Fate of elemental contaminants during biomass thermochemical process

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Heavy Metal Contamination and Phytoremediation

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- Heavy metal contamination widespread problem
    - Geologic origin and more significantly industrial activity- unsustainable use of metal resources

- Phytoremediation of metal contaminated land
    - Advantages: Low cost (initial investment, energy input during remediation process), Environmental friendly
    - Uncertainty & limitation: Management of residual biomass (high in toxic metal, costly to disposal of)
    - Solution to improve viability of phytoremediation

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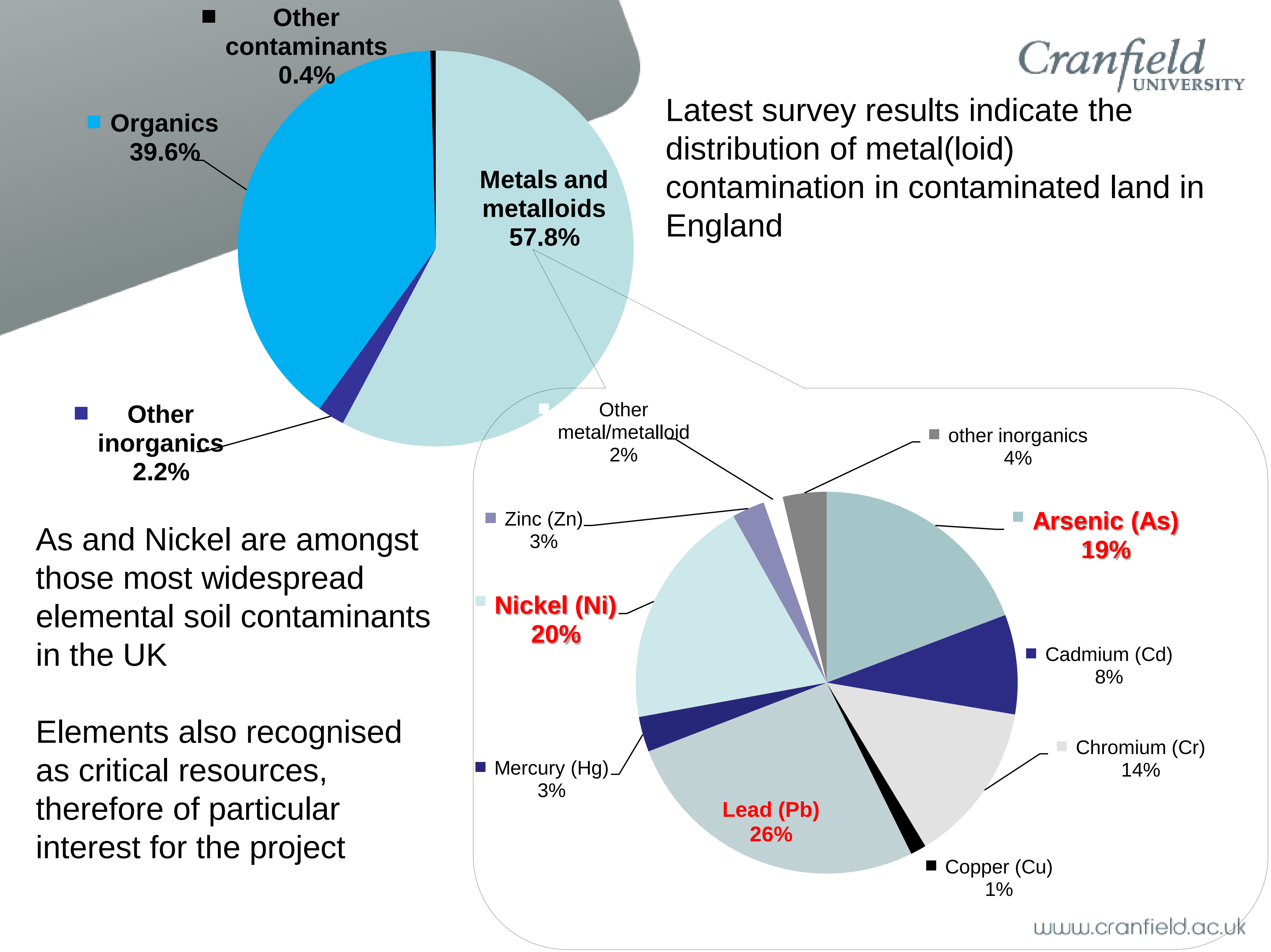
Latest survey results indicate the distribution of metal(loid) contamination in contaminated land in England



As and Nickel are amongst those most widespread elemental soil contaminants in the UK

Elements also recognised as critical resources, therefore of particular interest for the project

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An Integrated Model: Remediation with Biomass Energy and Resource Recovery

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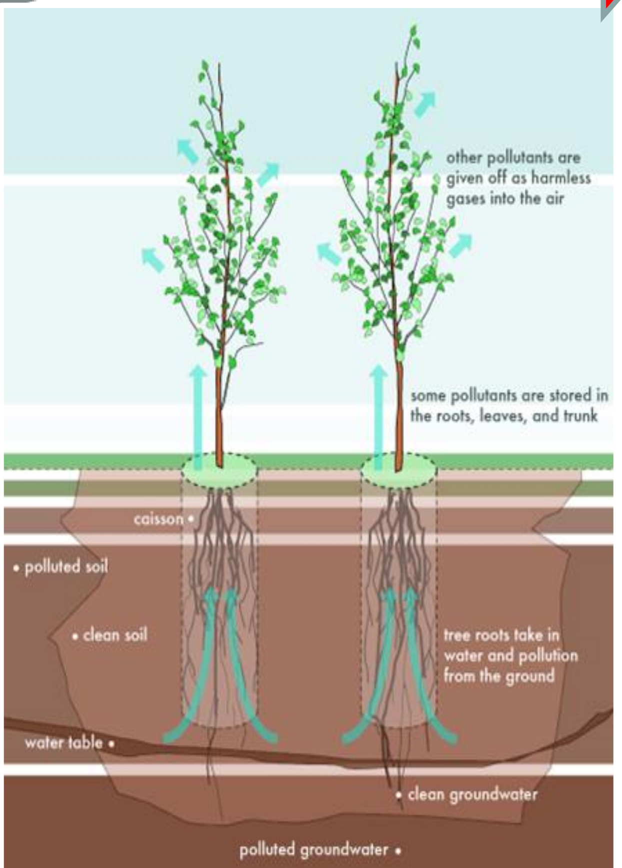
Phytoremediation → **Thermochemical Process for energy and by-products** → **Element and energy recovery and land reclamation**



Source: http://access.ncsa.illinois.edu/Stories/phytoremediation/

Thermochemical Biomass to Energy process

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- Suitable technologies:
  - Combustion: Heat and electricity
  - Gasification: Syngas ($CO+H_2$)
  - Pyrolysis: Bio-oil, combustible gaseous products

- Metal recovery is possible from process ash

However…

Emission of Toxic Element in Gaseous Forms

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Fractionation of element in solid phase (bottom and fly ash) and gaseous phase is intricate and depending on:

- Elemental composition of the biomass
- Thermochemical conditions, e.g. temp, pressures, atmosphere etc..

A few considerations:

- Environmental concerns
- Hot corrosion, damaging flue gas pipelines and facilities (gas turbine generator)
- Reduced metal recovery rate

Aim of the Research

- Develop a reliable method to predict the fate of metal contaminants in biomass during thermochemical process
  - Thermodynamic model often used to calculate phases formed at chemical equilibrium, such as combustion and gasification and predict possible products: requires full elemental composition of biomass sample
  - Biomass sample collection from heavy metal contaminated site and conduct detailed elemental analysis

Methodology

1. Modelling of the Fate of Metals during biomass thermochemical process (MTDATA)

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- Gibbs Energy Minimisation algorithm
  - Applies in any chemical equilibrium containing multiple components and phases such as thermochemical processes
  - Modelling software MTDATA predicts the phases formed at chemical equilibrium (Requires detailed elemental analysis and specific operational parameters)

- Thermodynamic modelling provide initial prediction for fate of elemental contaminants during the thermochemical process

2. Field sampling and sample preparation

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Acid digestion of samples before analysed using ICP-MS for metal

CNHO analysed by elemental analyser

Sampling site

- LA owned brownfield site
- Historically contaminated by metals due to industrial activities
- A number of common plant species found on site were collected along with soil samples

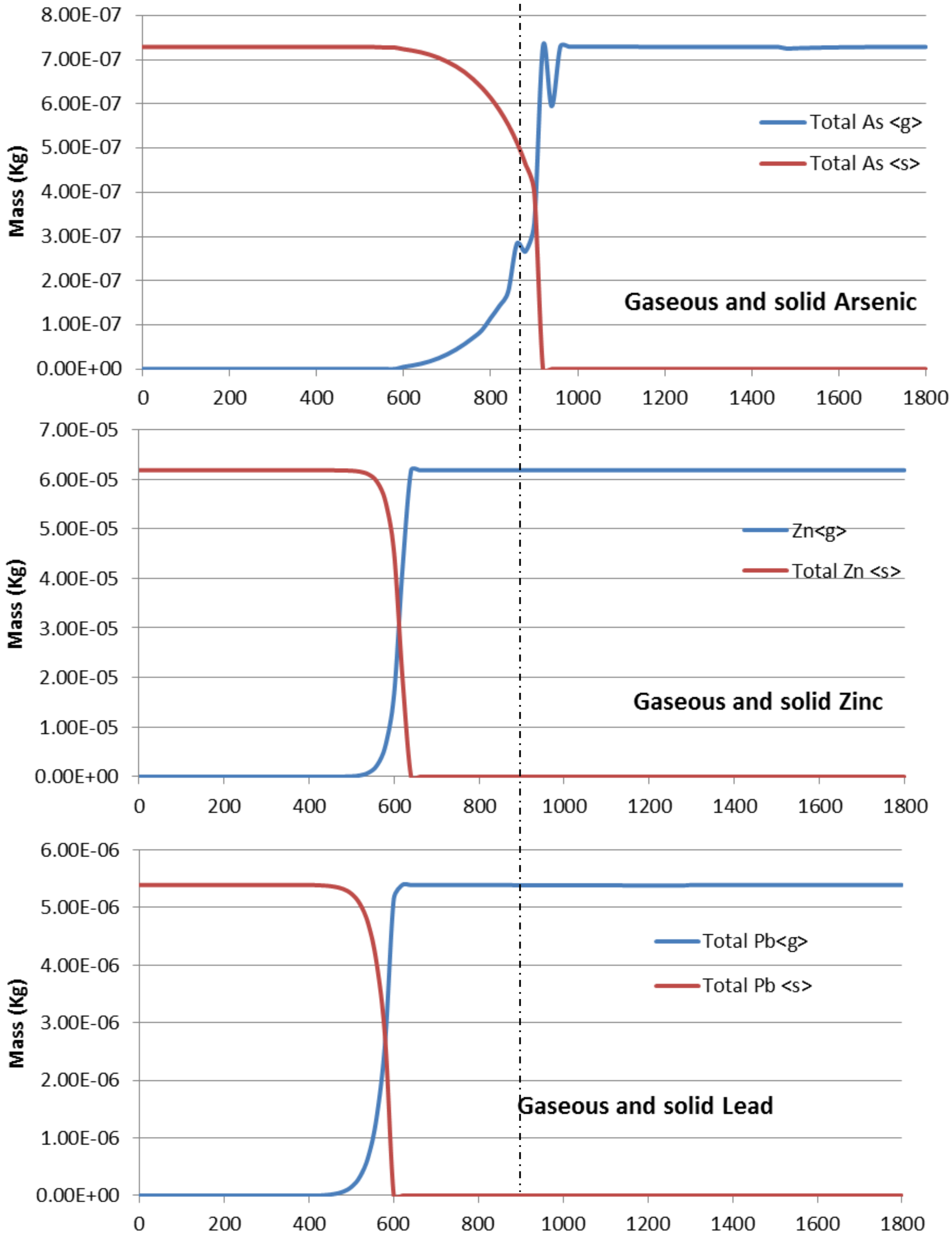
Field Sampling Results

- Selected elemental concentration in soil and biomass samples

Metals	Soil (mg/Kg)	Plants (mg/Kg)
Nickel	24 - 28	0.016 – 4.804
Arsenic	3.5 – 8.5	0.121 – 1.217
Cobalt	8.5 – 9.2	0.029 – 1.078
Selenium	<0.7	0.055 – 0.5046
Iron	15900 - 17300	41.8 – 2615.4
Manganese	339 - 360	5.601 – 102.101

- Elemental composition of plant biomass provide information for thermo-dynamic modelling using MTDATA

Thermodynamic modelling Results



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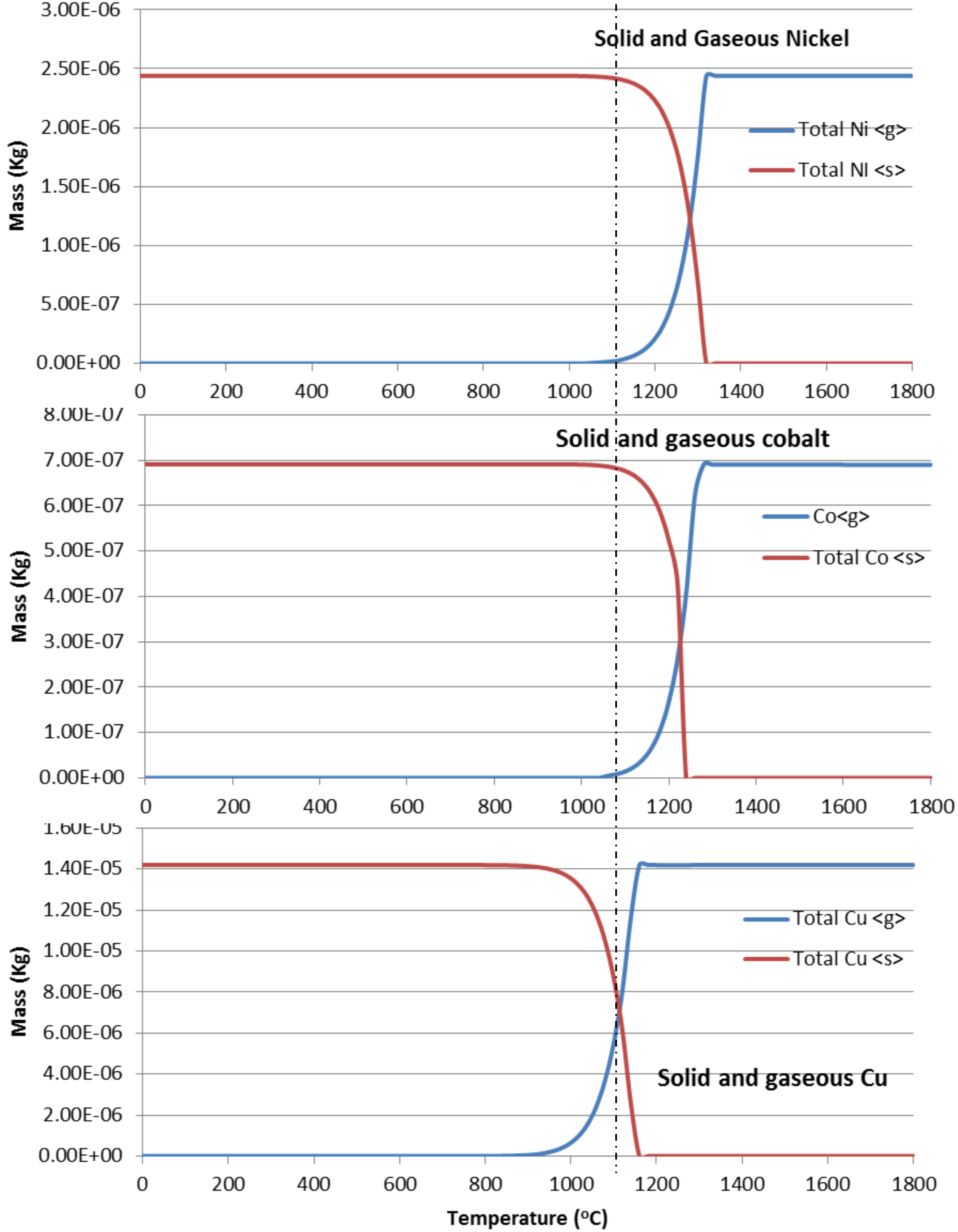
As, Zn and Pb tend to transform to their gaseous forms at relatively low temperatures (<900 ^{o}C).



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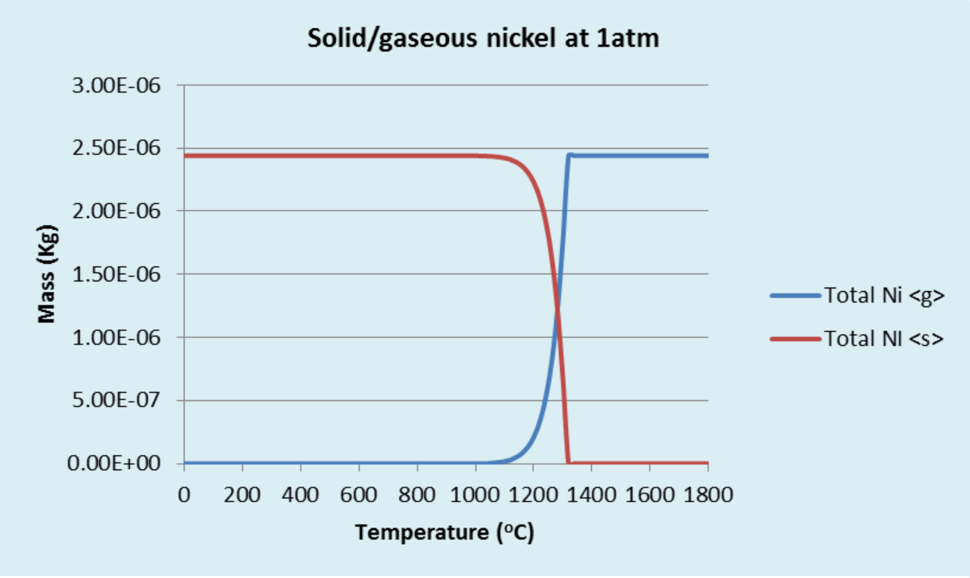
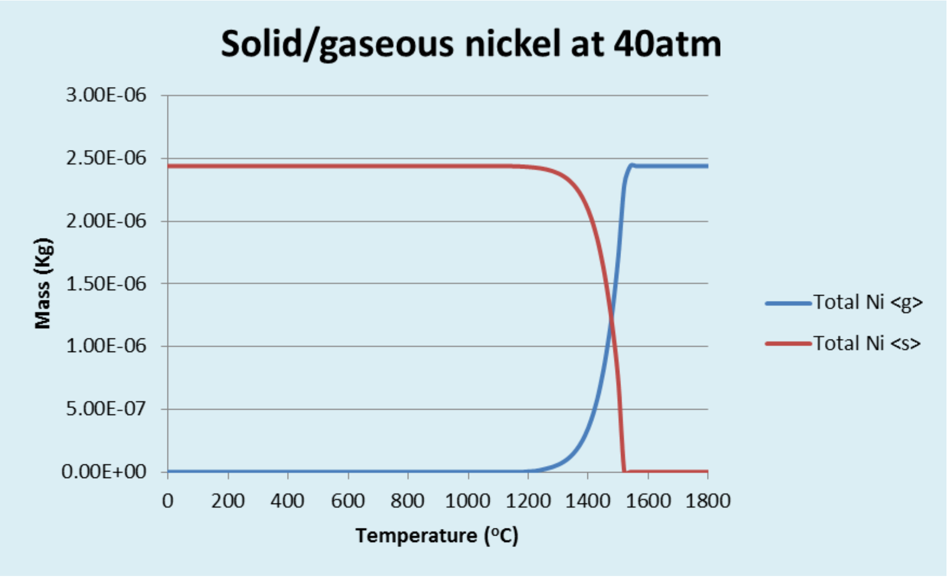
Ni, Co, Mg and Cu tend to transform to their gaseous forms within the typical gasification temperature range at >900-1200 ºC.

Cr, Al, and Fe remain in solid phase at higher temperatures (>1200 ºC)

Thermodynamic modelling Results

Nickel

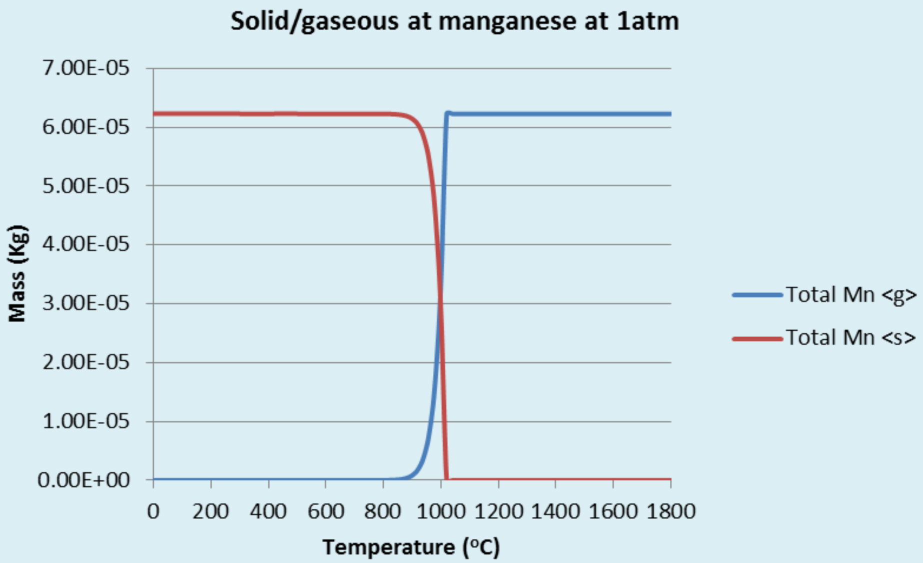


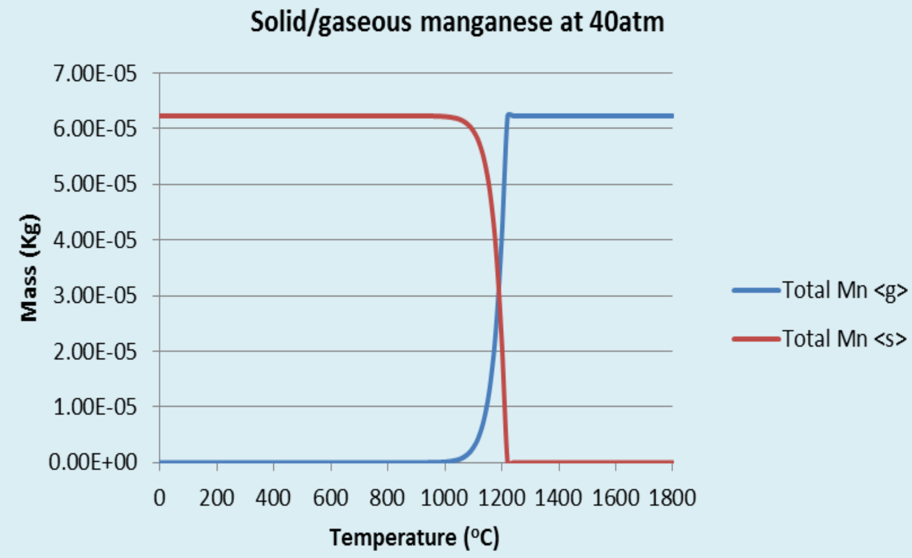


At standard pressure, Ni solid/gaseous phase transition starts at 1100ºC while at increased pressure it starts at higher temp of 1240ºC.

Thermodynamic modelling Results

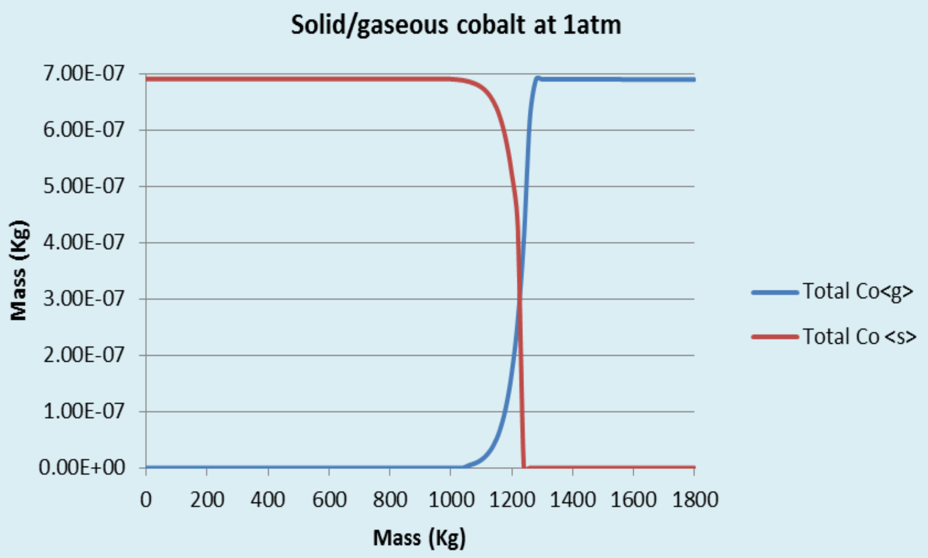
Manganese

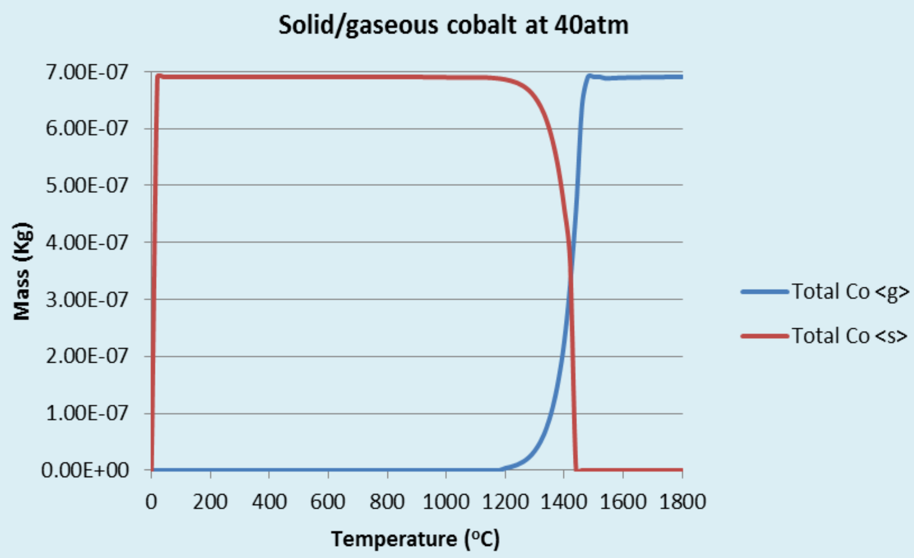




Thermodynamic modelling Results

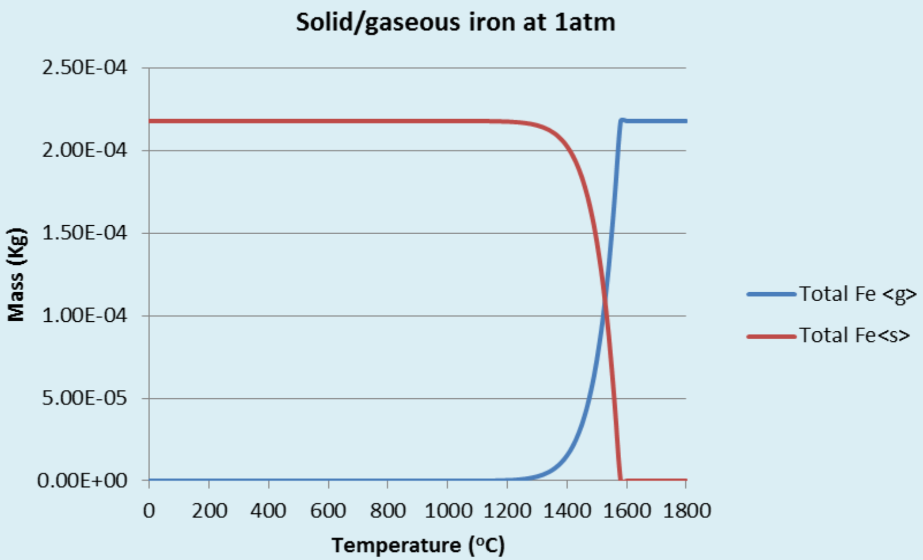
Cobalt

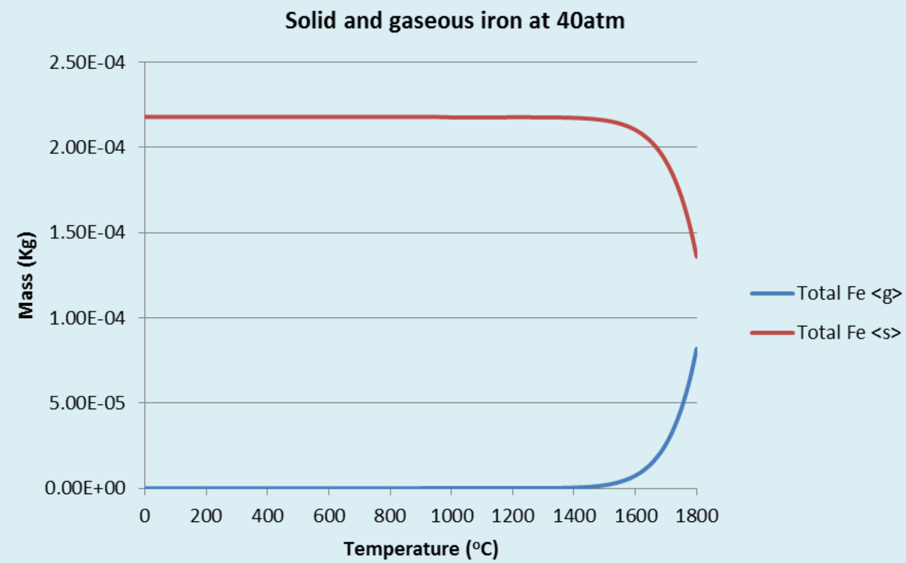




Thermodynamic modelling Results

Iron





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Conclusions

- Thermochemical biomass to energy conversion technologies offers a potential solution to the management of residual biomass derived from phytoremediation
- The fate of elements during gasification needs to be better understand to reduce facility hot erosion and toxic emission
- Transition of solid/gaseous phase is determined by fuel elemental composition and thermochemical parameters
- Among the element modelled, solid/gas phase transition of As, Zn, Mg and Pb occur at low temperatures (<900 ^{o}C), therefore require special consideration

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For more information about our project please contact:
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