ARISTOTLE UNIVERSITY OF THESSALONIKI

DEPOTEC
LIFE10 ENV/IE/000695

Towards an integrated depolymerisation option of End of Life Tyres into carbon materials by means of the DEPOTEC LIFE+ concept

N. Antoniou and A. Zabaniotou

Department of Chemical Engineering, Aristotle University of Thessaloniki, 54124, Thessaloniki, Greece

2-4 July 2015:
3rd INTERNATIONAL CONFERENCE on Sustainable Solid Waste Management,
Tinos island, Greece

ARISTOTLE UNIVERSITY OF THESSALONIKI

End Of Life Tyres

DEPOTEC
LIFE10 ENV/IE/000695

Waste Tyres, Used Tyres, Automotive Shredder Residues

Non Hazardous Waste 16 01 03

Wastes containing principally organic constituents, which may contain metals and inorganic materials B3140

2-4 July 2015:
3rd INTERNATIONAL CONFERENCE on Sustainable Solid Waste Management,
Tinos island, Greece

ARISTOTLE UNIVERSITY OF THESSALONIKI

End Of Life Tyres

DEPOTEC
LIFE10 ENV/IE/000695

Composition (% w/w)	PCT USA	TT USA	PCT EU	TT EU
Natural rubber	14	27	22	30
Styrene rubber	27	14	23	15
(Carbon Black)	28	28	28	20
Steel	14-15	14-15	13	25
Fibers and other materials	16-17	16-17	14	10

Fuel	Heating Value (MJ/kg)
End of Life Tyres	36-40
Pet coke	32.0 - 36
Coal (Bituminous)	32-36.3
Coal (Subituminous)	29-30.7
Lignite	11.7- 15.8

ARISTOTLE UNIVERSITY OF THESSALONIKI

End Of Life Tyres

DEPOTEC
LIFE10 ENV/IE/000695

Possible cause for severe environmental threats

Revenue Loss from limited use as energy and materials source

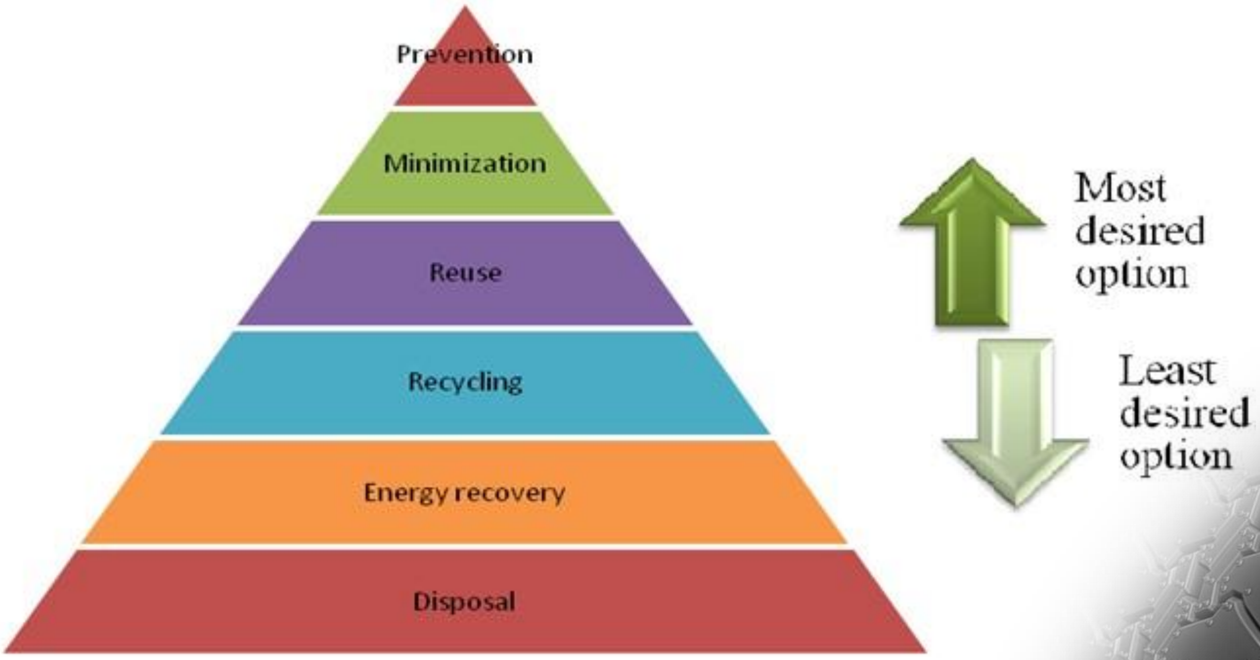
High Cost to manage them as waste

Policy & legislation

Waste management hierarchy

The hierarchy in European Union which basic concept has remained the cornerstone for the most waste minimization strategies, has 5 different steps:

Reduce, Reuse, Recycle, Recovery and Disposal.



ARISTOTLE UNIVERSITY OF THESSALONIKI

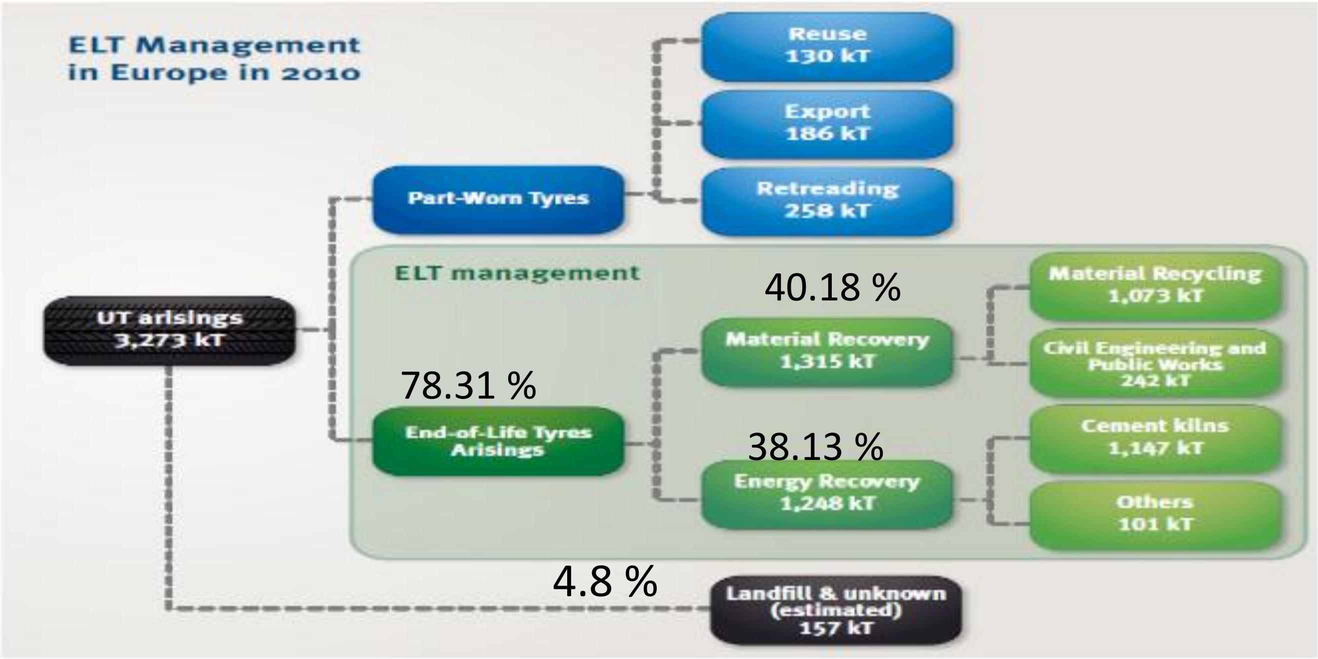
ELT management schemes across Europe

DEPOTEC
LIFE10 ENV/IE/000695

* ETRMA

2-4 July 2015:
3rd INTERNATIONAL CONFERENCE on Sustainable Solid Waste Management,
Tinos island, Greece

ELT management schemes across Europe



***ETRMA 2011 edition : End of life tyres - A valuable resource with growing potential**

ARISTOTLE UNIVERSITY OF THESSALONIKI

ELT depolymerisation via pyrolysis

DEPOTEC
LIFE10 ENV/IE/000695

Pyrolysis of tyres is their thermal decomposition in the absence of air to prevent oxidation.

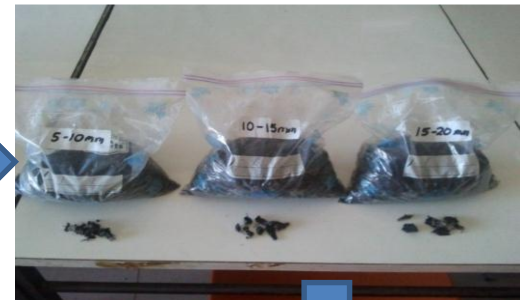
It was studied thoroughly during the last decade and seems to be an interesting approach towards the production of liquid hydrocarbons. However, the potentials of upgrading the solid pyrolysis product into a high added value material are of great importance.

It has not been applied to an extensive industrial scale so far, due to the lack of products standardization and available markets, legislative barriers and sometimes public acceptance.

Integrated ELT depolymerisation scheme

Classification/Raw material characterisation

Ambient Grinding



Classification

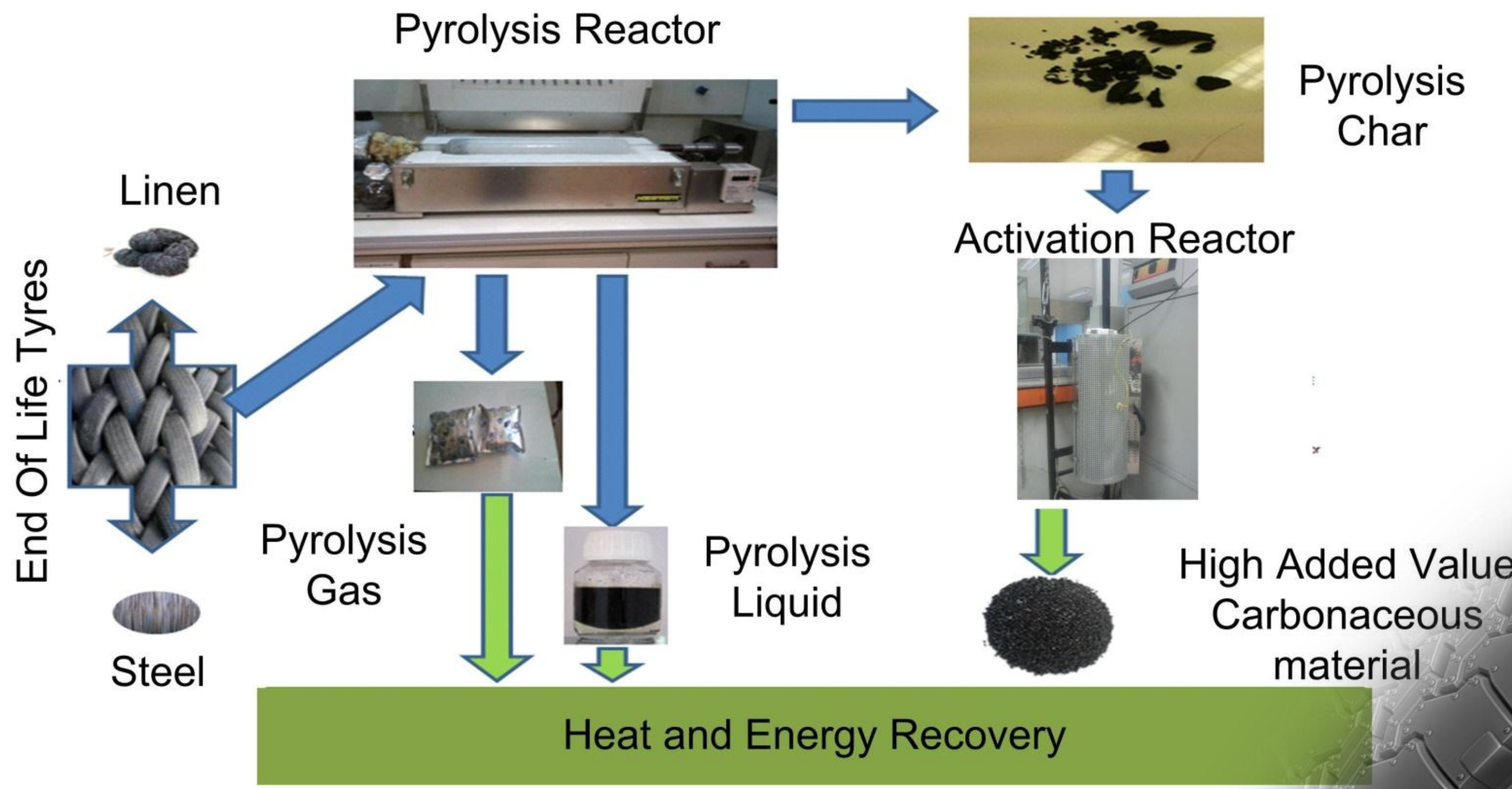
Sample particle size	C (wt %)	H (wt %)	N (wt %)	S (wt %)
Sample 510: 5-10 mm	84.02	7.42	1.22	2.63
Sample 1015: 10-15mm	83.41	7.26	1.58	2.35
Sample 1520: 15-20 mm	83.88	7.33	1.33	2.49

2-4 July 2015:
3rd INTERNATIONAL CONFERENCE on Sustainable Solid Waste Management,
Tinos island, Greece

Integrated ELT depolymerisation scheme

ARISTOTLE UNIVERSITY OF THESSALONIKI

DEPOTEC
LIFE10 ENV/IE/000695



ARISTOTLE UNIVERSITY OF THESSALONIKI

Integrated ELT depolymerisation scheme

DEPOTEC
LIFE10 ENV/IE/000695

Expected pyrolysis products and uses

- Energy valorization (green triangle)
- Material valorization (purple triangle)

EOL tyre pyrolysis

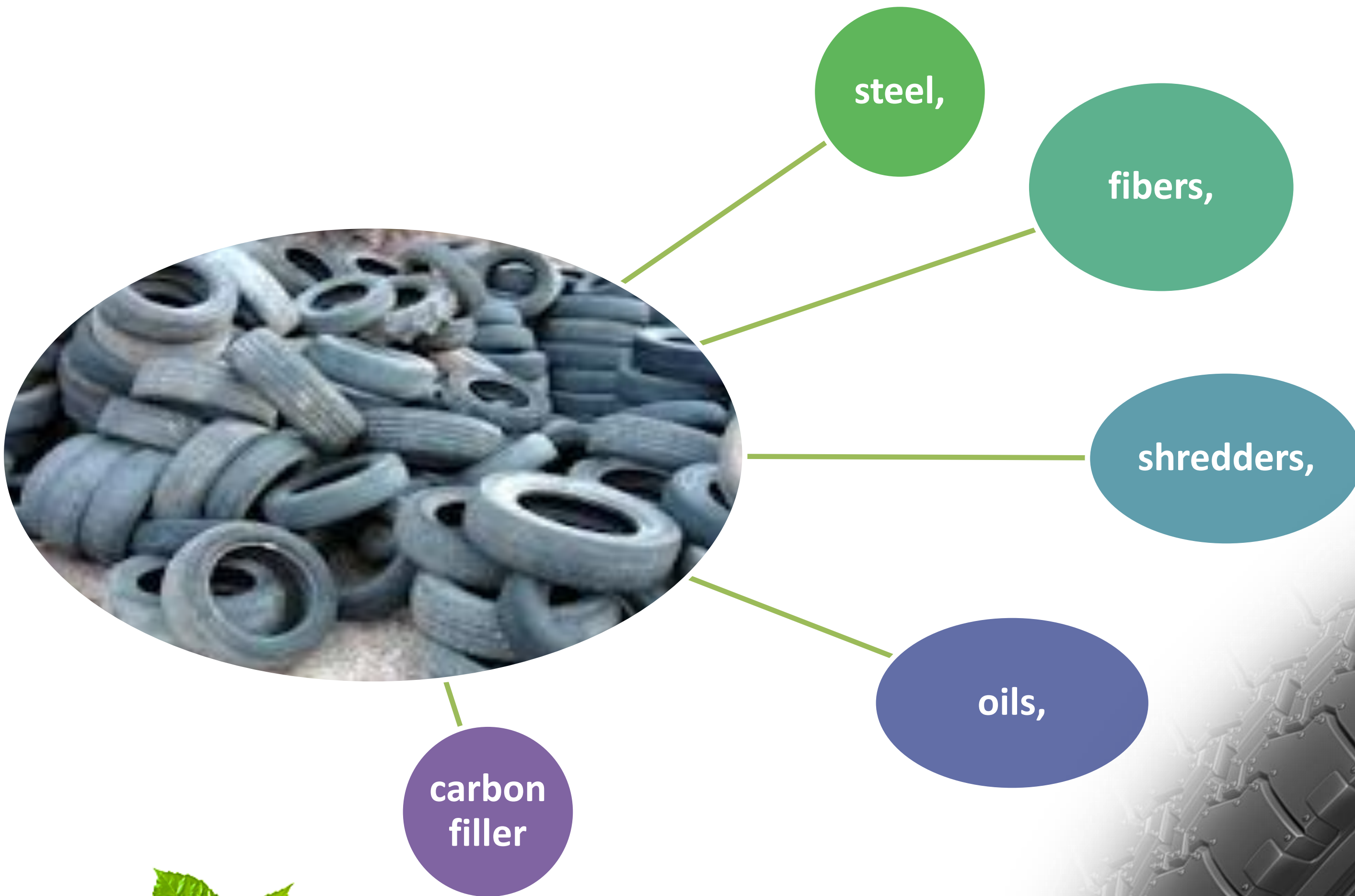
- **Pyrolytic gas**
  - LHV >20 MJ m^{-3}
  - Fuel for energy recovery (reactor and boiler)
- **Char**
  - Carbon Black (CBp)
  - N 600 – N 700
  - LHV ~ 17-19 MJ m^{-3}
    - 1)Activated Carbon
    - 2)Wastewater treatment
    - 3)Pesticide adsorption
    - 4)Catalyst support
- **Pyrolytic oil**
  - Used as fuel in I.C.E.
    GCV=42.6 MJ/KG
  - Extraction of chemicals

2-4 July 2015:
3rd INTERNATIONAL CONFERENCE on Sustainable Solid Waste Management,
Tinos island, Greece

Integrated ELT depolymerisation scheme

LIFE10 ENV/IE/000695

Expected pyrolysis by-products



2-4 July 2015:
3rd INTERNATIONAL CONFERENCE on Sustainable Solid Waste Management,
Tinos island, Greece

Characterisation of ELT pyrolysis products

ARISTOTLE UNIVERSITY OF THESSALONIKI

DEPOTEC
LIFE10 ENV/IE/000695

Pyrolysis gas

- ❑ Yield ranges between 5-15 wt%.
- ❑ The calculated LHV ranges between 20-24 MJ/m^3.
- ❑ Syngas percent ranges between 30-50 %.

PYROLYSIS GAS

Pyrolysis oil

- ❑ Yield ranges between 45-55 wt%.

PYROLYSIS LIQUID

Elemental analysis and calorific values of pyrolysis liquid products. GCV determined by ASTM D4809.

Pyrolysis char

- ❑ Yield ranges between 25-35 wt%.

- ❑ SEM analysis

Micro- and meso-porosity were not developed in pyro-char. Instead few cracks were identified, indicating a possible trend for pore creation, under further treatment.

- ❑ N_2 isotherm

Pyrolysis char is a macroporous material (>50 nm, IUPAC classification). The total pore volume (VT) (p/p0 = 0.98) was calculated to 0.3679 cm^3/g.

- ❑ XRD analysis

The crystalline phases identified, correspond to wurtzite, sphalerite (α- and β-ZnS) and lead sulphide (PbS). Graphitic carbon was also identified.

Reduced environmental impact

LIFE10 ENV/IE/000695

1. Valorisation of pyrolysis by-products

2. Energy conservation techniques

2.1 Co-generation unit that supplies the activation steam (Heat Recovery Steam Generator)

2.2 High temperature waste streams ideal for heat recovery

2.3 Boiler economizer for steam production

3. Adsorptive materials production

Conclusions

ELT constitute wastes with high calorific value. They are generated across the globe in huge amounts annually. Through pyrolysis and activation, a solid material eligible for environmental depollution applications can be produced. However the energy intensive nature of the applied processes, may set limits to this innovative valorization route. To properly address the above, recommendations were made regarding:

(i) **pyrolysis gas valorization (for pyrolysis process),**

(ii) **pyrolytic oil valorisation (for activation process) ,**

(iii) **heat and energy recovery, through a detailed schematization of the process and**

(iv) **Adsorptive materials production**

ARISTOTLE UNIVERSITY OF THESSALONIKI

Biomass and Wastes Group
Research field

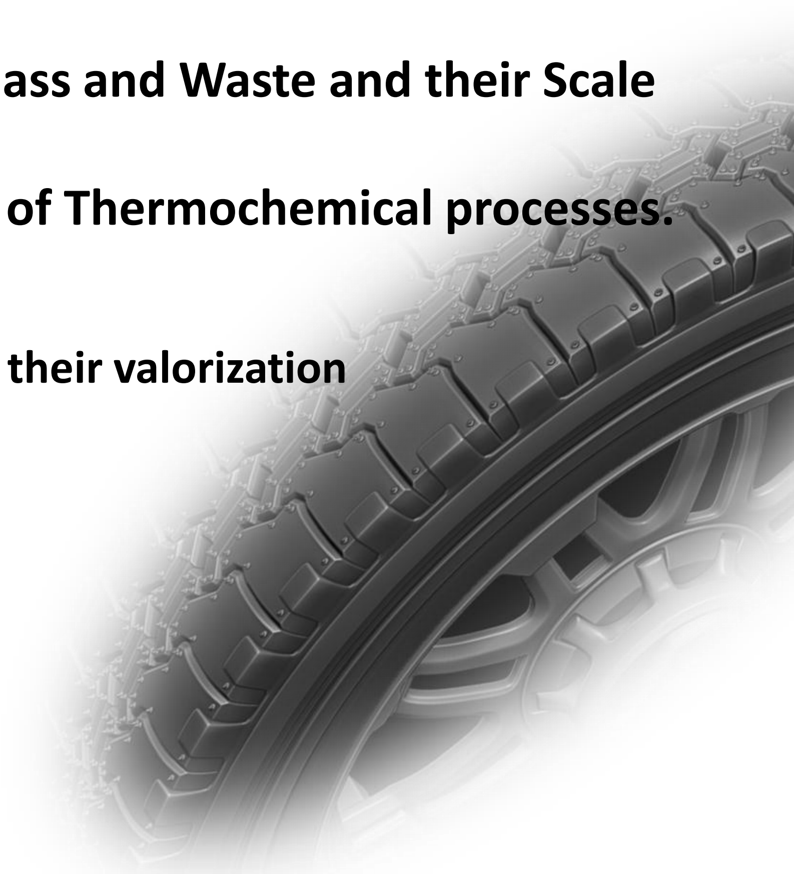
DEPOTEC
LIFE10 ENV/IE/000695

Biomass Group
LABORATORY OF CHEMICAL PROCESS AND PLANT DESIGN

- Renewable Energy Sources (RES) with emphasis on Biomass and Wastes.
- Gasification and Pyrolysis systems for Bioenergy, Biofuels , H_2 and Bio-material production.
- Design of Thermochemical reactors for Biomass and Waste and their Scale up.
- Feasibility studies, Modeling and Simulation of Thermochemical processes.
- Waste recycling.

Especially on End of Life Tyres and their valorization

- 7 published papers in top Scientific Journals
- More than 30 presented works on Conferences
- Participation in European and Greek Projects



2-4 July 2015:
3rd INTERNATIONAL CONFERENCE on Sustainable Solid Waste Management,
Tinos island, Greece

ARISTOTLE UNIVERSITY OF THESSALONIKI

Biomass and Wastes Group: A DEPOTEC member

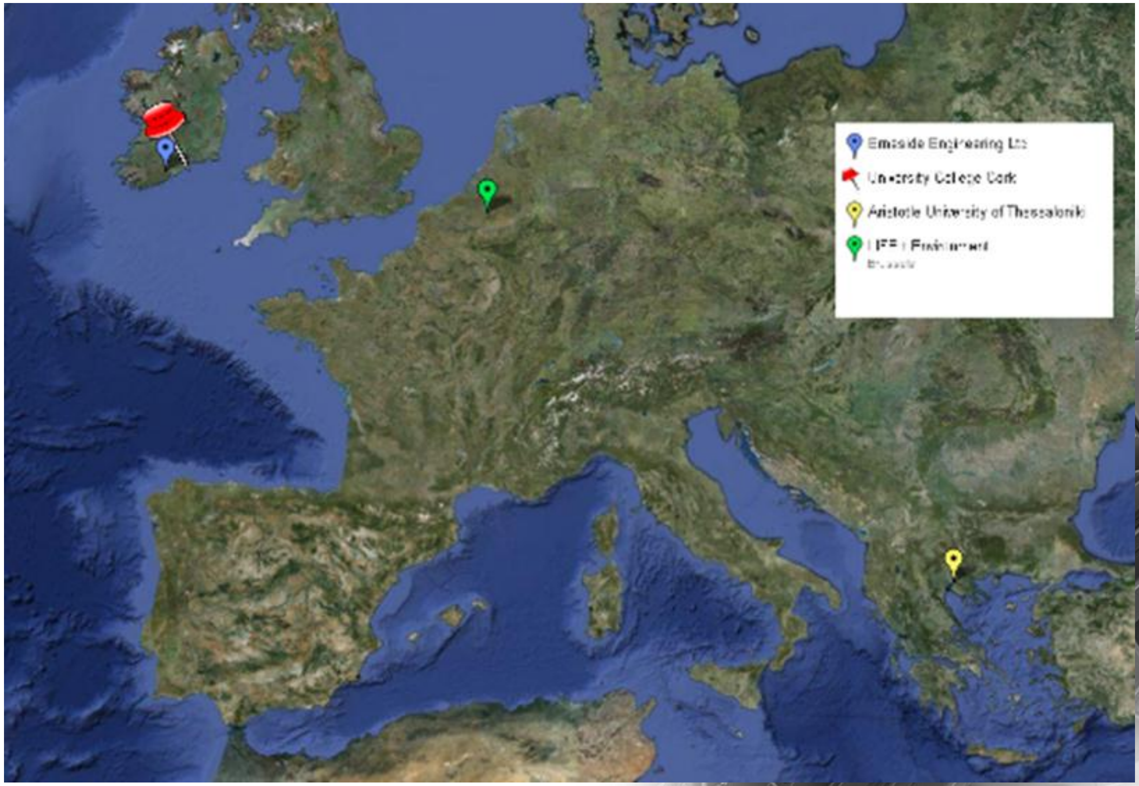
DEPOTEC
LIFE10 ENV/IE/000695

Biomass Group
LABORATORY OF CHEMICAL PROCESS AND PLANT DESIGN

Depolymerisation Technology for Rubber with Energy Optimisation to Produce Carbon Products.

Life

LIFE10 ENV/IE/000695



2-4 July 2015:
3rd INTERNATIONAL CONFERENCE on Sustainable Solid Waste Management,
Tinos island, Greece

Biomass and Wastes Group:
A DEPOTEC member

DEPOTEC
LIFE10 ENV/IE/000695

ARISTOTLE UNIVERSITY OF THESSALONIKI

Biomass Group
LABORATORY OF CHEMICAL PROCESS AND PLANT DESIGN

DEPOTEC

Aristotle University of Thessaloniki
Polytechnic School, Chemical Engineering Department
Prof. A. Zabaniotou

UCC
Coláiste na hOllscoile Corcaigh, Éire
University College Cork, Ireland

University College Cork, Ireland
Sustainable Energy Research Group
Environmental Research Institute
Dr Gillian Bruton

erneside engineering

Erneside Engineering, a Mechanical Engineering Specialists company located in Cork, Ireland

2-4 July 2015:
3rd INTERNATIONAL CONFERENCE on Sustainable Solid Waste Management,
Tinos island, Greece

ARISTOTLE UNIVERSITY OF THESSALONIKI

Biomass and Wastes Group: A DEPOTEC member

DEPOTEC
LIFE10 ENV/IE/000695

Biomass Group
LABORATORY OF CHEMICAL PROCESS AND PLANT DESIGN

UCC
Coláiste na hOllscoile Corcaigh, Éire
University College Cork, Ireland

erneside engineering

Life

Sustainable
+
Environmental friendly process

Feedstock : Waste tyres

Low cost procedure

TARGET

High added value materials

CBp, Activated Carbon, Pesticide absorber

2-4 July 2015:
3rd INTERNATIONAL CONFERENCE on Sustainable Solid Waste Management,
Tinos island, Greece

Biomass and Wastes Group: A DEPOTEC member

LIFE10 ENV/IE/000695

ARISTOTLE UNIVERSITY OF THESSALONIKI

Biomass Group
LABORATORY OF CHEMICAL PROCESS AND PLANT DESIGN

✓ **A pilot plant unit was designed and constructed in Ireland.**

2-4 July 2015: 3rd INTERNATIONAL CONFERENCE on Sustainable Solid Waste Management, **Tinos island**, Greece

ARISTOTLE UNIVERSITY OF THESSALONIKI

Biomass and Wastes Group: A DEPOTEC member

Biomass Group
LABORATORY OF CHEMICAL PROCESS AND PLANT DESIGN

DEPOTEC

LIFE10 ENV/IE/000695 DEPOTEC

For more information on project's progress please visit

www.depotec.eu

2-4 July 2015:
3rd INTERNATIONAL CONFERENCE on Sustainable Solid Waste Management,
Tinos island, Greece

Biomass and Wastes Group

LIFE10 ENV/IE/000695

Thank you for your attention!!!

www.depotec.eu

E-mail: azampani@auth.gr

2-4 July 2015:
3rd INTERNATIONAL CONFERENCE on Sustainable Solid Waste Management,
Tinos island, Greece