Life Cycle Assessment of Greenhouse Gas Balances in Irish Short Rotation Forestry

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Contents

- ShortFor project overview
- Life cycle assessment (LCA) project definition
- LCA framework, materials & methods
- LCA assumptions
- Biomass yields & project results to-date
- Conclusion – LCA work remaining

Project overview

- Context:
  - Assess the environmental impacts of Short Rotation Forestry (SRF) biomass for renewable bioenergy.

- SRF definition:
  - In this project SRF is confined to single stem species suitable to Irish climate and soil conditions.
  - Plantations managed over rotations of 10-15 years.
  - Minimum planting density of 2,500 stems ha^{-1}.
  - Potential Irish SRF genera: Eucalyptus, Italian Alder, Hybrid aspen & Poplar clones. As specified in the DAFM 2014-2020 “Forestry for Fibre” Grant and Premium Categories.

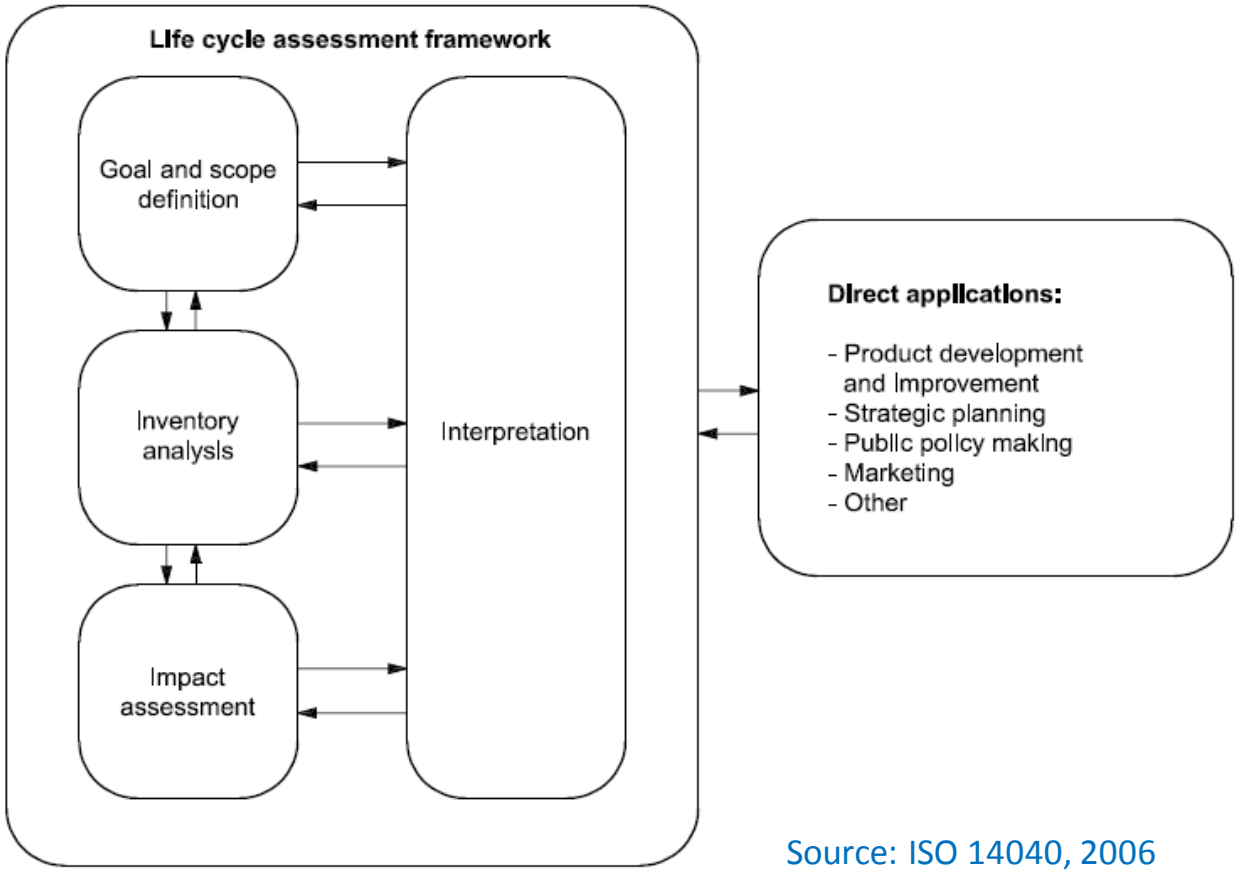
ShortFor: LCA - project definition

- LCA context:
  - Measure the environmental impact of SRF biomass for bioenergy, by examining the GHG balance of the material and energy inputs and outputs within a defined system boundary.

- Scope of current LCA study:
  - SRF: Eucalyptus nitens biomass (stem, wholetree, stump) over 10 year rotations.
  - Reference system: Potentially available biomass for bioenergy from Sitka spruce (SS) forestry, i.e., pulpwood from thinnings and clearfell, forest residues, and stumps.
  - Biomass life cycle: cradle-to-gate (nursery to power plant gate).
  - The functional unit (FU), a quantitative measure of the functions that the product or service provide, for this study is 1 ha of biomass converted to woodchip (m^3 loose volume (l.v.)).

LCA framework and applications

- LCA is a method of comparing products and services using the framework outlined below, which can identify environmental impacts attributable to resource consumption, emissions and wastes (Pennington et al, 2004).
- The LCA is usually conducted via specialised software tools and databases, e.g. openLCA v1.5 and ecoinvent v3.2, respectively.



Source: ISO 14040, 2006

LCIA methods

- **ReCiPe Midpoint (H) = GWP over 100 years**

"The main objective of the ReCiPe method is to provide a method that combines Eco-Indicator 99 and CML, in an updated version" (GreenDelta, 2015).

ReCiPe distinguishes two levels of indicators:

1. Midpoint indicators = environmental impact characterisation
   - radiative forcing
   - PM10 concentration
   - ozone concentration

2. Endpoint indicators = the following characterisation:
   - damage to human health (DALY)*
   - damage to ecosystems
   - damage to resource availability

*DALY = YLD (years lived with disability) + YLL (years of life lost)

Materials & Methods

- **LCA software tools**: openLCA v.1.5, MS Excel.
- **LCA data:** EcoInvent v.3.2, literature on Irish and international forest bioenergy LCA.
- Biomass harvest and combustion options for:

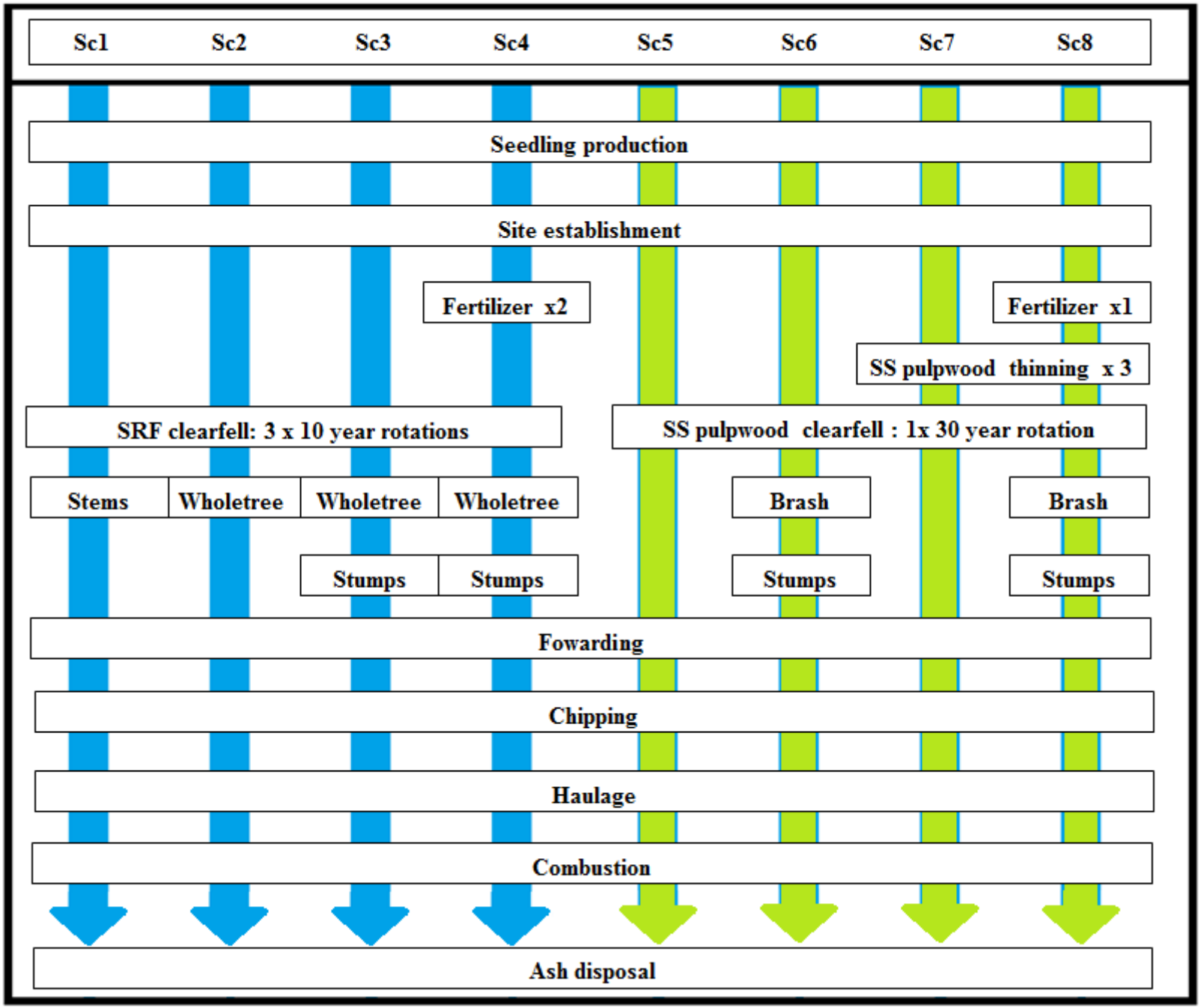
LCA scenarios:

1. SRF stem-only
2. SRF whole-tree
3. SRF whole-tree + stump
4. SRF whole-tree + stump + N, P, K fertilizer
5. SS clearfell pulpwood
6. SS clearfell pulpwood, brash + stump
7. SS thinning + clearfell pulpwood
8. SS thinning + clearfell pulpwood, brash + stump, +N, P, K fertilizer

LCA Assumptions

1. Aboveground biomass harvesting is 98% mechanized cut-to-length (CTL), 2% manual power sawing.
2. All biomass is left to season in the forest to dry to 45% moisture content.
3. SRF/*E. nitens* biomass yields based on literature, solid over bark (o.b.)
4. Irish grown E.nitens basic density = 435 kg m^{-3}
5. Irish grown Sitka spruce (SS) basic density = 380 kg m^{-3}
6. Solid biomass to woodchip/hogfuel conversion factors are based on Irish data.
7. SRF biomass yields for each rotation are the same.
8. SS biomass yields based on GROWFOR modelling of Dooary, Co. Laois site.
9. SS available biomass for bioenergy consists only of thinning and/or clearfell pulpwood (7-13 cm diameter), all other roundwood goes to sawmills.
10. Combustion of biomass takes place at Edenderry Power (EPL), with ash disposal to local landfill.
11. Transport of machinery and materials is included in each life cycle process.
12. Upstream supply chains for materials, machines, and infrastructure per Ecoinvent v3.2 are included.
13. GHG balance related to direct land use change (LUC) is included, indirect LUC is not.

LCA system boundary



SRF harvesting operations: stems, whole-tree, and stumps

SRF and SS biomass yields (solid m^3 o.b.)

SRF Assortments	SRF stem-only (m^3 ha^{-1})	SRF wholetree (m^3 ha^{-1})	SRF stump[3] (m^3 ha^{-1})	Total SRF wholetree & stump biomass (m^3 ha^{-1})
Clearfell rotation #1 (10 yrs)	200	240	27	267
Clearfell rotation #2 (20 yrs)	200	240	27	267
Clearfell rotation #3 (30 yrs)	200	240	27	267
Total Clearfell - 3 rotations	**600**	**720**	**81**	**801**

SS Assortments	SS totals: above & belowground biomass (m^3 ha^{-1})	SS Roundwood (14 - > 20 cm) (m^3 ha^{-1})	SS Pulpwood (7 - 13 cm) (m^3 ha^{-1})
SS Thin #1 (18 yrs)	50	20	30
SS Thin #2 (22 yrs)	50	31	19
SS Thin #3 (26 yrs)	50	37	13
SS Thin total			**62**
SS Clearfell (30 yrs)	521	503	**18**
SS Thin x3 + Clearfell at 30 yrs	**671**	**591**	80
SS clearfell brash[1]	**156**	=>	**86**
SS clearfell stump[2]	**115**	=>	**48**
Total biomass (m^3 ha^{-1}) 1x30 yr. rotation	**942**		**214**

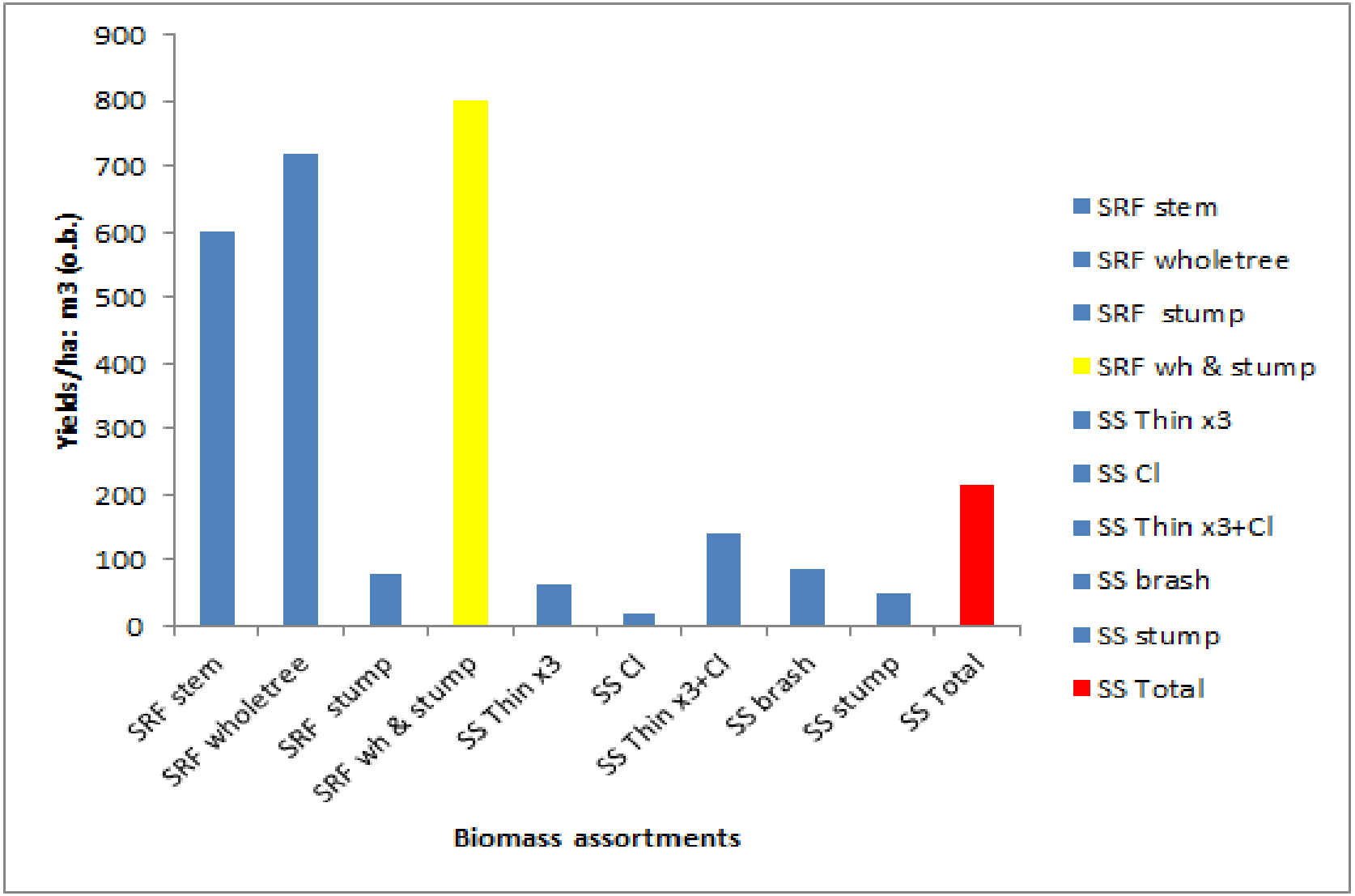
*ABG = Aboveground biomass

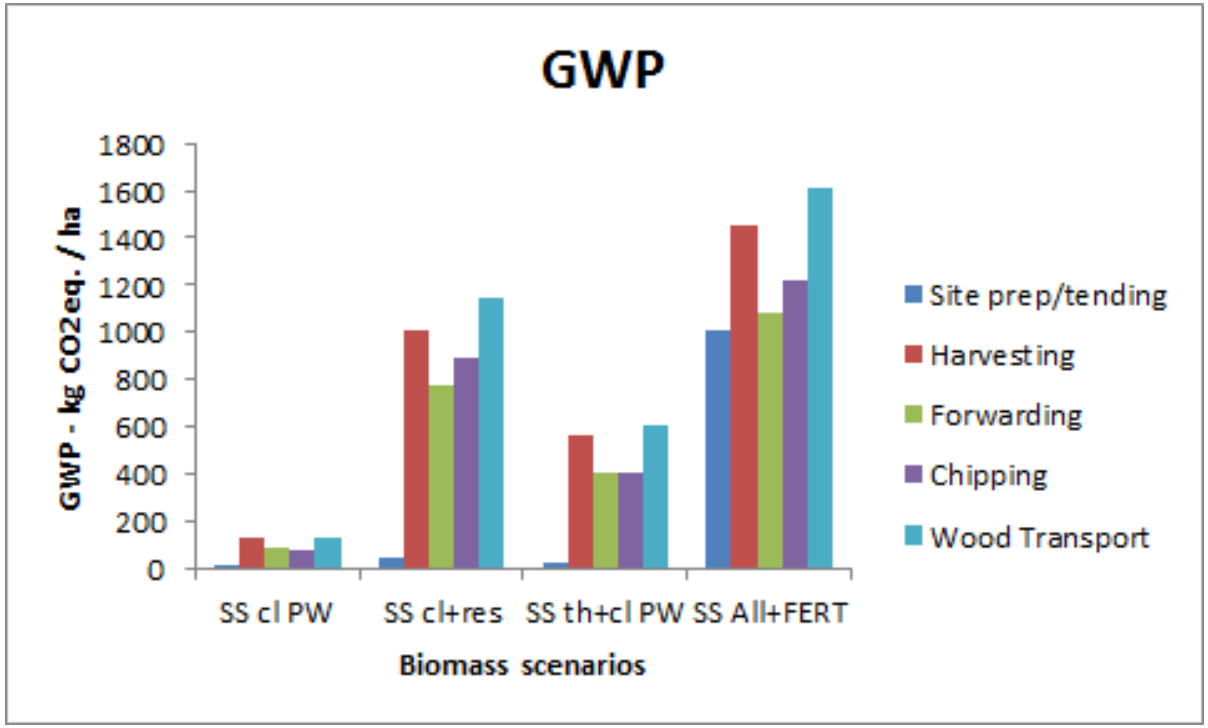
[1] SS brash (available yield = 30% of clearfell ABG, only 55% removed)

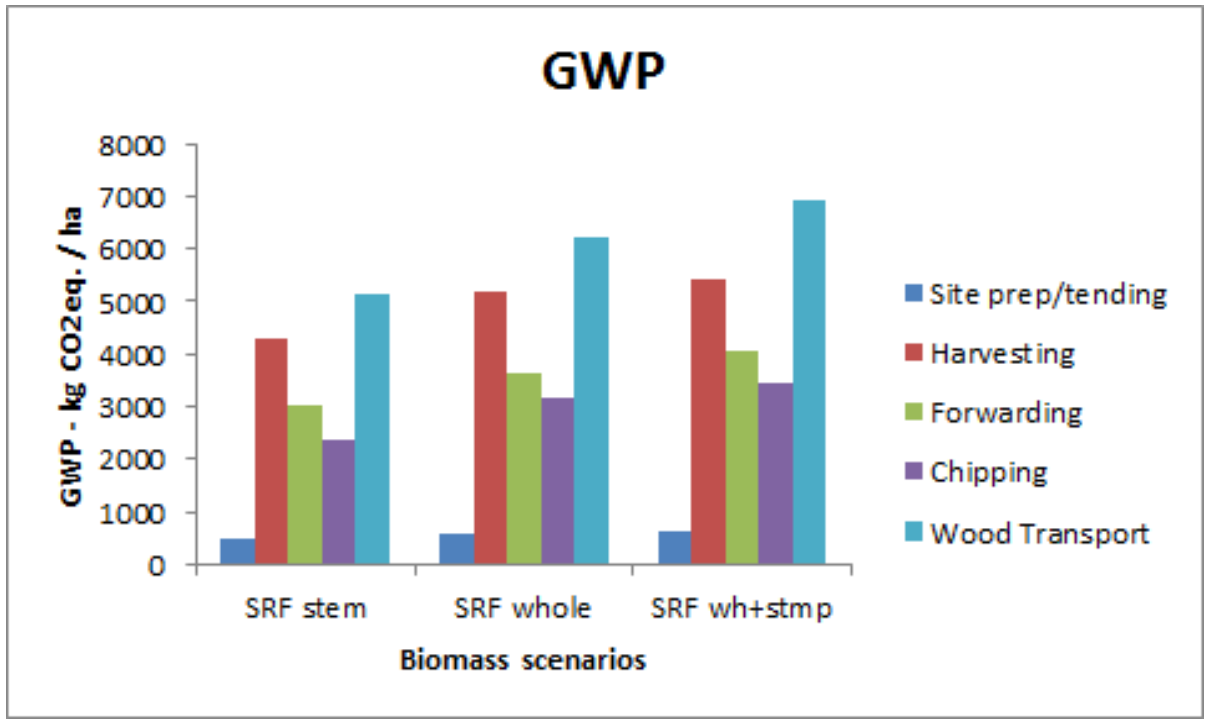
[2] SS stump (available yield = 22% of clearfell ABG, only 42% removed)

[3] SRF stump (available yield = 22.5% of wholetree, only 50% removed)

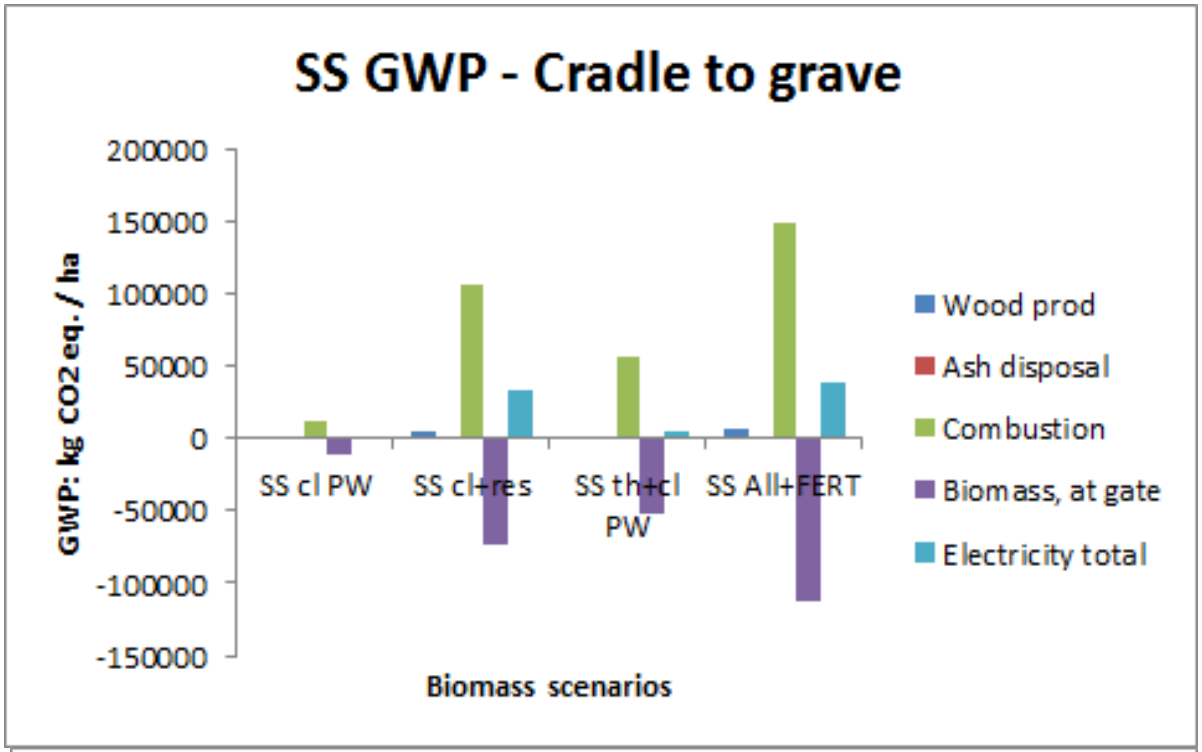
SRF & SS biomass yield ha^{-1} (m^3 o.b.)

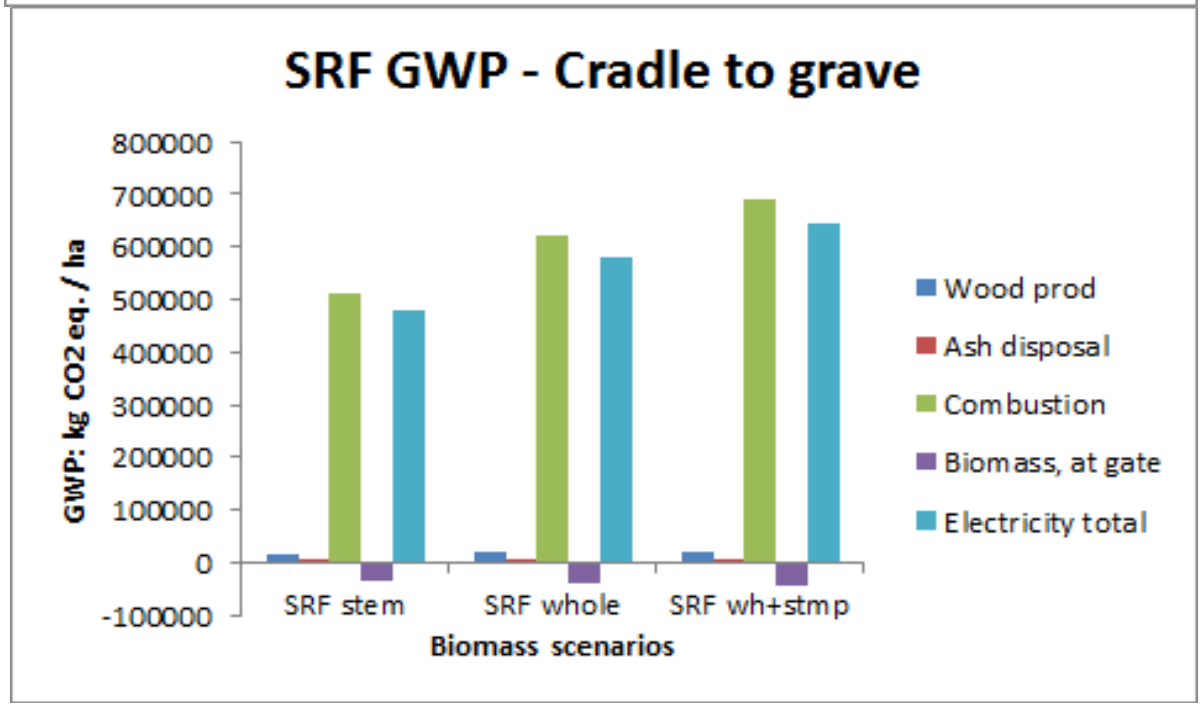






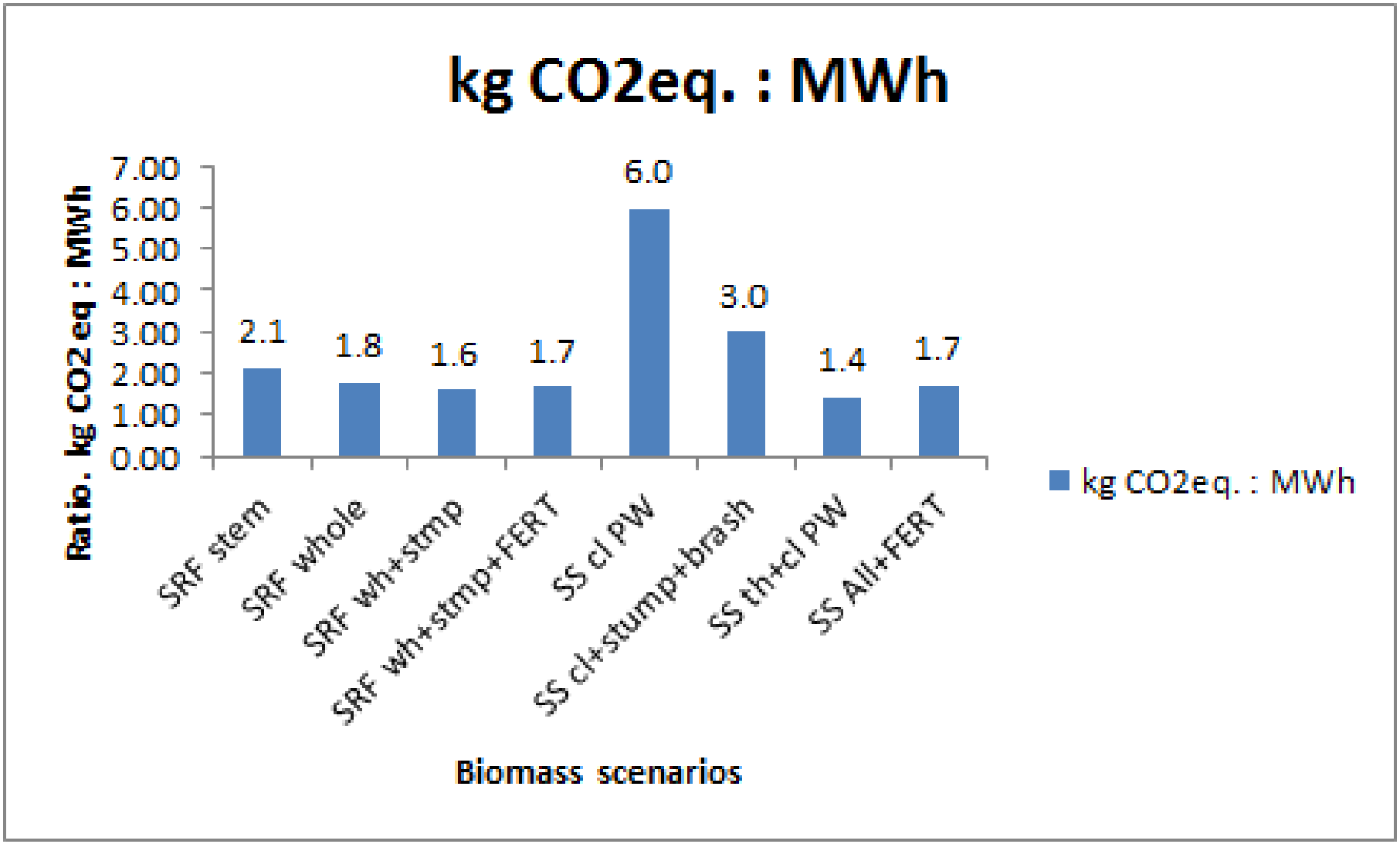
GWP comparison of SS & SRF bioenergy production scenarios





GWP comparison of SS & SRF scenarios

GWP Cradle to grave



Conclusion: LCA work remaining

- Uncertainty analysis
  - Quantifying the uncertainty in the LCI results due to the cumulative effects of model imprecision, input uncertainty, and data variability.
- Sensitivity analysis
  - Estimating the effects of the choices made regarding methods and data on the study results.
- Interpretation phase
  - Assess greenhouse gas (GHG) balance of Irish SRF in comparison to SS, in terms of reaching the goal of 16% renewable energy by 2020.

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Thank you for your attention.