International Poplar Commission,

24th Session, Dehradun, India

ECONOMICS of POPLAR PYROLYSIS stemming from PHYTOREMEDIATION of METAL POLLUTED SOILS

Theo Thewys & Tom Kuppens

Research group Environmental Economics

universiteit hasselt CENTRUM VOOR MILIEUKUNDE

Overview

- Problem statement: profitability of bio-oil production
- Methodology: cost-benefit analysis & risk analysis
- Pyrolysis: oil yields & combined heat & power (CHP) production
- Economic model: investment; expenditures & revenues
- Base case: results & sensitivity analysis
- Optimistic and pessimistic scenario analysis
- Discussion and conclusions

Campine region: cadmium pollution

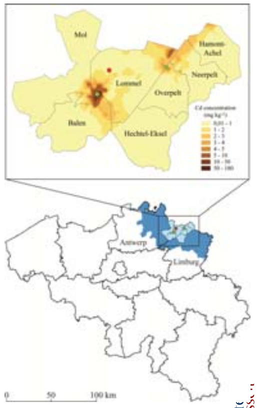
Cd concentrations exceed threshold values for agriculture

↓

Vast area of 3400 ha of farmland in the Belgian Campine require soil remediation

↓

Phytoremediation is better suited (costs) than conventional soil remediation



Phytoremediation

- **Phytoextraction**
  - Special form of phytoremediation
  - Metal uptake by plant
  - Translocation of metals from soil to **harvestable parts of the plant**

= **biomass**

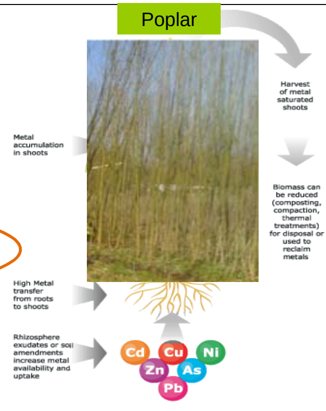
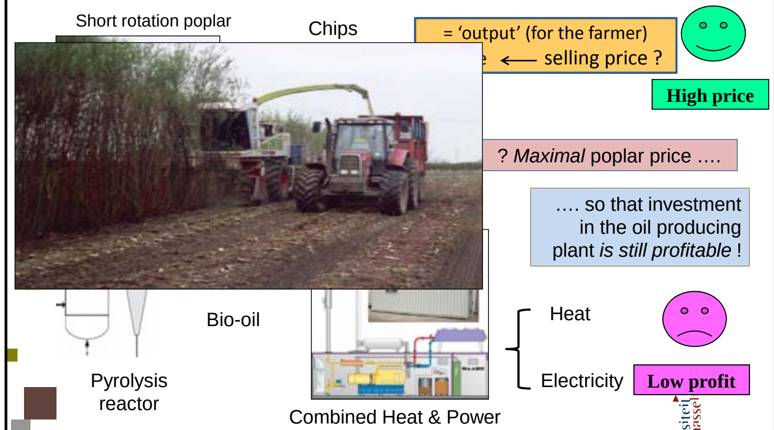


Figure 1 - Schematic representation of the processes involved in phytoextraction of metals from soils.

Problem: output price (farmer) versus input price (oil producer)



universiteit hasselt CENTRUM VOOR MILIEUKUNDE

Risk analysis (1)

The poplar price (p_{poplar}) is the maximal price an investor in a pyrolysis installation is willing to pay for the use of poplar as a feedstock for the conversion plant

⬇

Guaranteeing a 95 % chance of a positive net present value of cash flows generated by the investment

⬇

The poplar price thus should be determined by taking into account **uncertainties/risks** of the project

universiteit hasselt CENTRUM VOOR MILIEUKUNDE

Risk analysis (2)

How to measure economic risk?

- *Monte Carlo simulations (MC)*
  - How sensitive is the NPV of the cash flows for changes in the values of the input variables (e.g. yearly volume of biomass; oil yield (wt %); sales of heat) in the simulation model?
  - Requires knowledge (assumptions) about minimal, most probable and maximal values of input variables and their respective frequency of appearance
  - Results in probability distribution of NPV after thousands of simulations

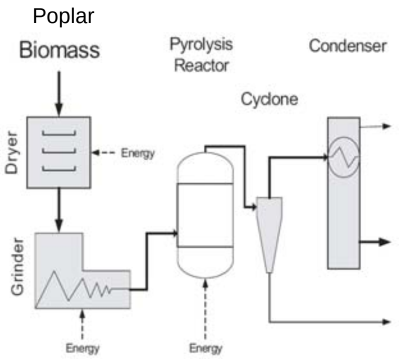
universiteit hasselt CENTRUM VOOR MILIEUKUNDE

Thermochemical conversion

- Pyrolysis
  - Lower process temperatures
    → metals are concentrated in char
  - Slow pyrolysis → max! char formation
    (but market value of biochar is unknown)
  - **Flash** pyrolysis: quantity of O_2 added / O_2 required for complete combustion = 0
    - → max! **oil** formation

universiteit hasselt CENTRUM VOOR MILIEUKUNDE

Flash pyrolysis



Anaerobic cracking of biomass molecules (lignin, cellulose) into solid and gaseous fraction

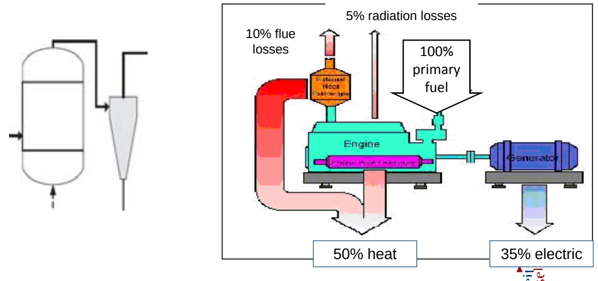
13 – 25 wt. % **biogas**
Internal energy consumption

52 – 71 wt. % **pyrolysis oil**
calorific value: 17,5 GJ/ton

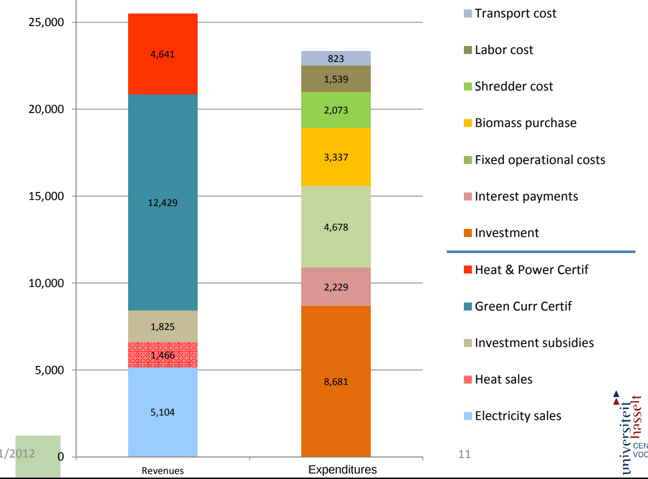
16 – 23 wt. % **char**
Internal energy consumption

Conversion process

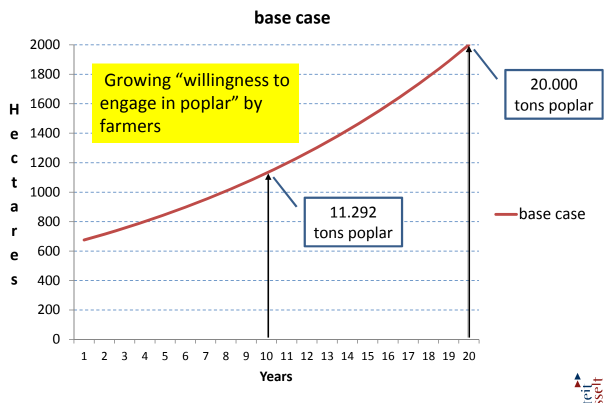
Poplar (SRC) → Pyrolysis reactor → Pyrolysis oil → CHP engine → Electricity and heat



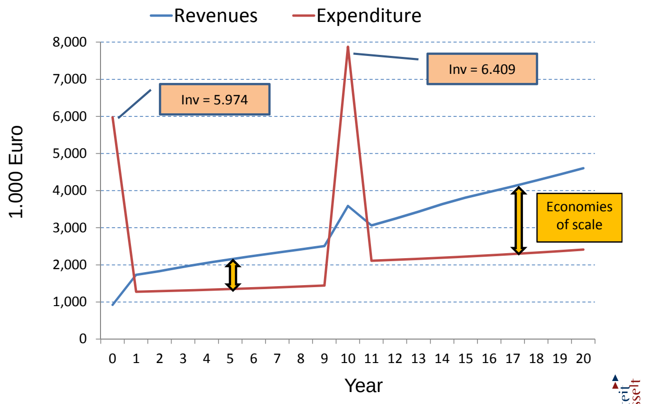
Revenues & Expenditures
(net present value over 20 yrs, 1.000 Euro)



Cultivated surface



Cash flows



Overview

- Problem statement: profitability of bio-oil production
- Methodology: cost-benefit analysis & risk analysis
- Pyrolysis: oil yields & combined heat & power (CHP) production
- Economic model: investment; recurring expenditures & revenues
- Base case: results & *sensitivity* analysis
- Optimistic and pessimistic *scenario* analysis
- Discussion and conclusions

Median NPV (base case) & importance of 5 base case ranges

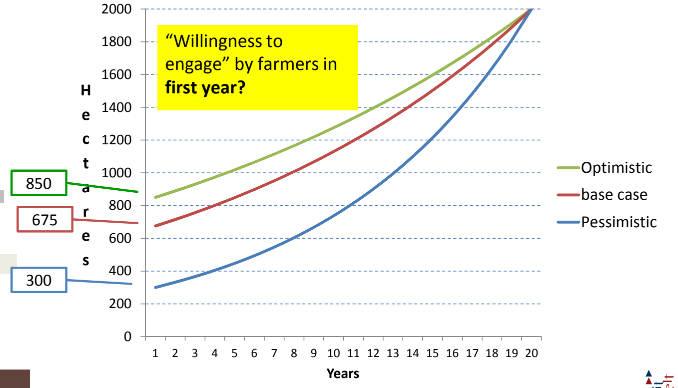
Row (1)	Variable (2)	Minimum (3)	Middle (4)	Maximum (5)	NPV sensitivity (6)
1	*Biomass price*	31,5 EUR/odt	35 EUR/odt	38,5 EUR/odt	-2,0 %
2	*Starting surface* $S_{year\ 1}$	607,5 ha	675 ha	742,5 ha	5,0 %
3	*Oil yield* Y_{oil}	63 wt.%	70 wt.%	77 wt.%	92,5 %
4	*Heat sales* Q_{sold}	45 %	50 %	55 %	0,4 %
5	*Discount rate i*	8,1 %	9 %	9,9 %	0,0 %
6	***Median NPV***				***696.194***
7	***Probability NPV > 0***				***86,1 %***

Risk (NPV<0) = 14%

Overview

- Economic model: investment & recurring expenditures & revenues
- Base case: results & sensitivity analysis
- Optimistic and pessimistic scenarios about:
  1. yearly volume of poplar (cultivated surface)
  2. oil yield
  3. % of heat sold locally

Cultivated surface



Maximum price poplar

Condition: 95% probability that NPV of the pyrolysis investment > 0

	pessim	base case	optimist
Surface occupied by poplar (ha)	300	675	850
max price poplar (EUR/odt)	-20	30	40

Conclusions (1)

1. Installation: 1,6 odt/hr (year 1-10); 2,8 odt/hr (year 11-20)
2. Base case:
   1. Assumptions: 675 ha; 70% oil yield; 50% heat sold
   2. Net present value (NPV) cash flows: 696,000 Euro (mean value)
   3. Probability of a positive NPV of the cash flows: 86 %.
   4. Sensitiveness analysis: most important determinants:
      1. oil yield
      2. yearly volume of poplar (cultivated surface)
      3. % of heat sold locally

Conclusions (2)

3. **Maximum poplar price** (€/ton): scenarios (95 % prob >0)
   1. Larger surface: -20 ; 30 ; 40 €/ton
   2. Larger oil yield: -5 ; 30 ; 60 €/ton
   3. Lager % heat sold: : 25 ; 30 ; 35 €/ton
4. Explanation
   1. Returns to scale: average oil production cost decrease with larger volume biomass
   2. Cost are based on the supplied volume of processed *biomass (odt/year)*
   3. Greater valorisation of heat output

Discussion

Questions?

Suggestions?

Thank you for your attention!

theo.thewys@uhasselt.be

universiteit hasselt
CENTRUM VOOR MILIEUKUNDE