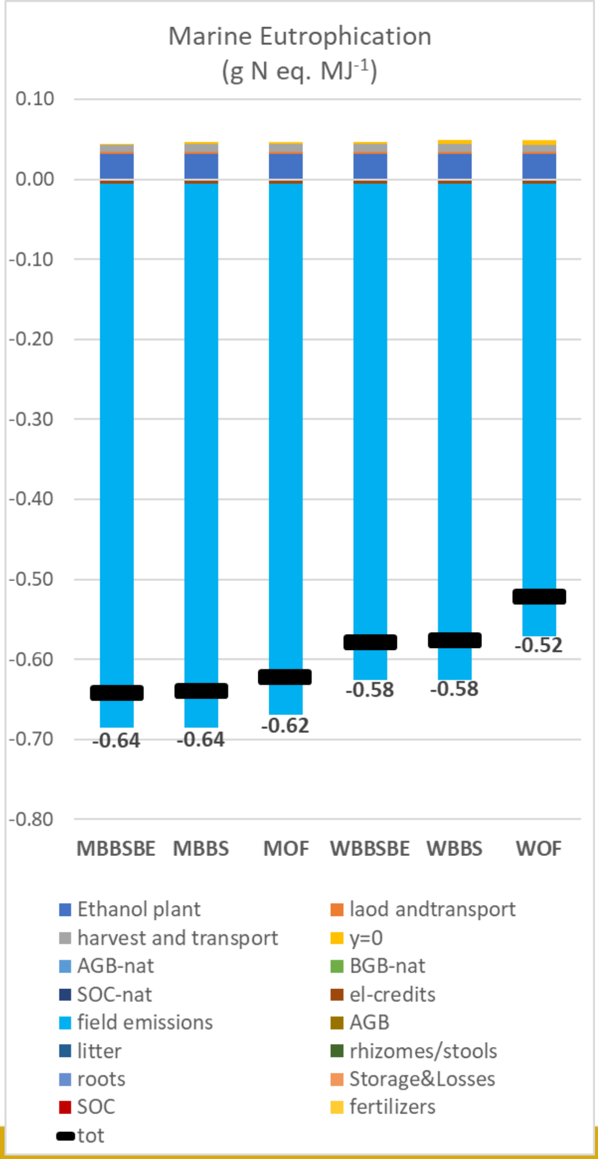


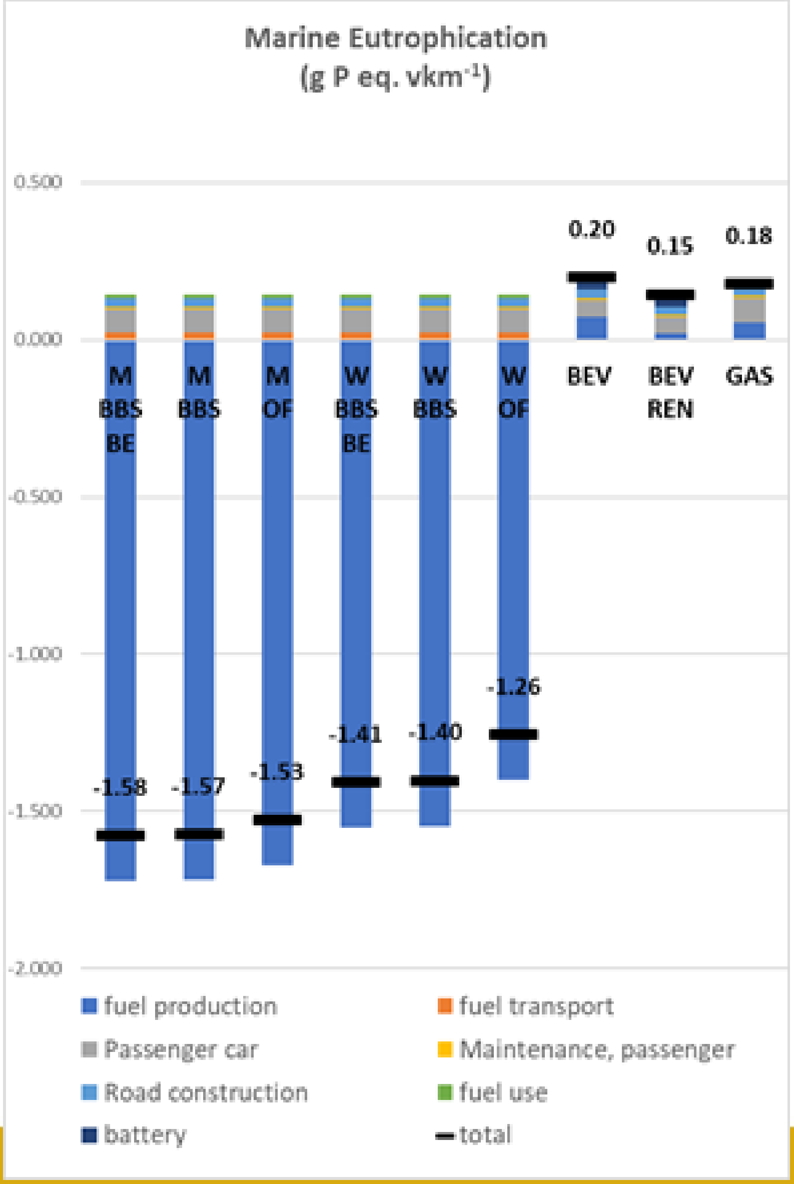
Resources depletion





Marine Eutrophication





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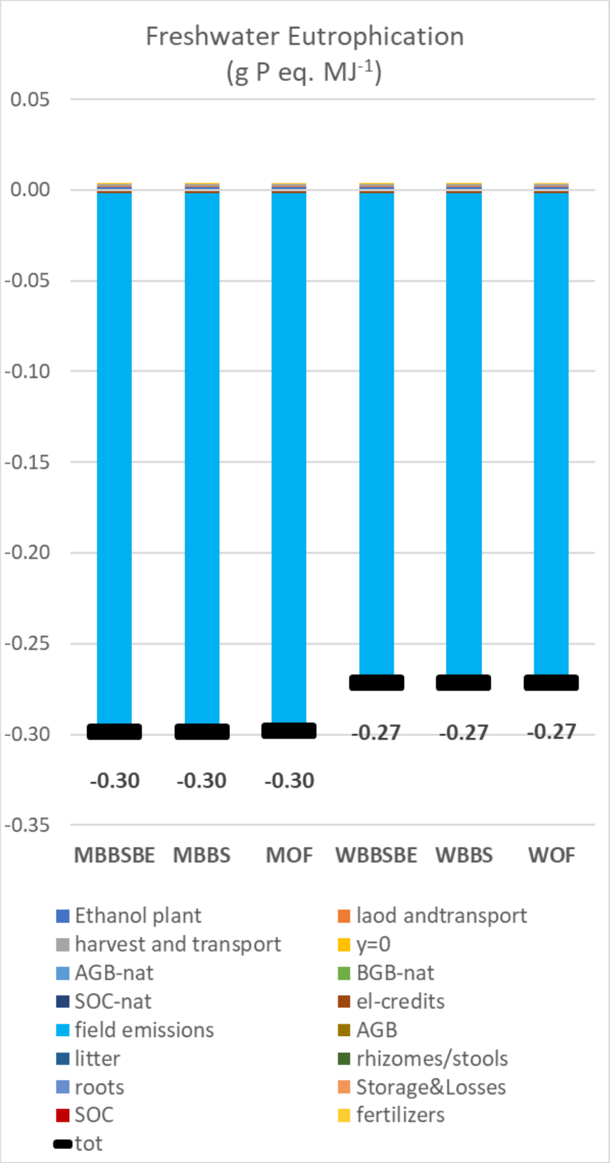
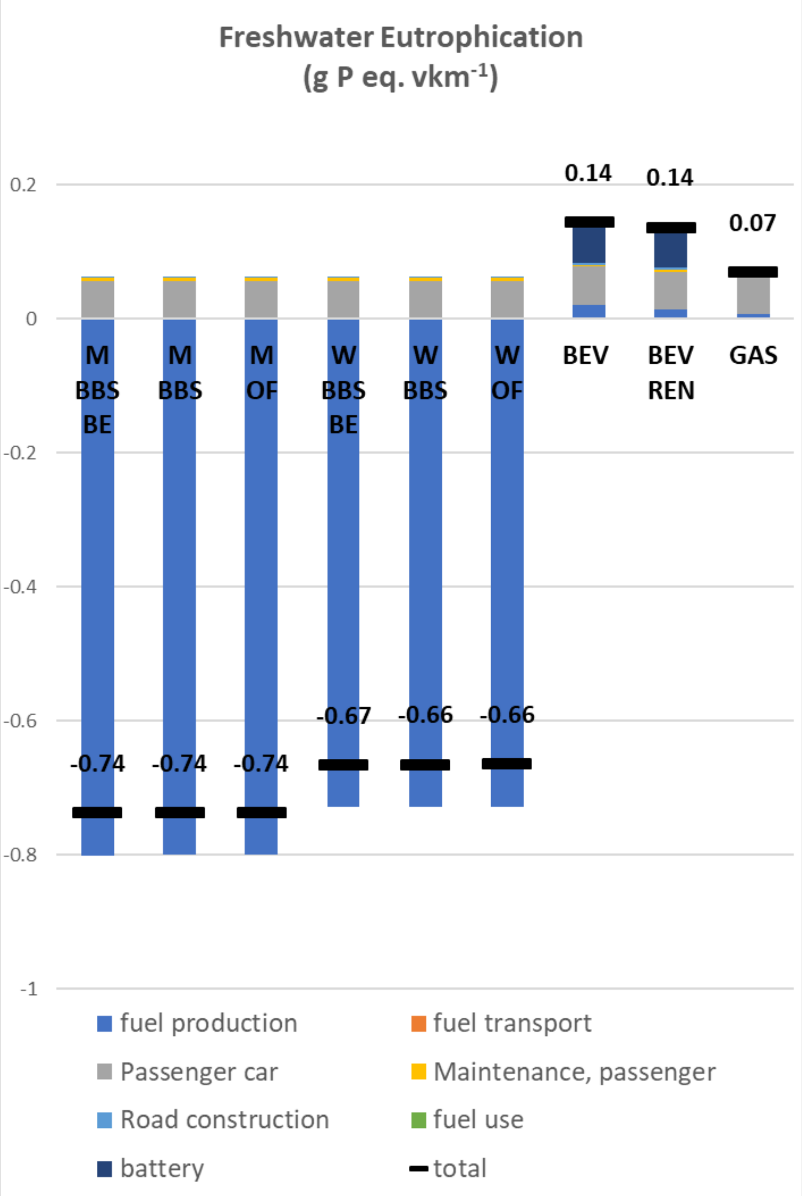
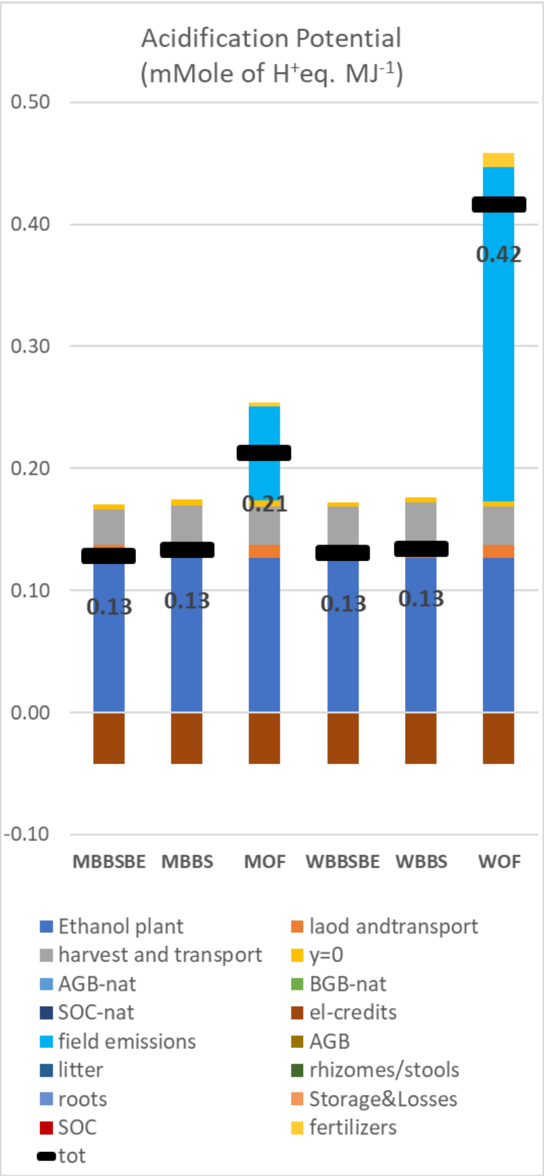
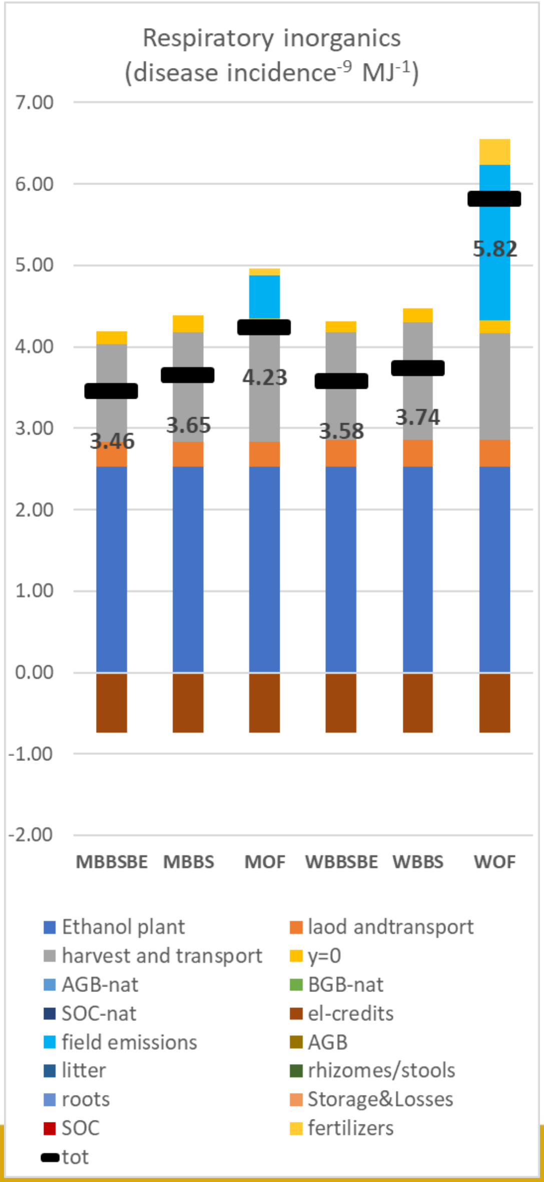
Freshwater Eutrophication

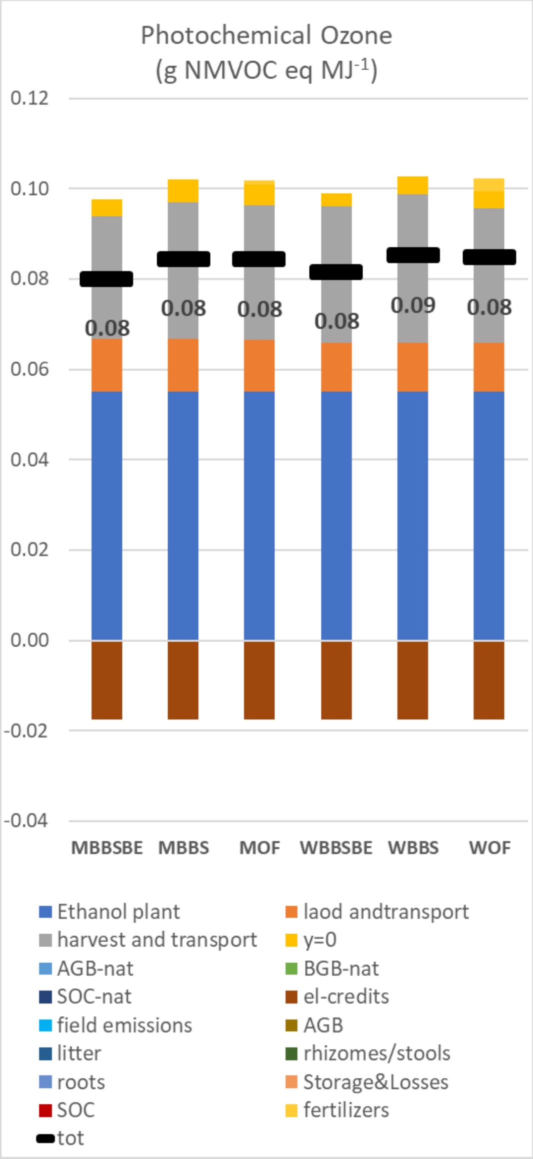




Airborne pollutants







INTERNAL RATE RETURN (IRR)

The **Internal Rate of Return (IRR)** is defined as the discount rate at which the NPV becomes zero.