Life cycle energy and GHG emissions of biomass-to-electricity systems in Portugal: Gasification *vs* Direct Combustion

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Abstract

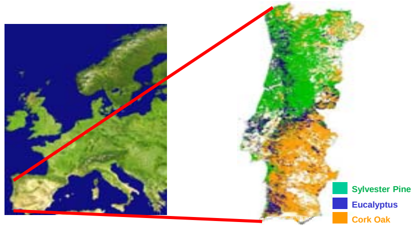
Lignocellulosic biomass has received recent attention in Portugal as a key renewable energy source to play an important role in electricity production and advanced technologies are being considered as a promising high efficiency pathway. However, the actual benefits of biomass--to-electricity systems have not been previously assessed in a life cycle perspective. This poster presents the development and implementation of a comparative life cycle model aiming at assessing the full cradle-to-grave energy and environmental performance of alternative lignocellulosic biomass-to-electricity production pathways for Portugal.

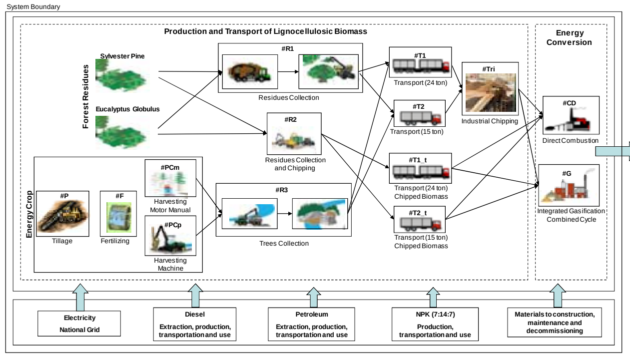
Research goals:

- *i)* to develop a comprehensive life cycle modeling of forest biomass-to-energy in Portugal;
- ii) to perform a comparative assessment of gasification versus direct combustion, accounting for energy and environmental performance and logistical/technological issues;
- iii) to assess the impact of methane emissions from forest residues decomposition, a sensitivity analysis has been performed (assuming various rates for methane release).

Life Cycle Model

Forest tree species distribution





Twenty-four alternative scenarios have been defined considering different combinations of:

- **forest biomass types: residues and energy crops;**
- **biomass collection and transportation processes;**
- **electricity production technologies: gasification and direct combustion.**

Life Cycle Inventory

	Input	Average Value
Energy crop: eucalyptus globulus [lit./ton]		
#P – Tillage	Diesel Petroleum	**0,93** **0,03**
#F – Fertilizing	NPK	**1,15**
#Cm – Harvesting: moto manual	Petroleum	**0,56**
#Cp – Harvesting: machine	Diesel	**1,28**
#R1 – Forest residues collection [lit./ton]		
# R1pin – Sylvester pine residues	Diesel	**1,35**
# R1euc – Eucalyptus globulus residues	Diesel	**1,61**
#R2 – Forest residues collection and chipping [lit./ton]		
# R2pin – Sylvester pine residues	Diesel	**3,91**
# R2euc – Eucalyptus globulus residues	Diesel	**4,66**
#R3 – Eucalyptus globulus trees collection [lit./ton]	Diesel	**1,89**
#Tri – Industrial chipping	Electricity	**41,04**
#T1 – Transport: truck (24 ton)		
# T1pin – Sylvester pine residues	Diesel	**1,97**
# T1euc – Eucalyptus globulus residues	Diesel	**1,55**
# T1pin_t – Chipping residues of sylvester pine	Diesel	**1,35**
# T1euc_t – Chipping residues of eucalyptus globulus	Diesel	**1,15**
# T1ce – Eucalyptus globulus trees	Diesel	**0,86**
#T2 Transport: truck (15 ton) [lit./ton]		
# T2pin – Sylvester pine residues	Diesel	**2,51**
# T2euc – Eucalyptus globulus residues	Diesel	**3,13**
# T2pin_t – Chipping residues of sylvester pine	Diesel	**1,81**
# T2euc_t – Chipping residues of eucalyptus globulus	Diesel	**2,10**
# T2ce – Eucalyptus globulus trees	Diesel	**1,42**
#CD – Direct combustion [MJ_{fossil}/ $MJ_{elec.}$]		
Furnace		**0,0003**
Silo		**0,0017**
Power Plant		**0,0010**
#G – Integrated gasification combined cycle [kg/$MJ_{elec.}$]		
	Concrete	**0,0060**
	Steel	**0,0020**

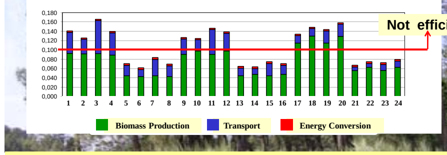
Energy Analysis

Energy Requirements (E_{req}, $MJ_{fossil}/MJ_{elec.}$)

$$E_{req} = \sum E_{in,\ fossil,\ prim}$$

per $MJ_{elec.}$ produced

Life Cycle Energy Results
[$MJ_{fossil}/MJ_{elec.}$]

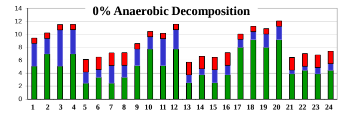


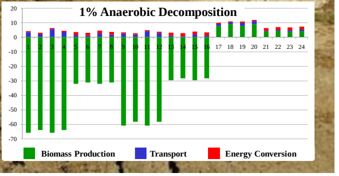
An energy-efficient criterion has been considered: *overall fossil LC energy requirements to not exceed 10% of the electricity produced.*

Sensitivity GHG Emissions Analysis

The following GHG have been considered CO_2, CH_4, N_2O (GWP for 100-year time horizon)

Life Cycle GHG Emissions
[$gCO_2eq/MJ_{elec.}$]





Main Conclusions

The results calculated for the 24 scenarios show that fossil energy requirements can vary from 0,062 MJ to 0,166 MJ per MJ of electricity produced. The most energy efficient scenarios are those with gasification of forest residues (total E_{req} <0.1 $MJ_{fossil}/MJ_{elec.}$). The processes that require more fossil energy are biomass chipping and transportation (from 19% to 50% of total E_{req}). Life Cycle GHG emissions range from 6 to 12 gCO_2eq/MJ of electricity.

The present analysis demonstrates that biomass-to-electricity can be an efficient option regarding fossil energy savings (2,1–2,8 $MJ_{fossil}/MJ_{elec.}$) and GHG emissions avoided (121–228 $gCO_2eq/MJ_{elec.}$) when conventional systems are displaced, but advanced energy conversion technologies, namely gasification, must be employed.

Concerning the release of methane (anaerobic decomposition of residues), it was found out that even a 1% methane production rate has important impacts on the GHG balance since removing forest residues to produce electricity would avoid the release of methane and a GHG credit should be included in the assessment.