European Commission

Expanding System Boundaries in Attributional LCA to Assess GHG Emissions and Climate Impacts of Advanced Biofuels and Bioenergy Pathways

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Joint Research Centre

Energy and Climate Challenges

The RED 2020 targets:

- decrease energy consumption by 20%
- increase the share of renewables to 20%
  (10% renewable energy in transport)

Energy and climate package post-2020

- 40% GHG reduction in 2030
- Calls for a range of alternative fuels for 2030, with special focus on 2G and 3G biofuels
- Wide coordination for large scale deployment of alternative fuels
- **Stable policy framework to attract investments**

NEW Energy Union – Sustainable Low-carbon economy

- Alternative fuels and clean vehicles
- Road transport and Renewable Energy package
- Achieve the 40% GHG reduction target

- **(indicative target) 0.5% of transport fuels from advanced biofuels in EU by 2020**

Biofuels and bioenergy from wastes and residues, potentials:

- Abundant, relatively cheap and widespread
- No competition with food or land
- Wastes have no or low iLUC
- Valorization of waste streams

> ➢ Mobilization of wastes and residues is essential but **all** the impacts of increased removal should be carefully assessed
>
> ➢ Policy decisions need to be backed up by a clear and comprehensive analysis of all associated environmental effects.

Attributional LCA is the tool often used for micro-level decision support or accounting.

*e.g. the **RED methodology** for accounting "supply-chain" GHG emissions accounting is a **simplified** A-LCA.*

→ could be one of the appropriate methodologies for policy **implementation** and **monitoring**

Consequential LCA is instead the appropriate methodology for policy analysis and meso/macro level decision support (i.e. large-scale analysis of consequences of a policy choice implementation)

→ ***Complex modelling frameworks***

An "Advanced" approach to attributional-LCA?

- Consequential thinking and advanced tools can be applied also to A-LCA studies:
  - For example, expanding the reference system to include the production o energy by a fossil source plus one or more development scenarios for the biomass without bioenergy (multiple "counterfactuals").
  - And using ecosystem models to calculate carbon pools development in agricultural or forest systems
- In addition to proper system design, this analysis can still provide relevant information on feedstocks, systems, configurations and management practices that carry potential environmental risks, highlighting particular red flags that will need to be looked at carefully

The purpose of our approach is to assess potential environmental risks (or benefits) deriving from deploying bioenergy systems as compared to other systems (including fossil-based ones).

The pathways we are analyzing:

Power generation

- Forest residues
  - 80 MW_{el} power plant
- Straw
  - 15 MW_{el} power plant
- Slurry-Biogas
  - 300 KW_{el} internal combust. engine

Heat

- Forest residues
  - Advanced log Stove
  - District Heating Plant
  - Domestic Pellet Stove

Biofuels

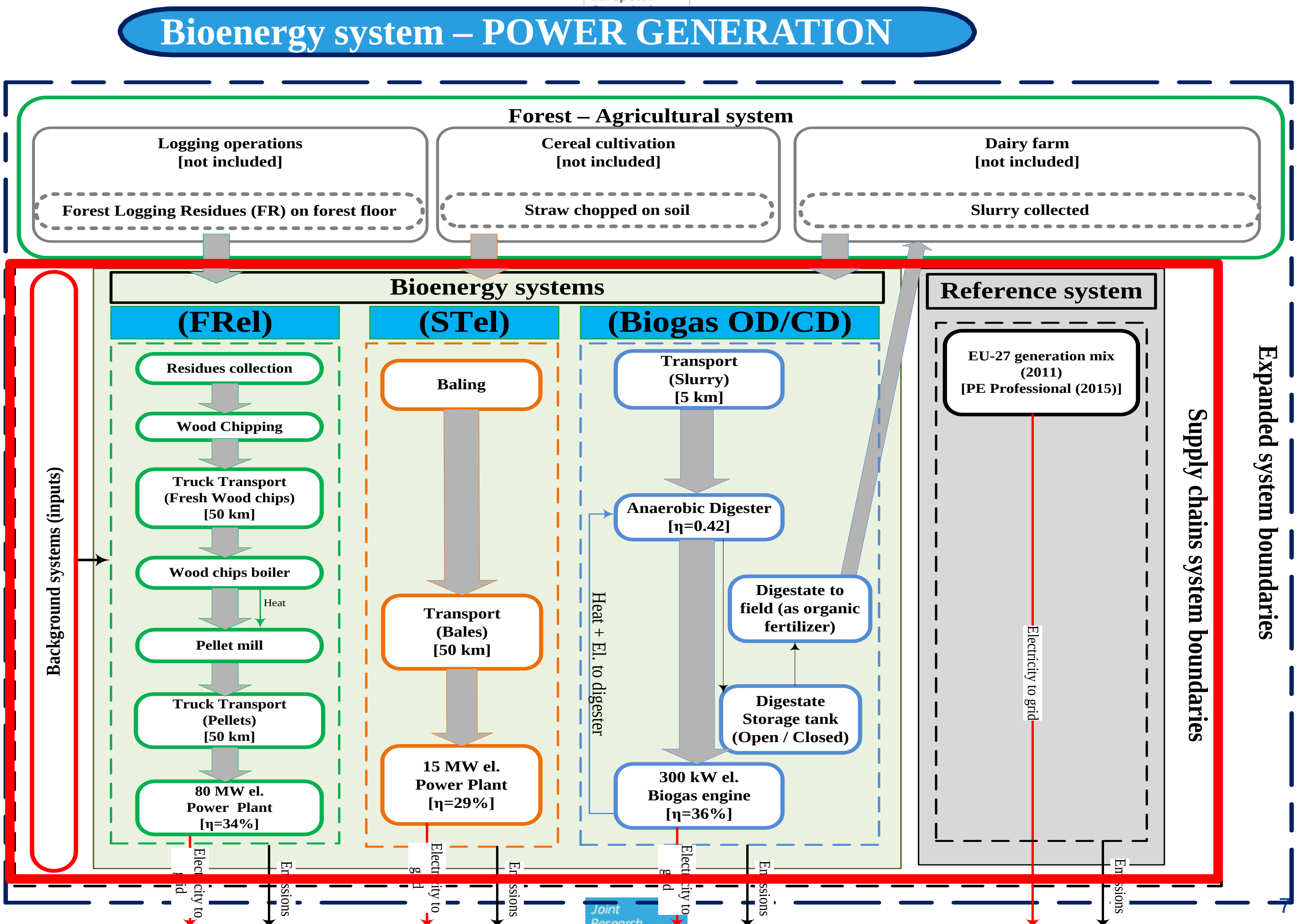
- Forest residues
  - FT-Diesel (based on a plant of 1 Mt dry matter/year in input. Circulating Fluid Bed pressurized at 25 bar)
- Straw
  - Ethanol (based on WtW v4 process with efficiencies from a modelled 60 Ktons/year ethanol plant)

Two-stage analysis:

1)supply-chain GHG emissions;

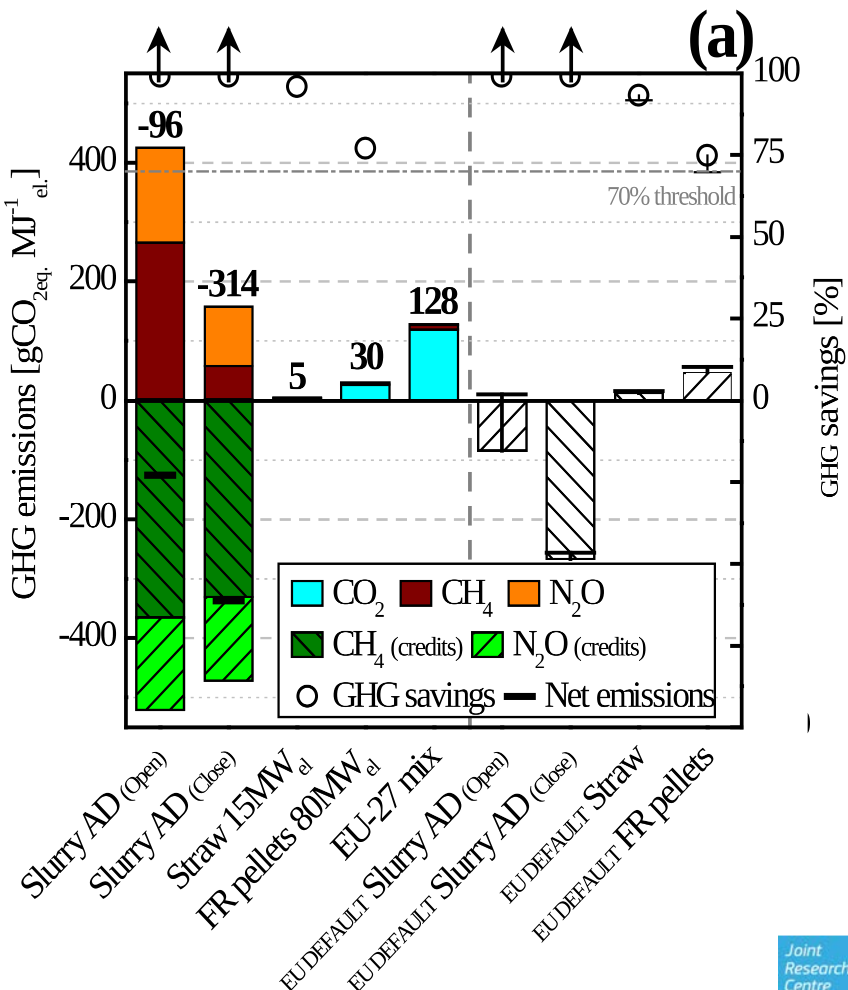
2)expanded system to include forest and soil systems;

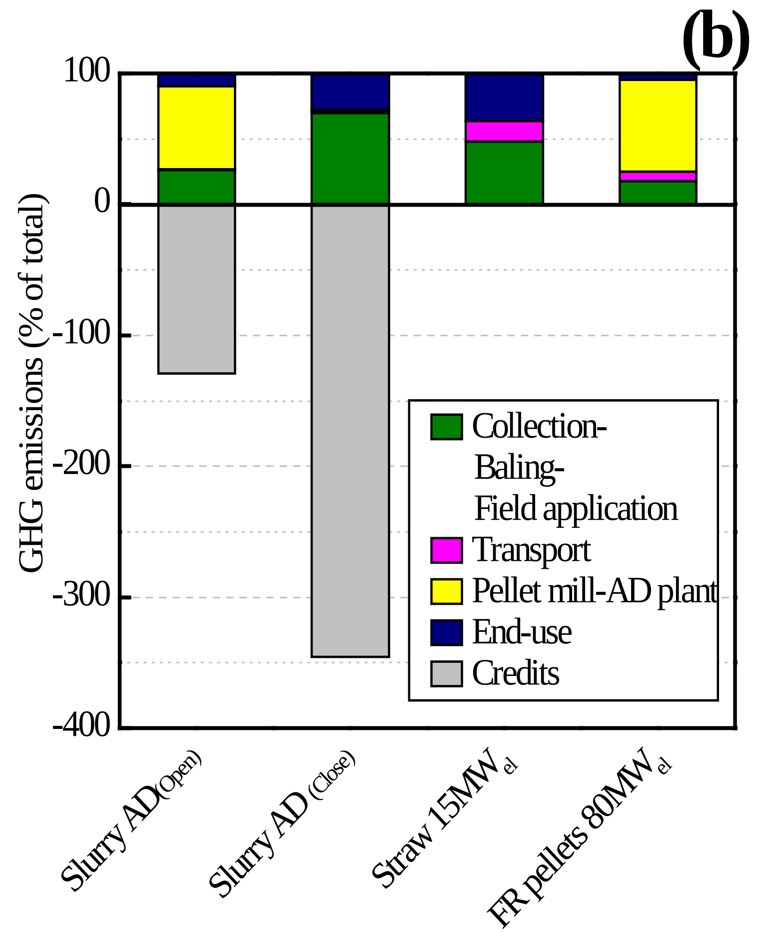
Stage 1) "Supply-chain" GHG emissions



Example of results

Bioenergy system – POWER GENERATION





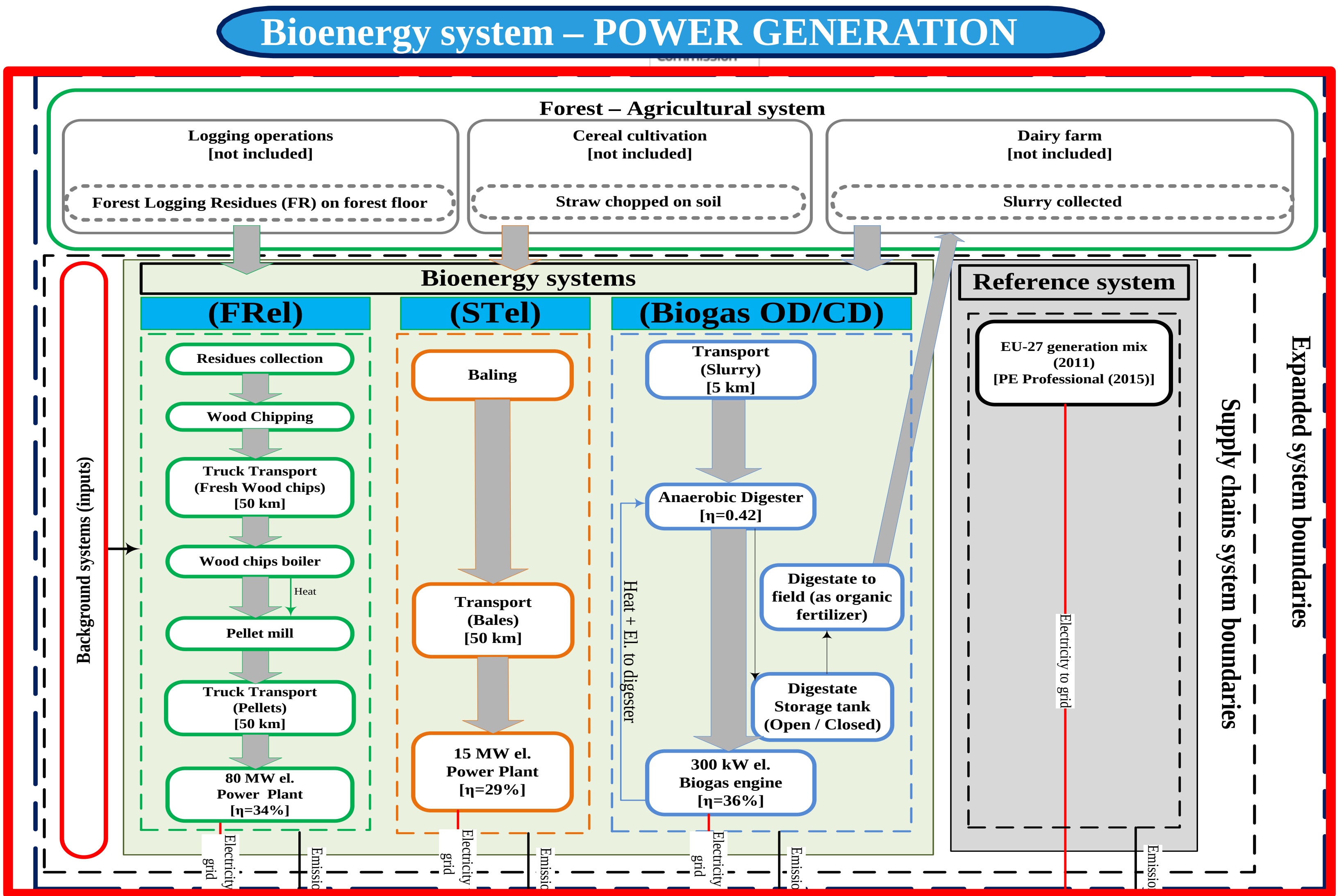
Points of concern in LCA of bioenergy (from residual biomass)

1. *Supply-chain* attributional LCA of bioenergy often overlooks, or excludes from system boundaries, the development of some important carbon pools, mainly related to **land use or management change** driven by bioenergy demand;

2. Many of these additional developments are time-dependent, bringing into play **transient emission profiles** which are dealt poorly by the "standard" GWP(100) metric;

3. Other climate forcers than WMGHG may have a significant mitigating impact on the overall climate impact of bioenergy. So we also wanted to look whether **other climate forcers, such as ozone precursors and aerosols,** may be significant or not for the case of the residual biomass considered. **Biogeophyisical forcers** may be relevant for certain feedstocks/systems but rarely for residual biomass.

Stage 2) "Expanding" system boundaries

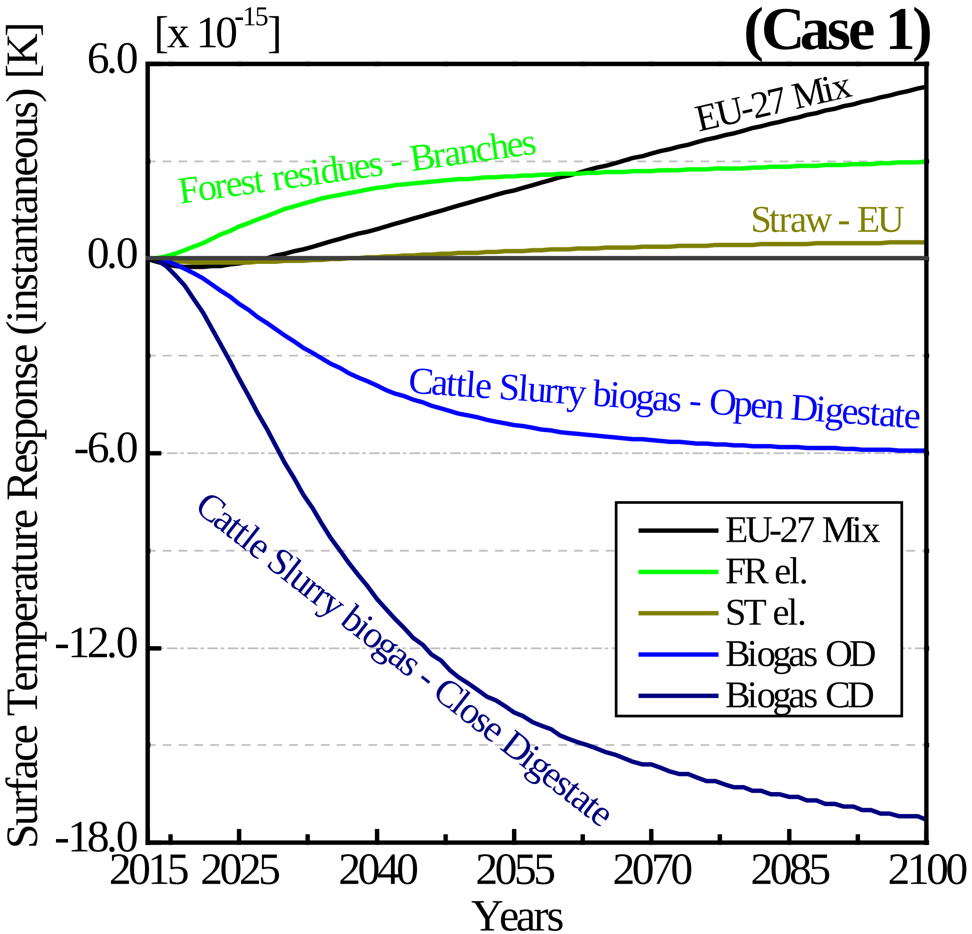


Impacts at mid-point Climate Change, Acidification, PM, Photochemical Ozone…

Results: Surface temperature Response

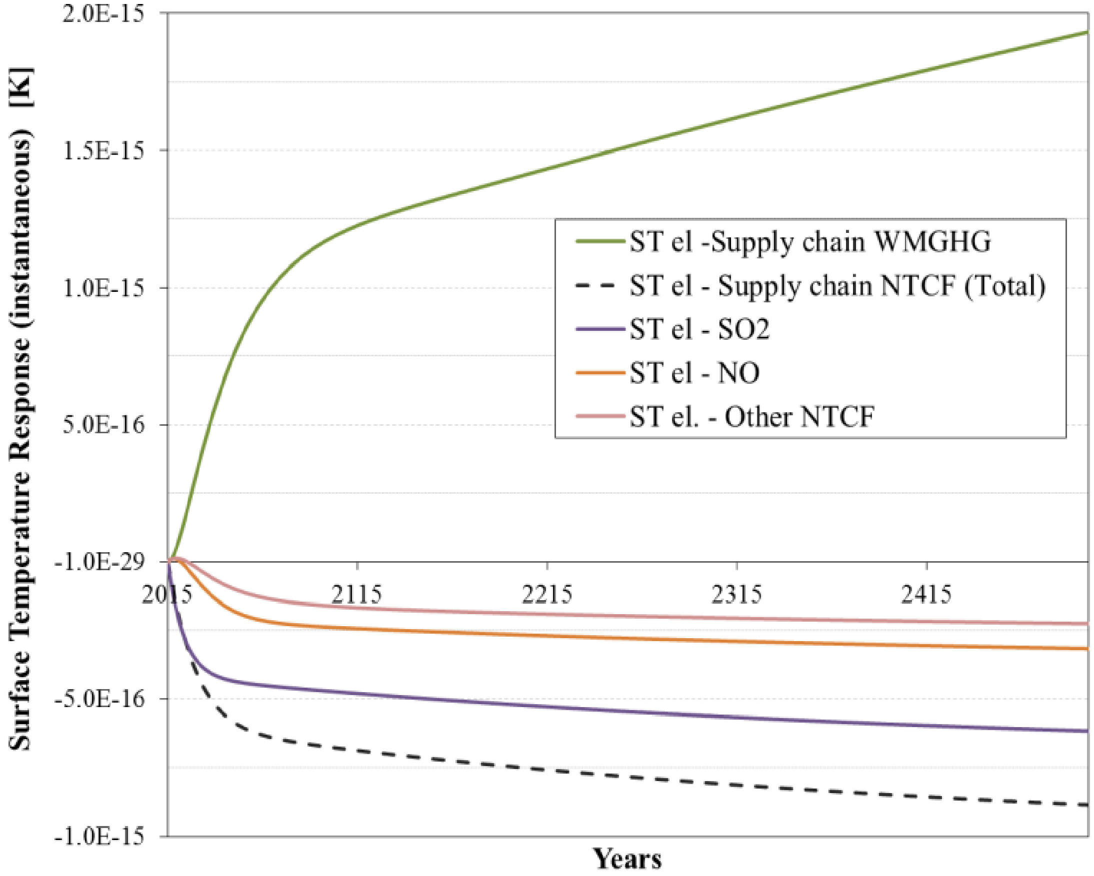
1. Power generation

Note: Results obtained applying AGTP model formulations from IPCC AR5, 2013. Including WMGHG (CO_2, CH_4, N_2O) and NTCF (NOx, CO, NMVOC, SO_2, BC, OC). Excluding infrastructure impacts.



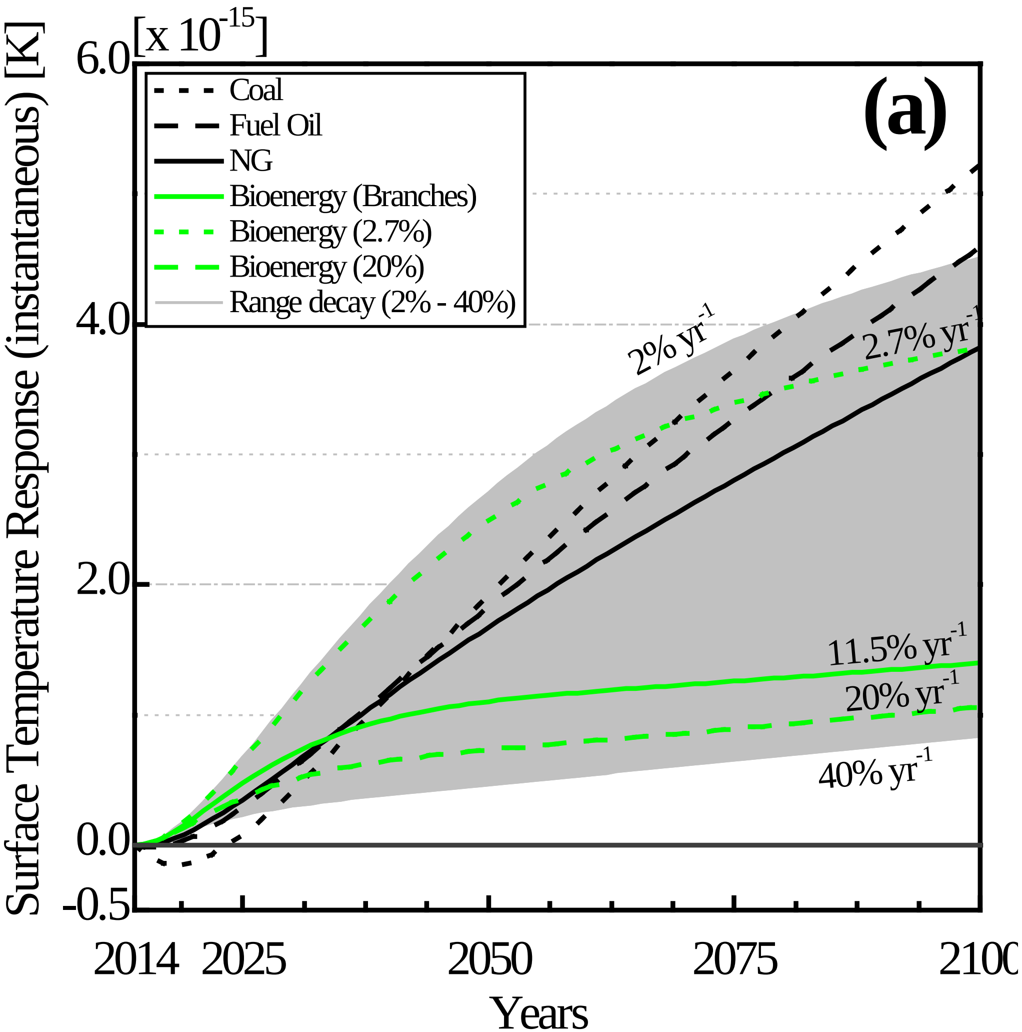
Results: Surface temperature Response

1. Power generation: WMGHG vs. NTCF (straw electricity)



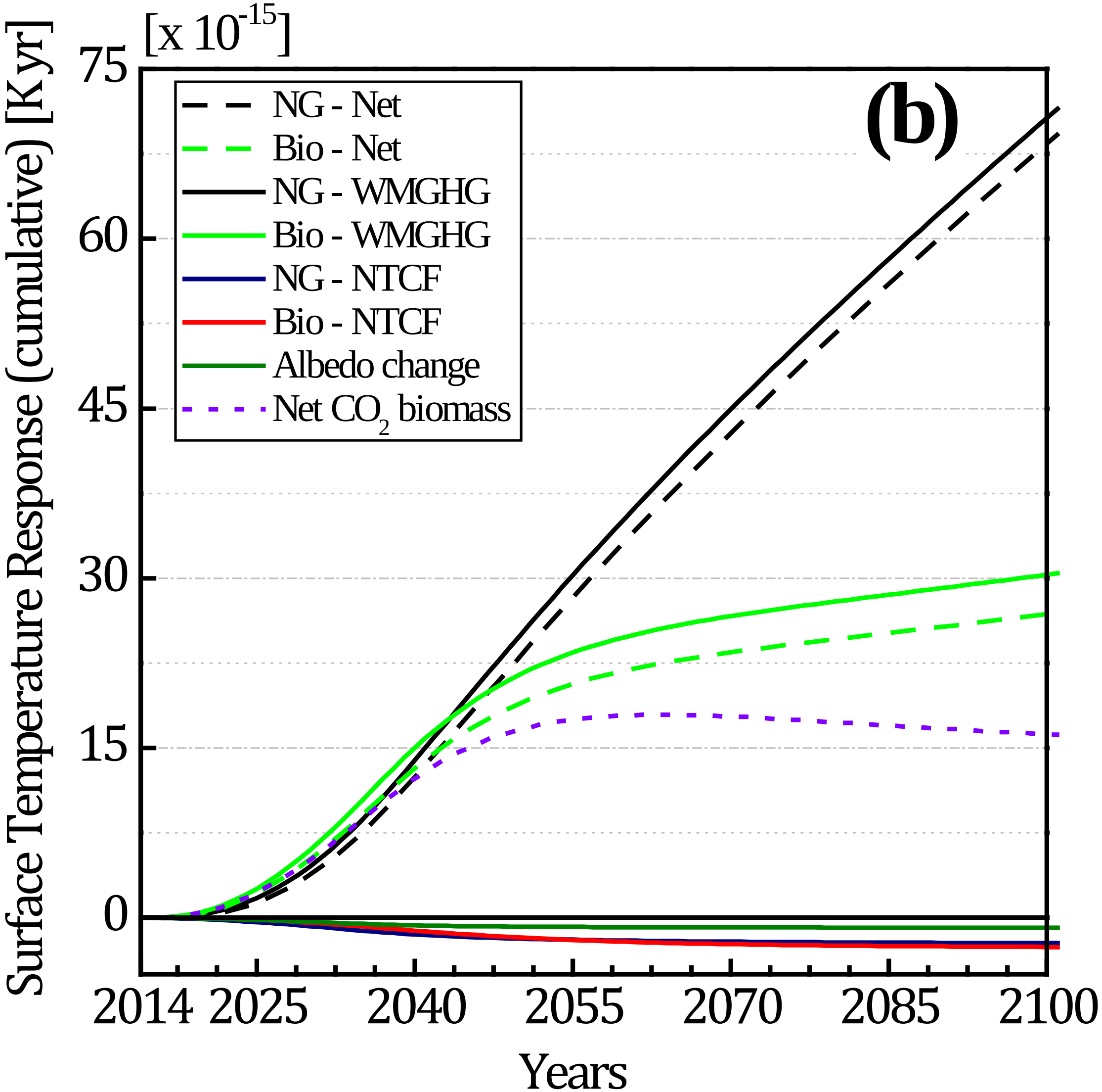
Results: Surface temperature Response

2. Heat generation (only pellet stove)



Results: Surface temperature Response

2. Heat generation (WMGHG vs NTCF vs Albedo)

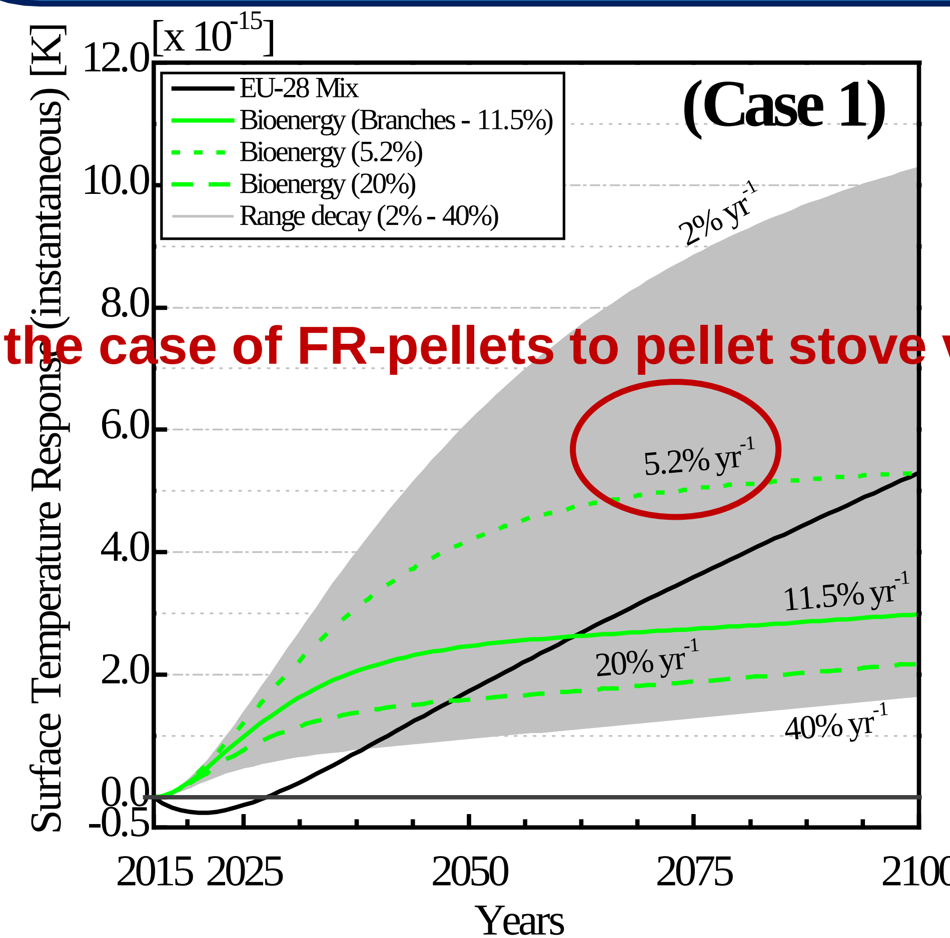


Stress test - Variability: Logging residues

Note: Results obtained applying AGTP formulations from IPCC AR5, 2013. Including WMGHG (CO_2, CH_4, N_2O) and NTCF (NOx, CO, NMVOC, SO_2, BC, OC). Excluding infrastructure impacts.

Decay rates (k) apply in an exponential decay of forest residues on the forest floor:
M(t) = M(0) * Exp(-k * t)

Bioenergy system – POWER GENERATION



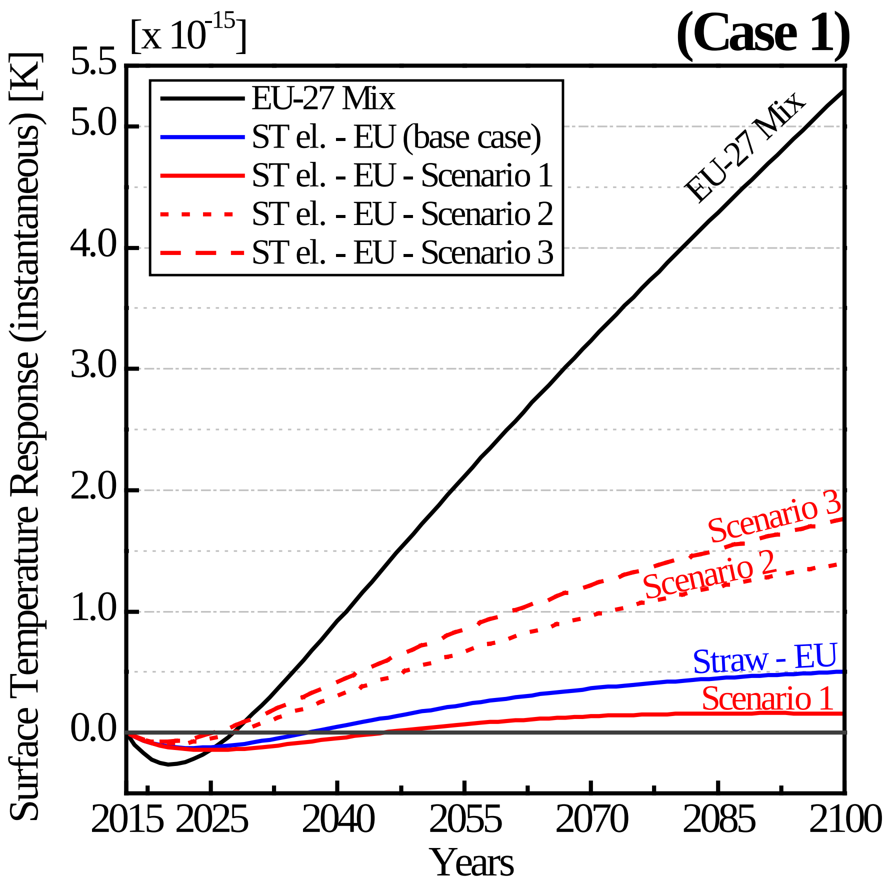
(2.7% in the case of FR-pellets to pellet stove vs. NG boiler)

Stress test - Sensitivity : straw

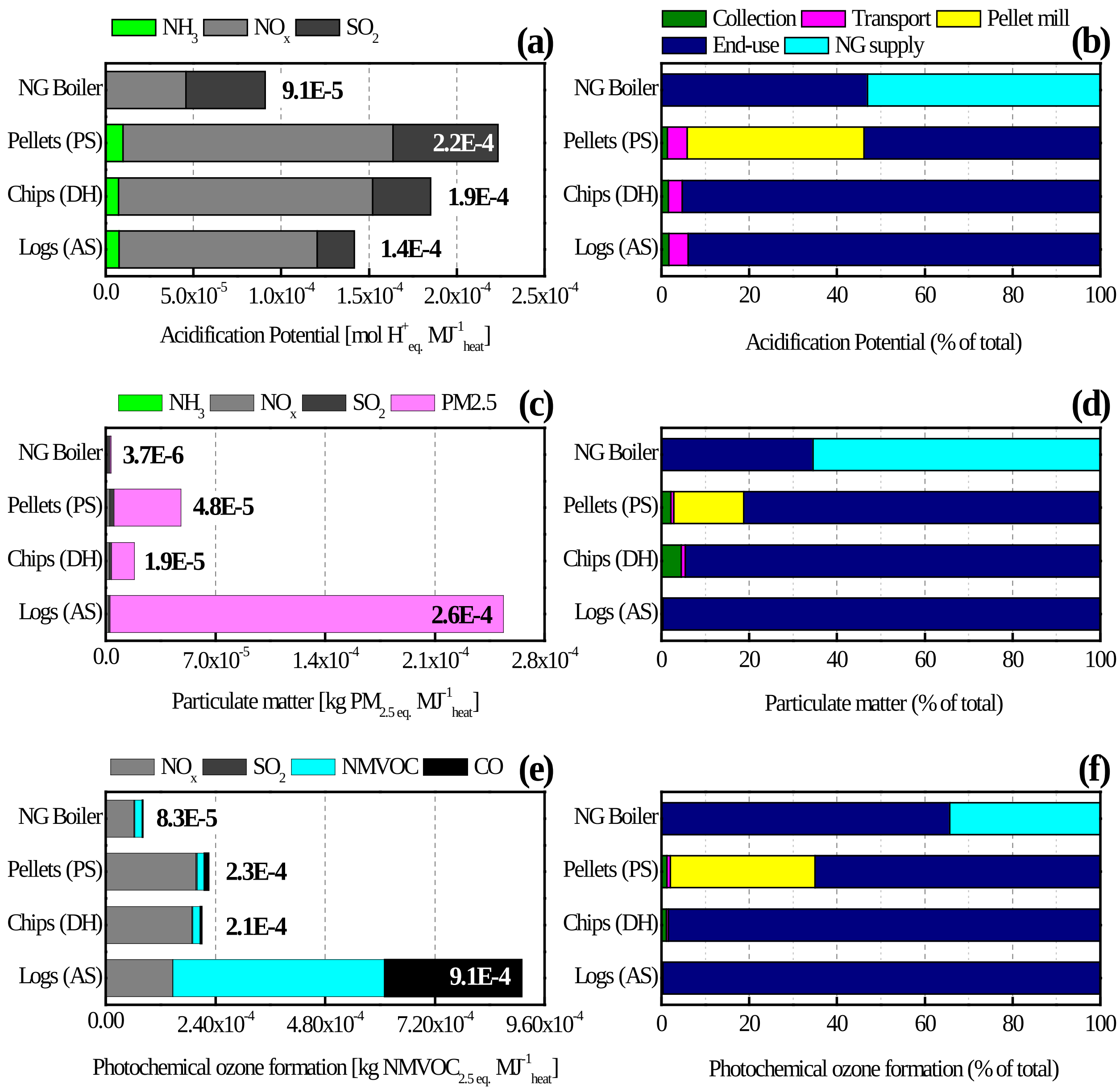
Note: Results obtained applying AGTP formulations from IPCC AR5, 2013. Including WMGHG (CO_2, CH_4, N_2O) and NTCF (NOx, CO, NMVOC, SO_2, BC, OC). Excluding infrastructure impacts.

Scenario 1) No additional mineral fertilization to compensate nutrients removal by straw (N, P, K) + N2O credits for removal of straw-N; Scenario 2) Additional mineral fertilization and no loss of yield; Scenario 3) Additional mineral fertilization and loss of 8% of long-term yield accounted with an iLUC factor (Ref: IFPRI for cereals) + additional emissions for cultivation of the additional wheat

Bioenergy system – POWER GENERATION



Other environmental impacts are relevant - example for forest residues to heat (Giuntoli et al. 2015)



Example of electricity generation from biogas from manure, maize and sorghum

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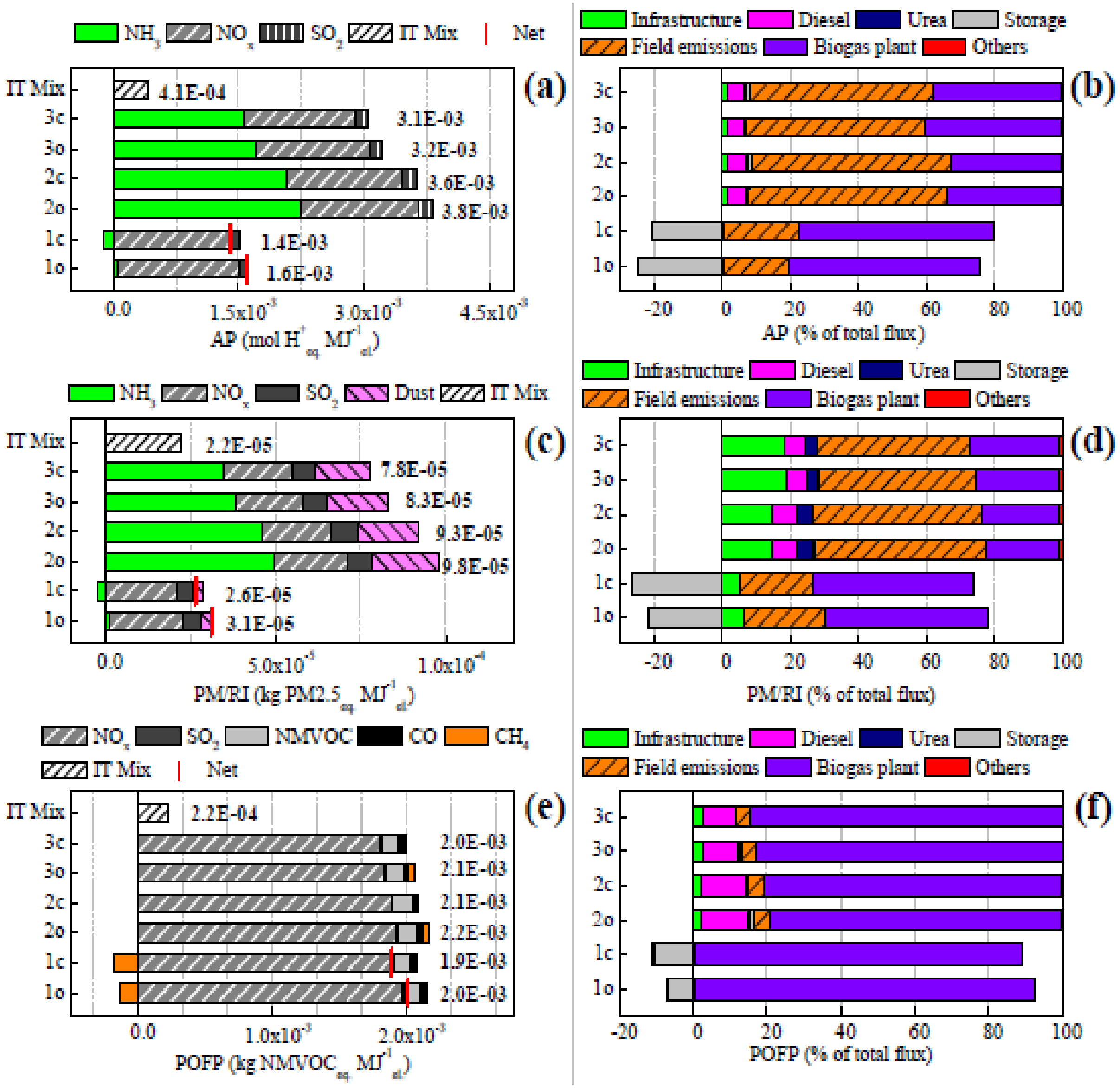


Non-standard environmental impacts

We have looked only <u>qualitatively</u> into potential impacts (or benefits) of some biomass <u>residues</u> removal.

(Baselines = left on soil except prunings)	Total GHG emissions compared to fossil fuels	SOC	Nutrients Pool	Soil health / fertility	N_2O, CH_4	Pests, diseases, odours	Bio-diversity	Water	Displacement effects
Straw	☺☺☺	☹☹☹	☹☹☹	☹☹☹	☺☺	☺☺	☹☹	☹	☹☹
Pruning residues	☺☺☺	☹☹☹	☹☹☹	☹☹☹	☺	☺☺	☹☹	☹☹	☹
Manure	☺☺☺	☹☹☹	☺	☺☺	☺☺☺	☺☺☺	☹☹	☹☹	No alternative use
Forest residues	Short term: ☹☹ Long-	☹☹	☹☹	☹☹	😐	☺☺	☹☹☹	😐	No alternative use

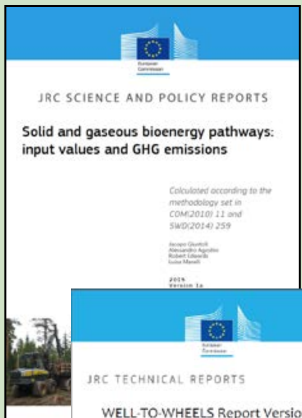
Conclusions - results

- ✓ **Supply GHG savings >75%** for all the analyzed pathways;
- ✓ Application of AGTP helps to interpret transient emission profiles: **by 2100 all bioenergy pathways considered achieve a mitigation of temperature increase compared to the chosen fossil reference**, albeit of different magnitude depending on the feedstock and pathway considered;
- ✓ **Caution** is needed when exploiting **logging residues with slow decay rates**;
- ✓ Biogas systems using slurry can **mitigate global warming in absolute terms** by decreasing GHG emissions from common agricultural practices;
- ✓ WMGHG dominate for FR but NTCF mitigate fully the warming for straw for the first 20 years and continue to mitigate about 50% of the total long-term impact;
- ✓ Additional environmental impacts usually worse than fossil alternative (eutrophication, PM, biodiversity etc…)

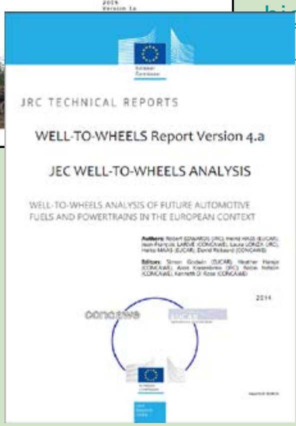
CONCLUSIONS - methodology

- Results that focus only on supply-chain GHG emissions and WMGHG are giving an incomplete information, e.g.:
  - excluding land use and C-stocks will largely underestimate total STR
  - Non considering NTCF overestimates warming impacts in some bioenergy systems.
  - and biogeophysical forcers are also important in certain systems (e.g. albedo in boreal, snow-covered forests)
- In addition to proper system design, “Advanced” A-LCA can still provide precious information about the potential impacts of bioenergy systems, avoiding the use of complex and time-consuming tools such as large integrated modelling suites.

Thank you for your attention!

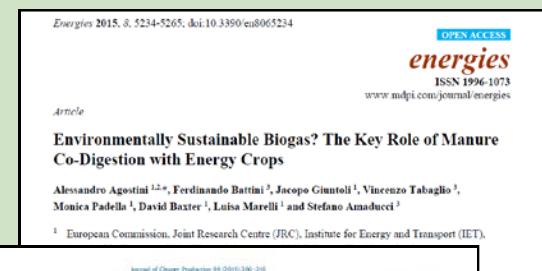


Giuntoli et al., 2015, JRC Database of input data and GHG emissions for solid and gaseous biomass for power and heat: http://bookshop.europa.eu/en/solid-and-gaseous-bioenergy-pathways-pbLDNA27215



JEC Well-to-Wheels study: http://iet.jrc.ec.europa.eu/about-jec/downloads

Agostini et al., *Environmentally Sustainable Biogas? The Key Role of Manure Co-Digestion with Energy Crops,* Energies 8 (2015) 5234 – 5265.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Article

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

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[1] European Commission, Joint Research Centre (JRC), Institute for Energy and Transport (IET).

Giuntoli et al., *Domestic heating from forest logging residues: environmental risks and benefits*, **Journal of Cleaner Production 99 (2015) 206 – 216.**


Journal of Cleaner Production

Domestic heating from forest logging residues: environmental risks and benefits

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ABSTRACT

Alternative Fuels project:
https://ec.europa.eu/jrc/alfa

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