Teagasc

AGRICULTURE AND FOOD DEVELOPMENT AUTHORITY

The Irish Agriculture and Food Development Authority

# Biomass Combustion and Utilisation

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Bioenergy Conference

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# Introduction

- Background – why the need for alternative biofuels?
- Overview of research in biomass combustion and utilisation conducted at Oak park since 2006
- Pelleting
  - Chemical and physical analysis
- Combustion
  - Combustion efficiency
  - Emissions
  - Emission reduction
- Utilisation

# Ireland's Bioenergy Targets

## RED 2009/28/EC – 16% TFC by 2020

- RES-E 40% renewable contribution by 2020
- RES-T 10% renewable contribution by 2020
- RES-H 12% renewable contribution by 2020

### Additional Targets

- 30% co-firing with biomass at peat power stations 2015

# Bioenergy Feedstocks

- Forestry thinnings: are the predominant bioenergy feedstock at present
- Supply Chains: have been established
- Greatest Potential: lies in private forests
- Forestry owners encouraged to thin as a management tool & to maximize revenue
- But! Only 7% of the land area in Ireland is forest

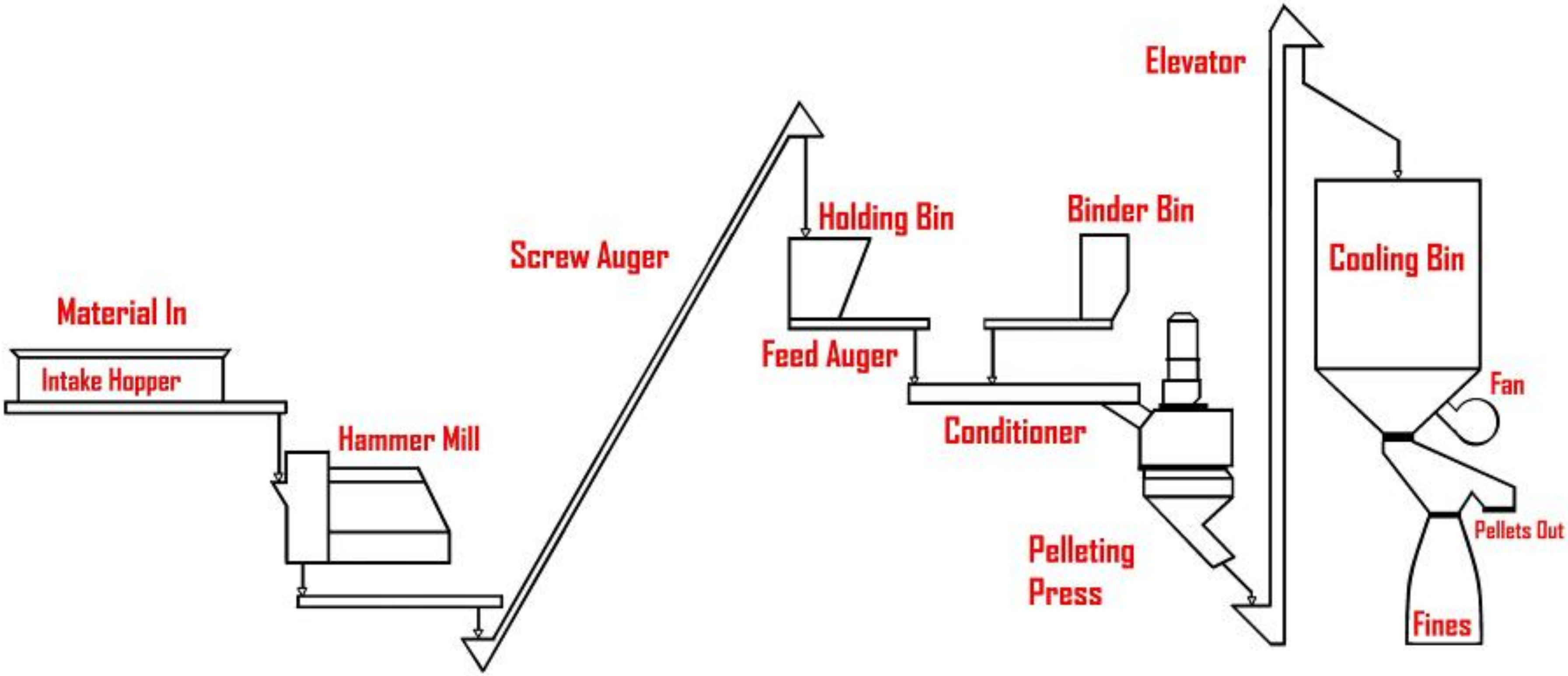
# Energy Crops/Cereal Residues

- Needed to meet bioenergy targets and our future energy needs
- Miscanthus/willow
- Cereal/Rape Straw
- Other crops
  - Hemp
  - Grasses
    - tall fescue,cocksfoot,
      reed canary grass

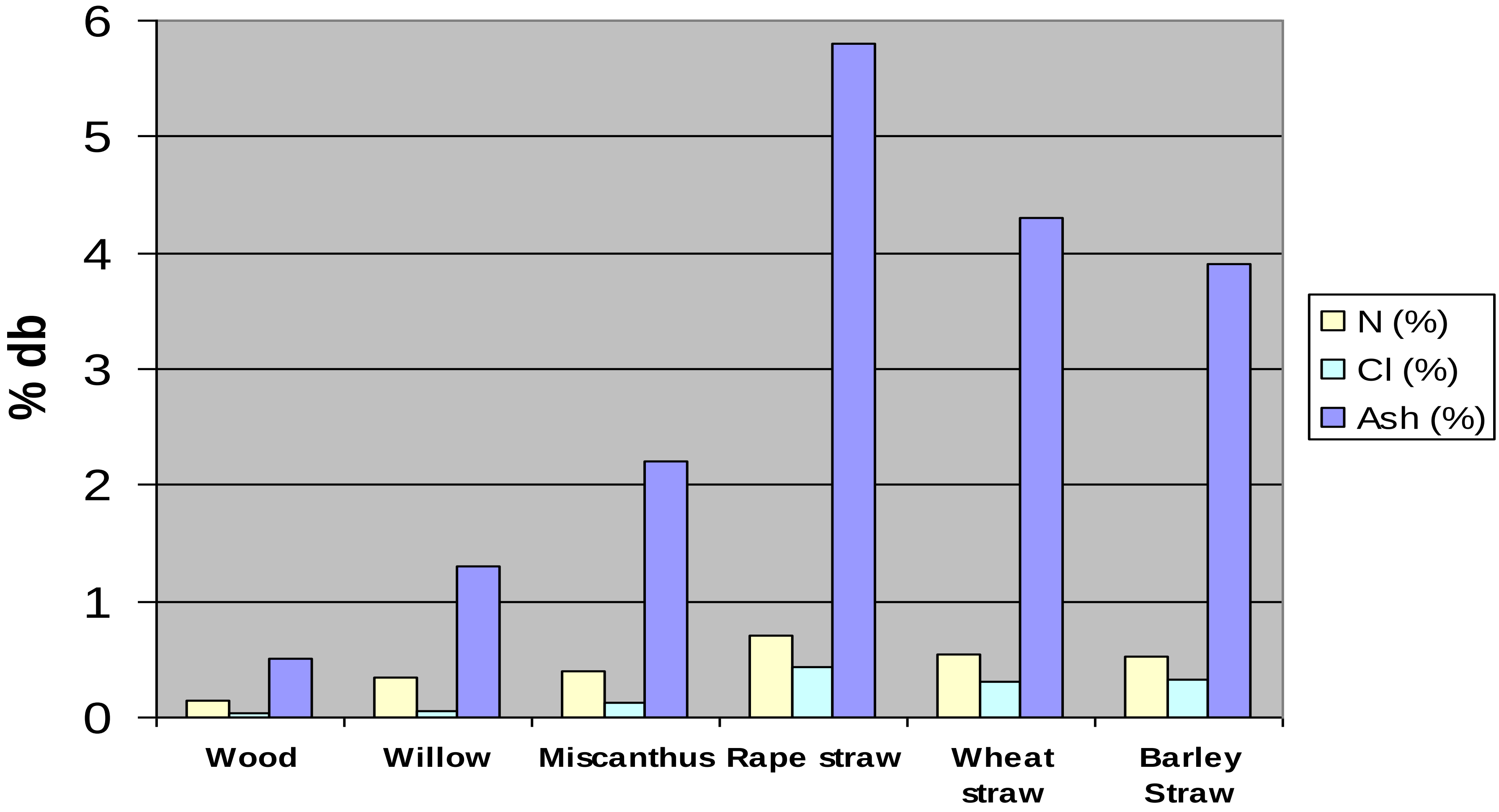
# Pellets for home heating (RSF 2006-2009)

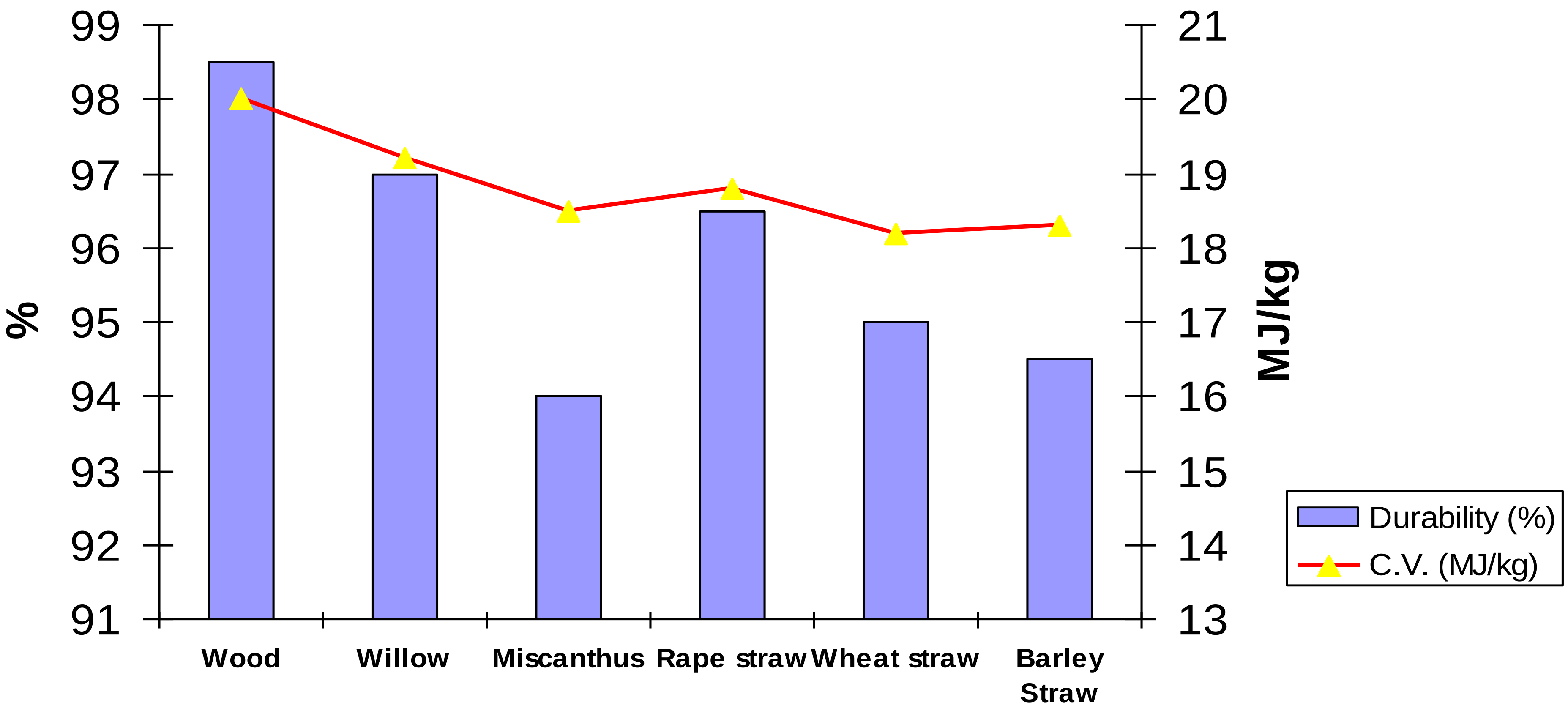
- Sawdust most suitable material
- Alternatives
  - Willow
  - Miscanthus
  - Rape Straw
  - Wheat Straw
  - Barley Straw
- How do they compare to wood pellets?

# Pellet mill layout



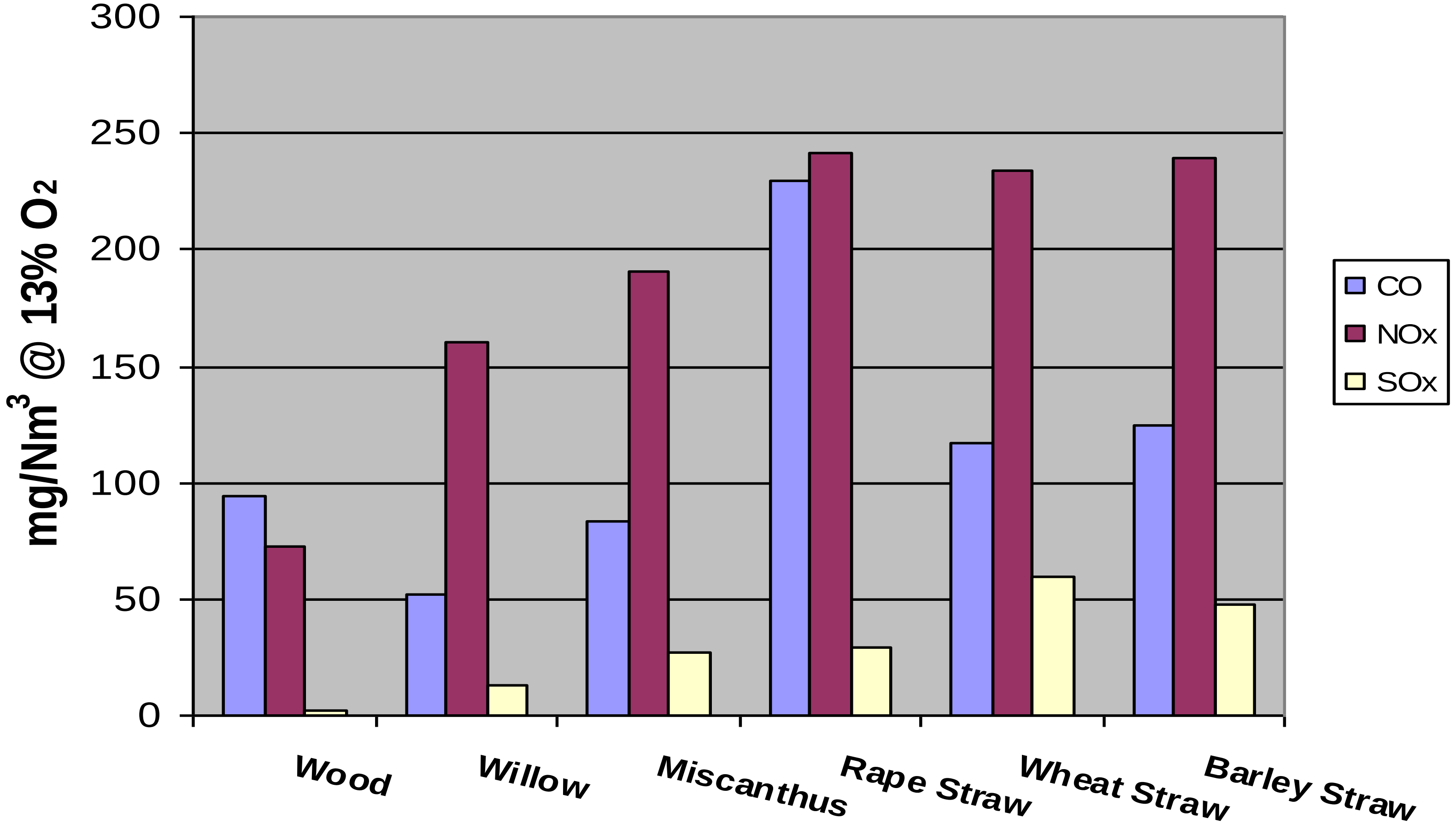
# Chemical Composition





99
98
97
96
95
94
93
92
91
%
21
20
19
18
17
16
15
14
13
MJ/kg
Wood
Willow
Miscanthus
Rape straw
Wheat straw
Barley Straw
Durability (%)
C.V. (MJ/kg)

# Emissions from biomass combustion



# Issues with alternative biomass pellets

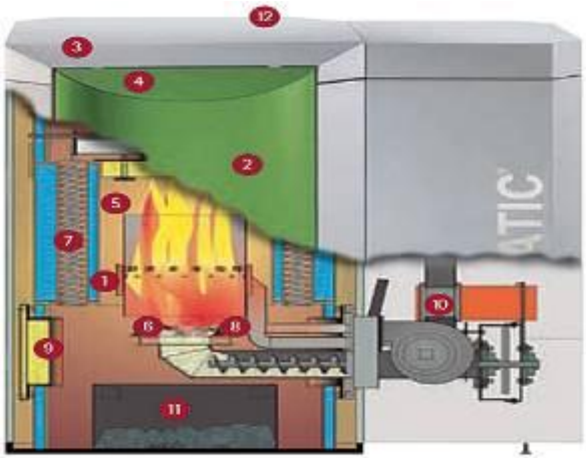
- Low bulk density
  - Pelleting difficulties
- Higher ash content
  - Need automated ash removal systems
- Lower ash melting point
  - Slagging and clinker
- Higher CL and S contents
  - Corrosive elements lead to boiler degradation
- Higher N content
  - Increased NOx emissions

# Combustion research

ERA-NET Bioenergy

Future Bio Tec

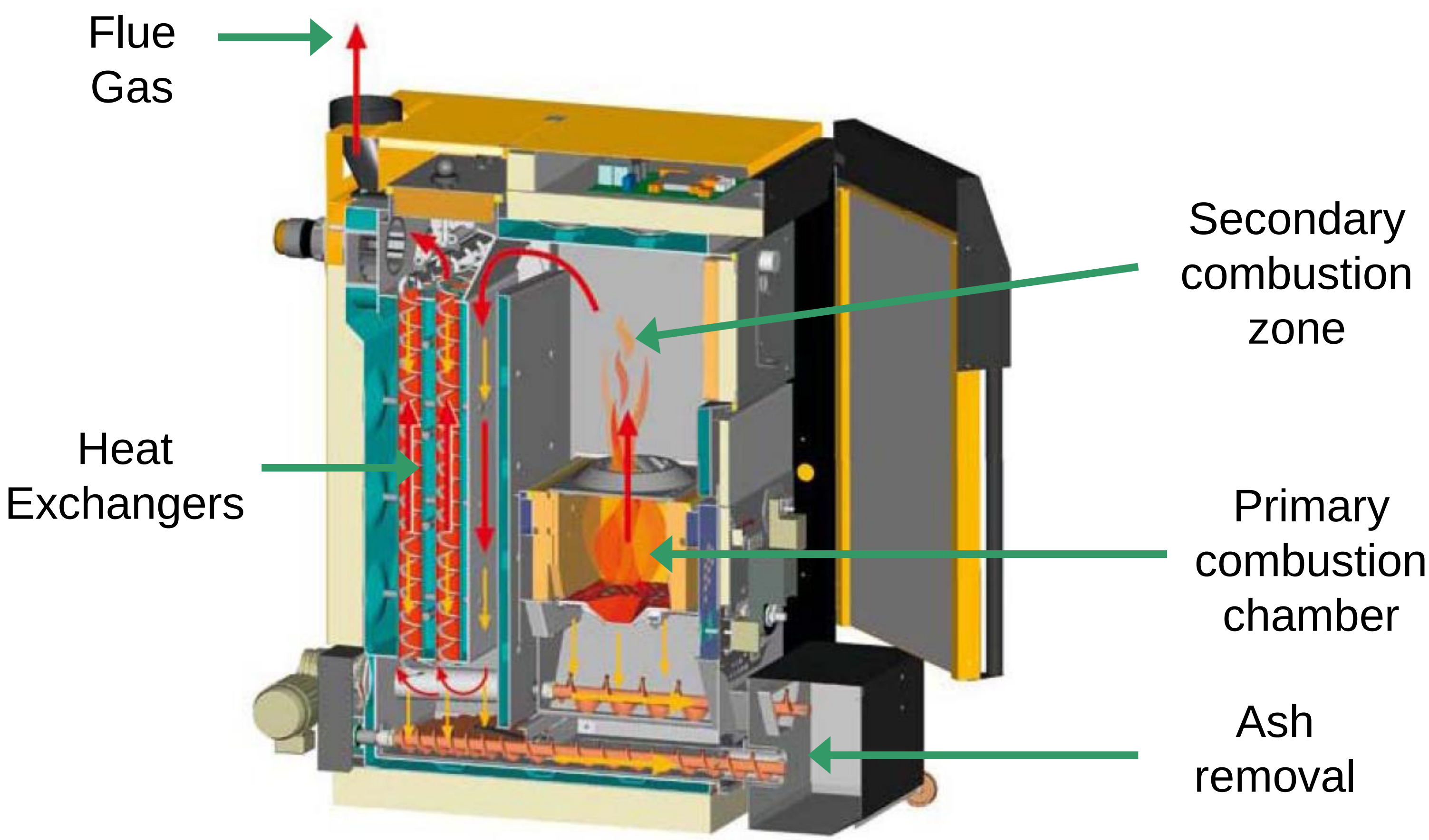
- Future low emission biomass combustion systems
- Partners from
  - Austria, Germany, Poland, Sweden, Finland
- Focus on NOx and PM emission reduction
  - Primary and secondary measures



# Emission Limits

- Currently in Ireland, limits based on EN 303-5:1999, upon boiler being accepted for certification by SEAI
- Stricter limits currently being introduced in many central European countries including Germany and Switzerland
- New EU Ecodesign directive
  - Currently going through European parliament
  - Will place strict emission limits in terms of particulate, CO, NOx and others?

# Combustion principles

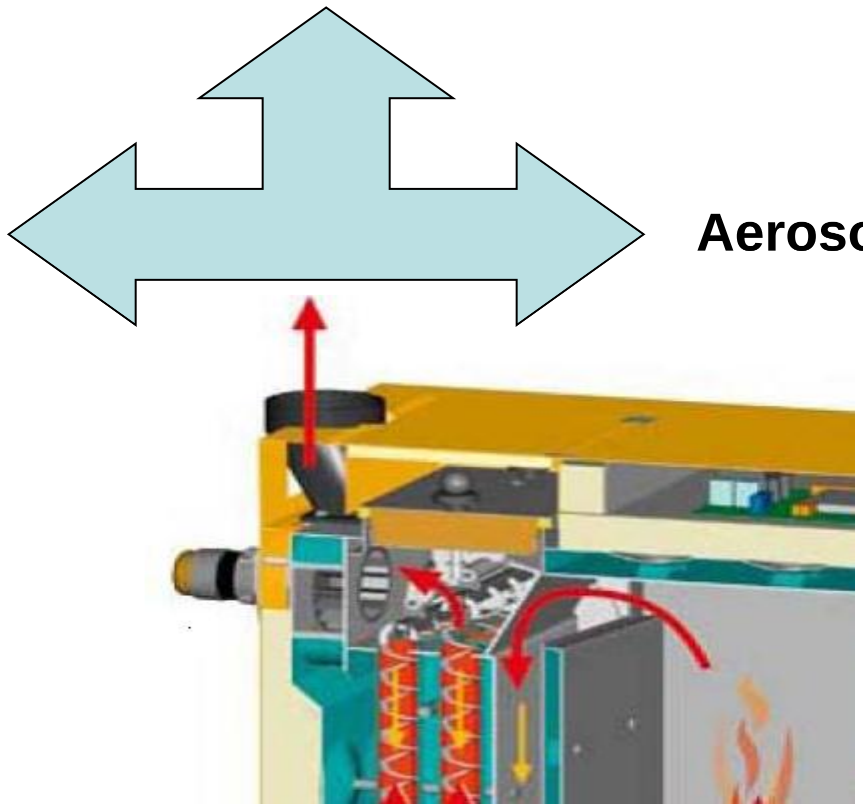


# Emissions

**Gaseous**

**Large particulates**

**Aerosols**



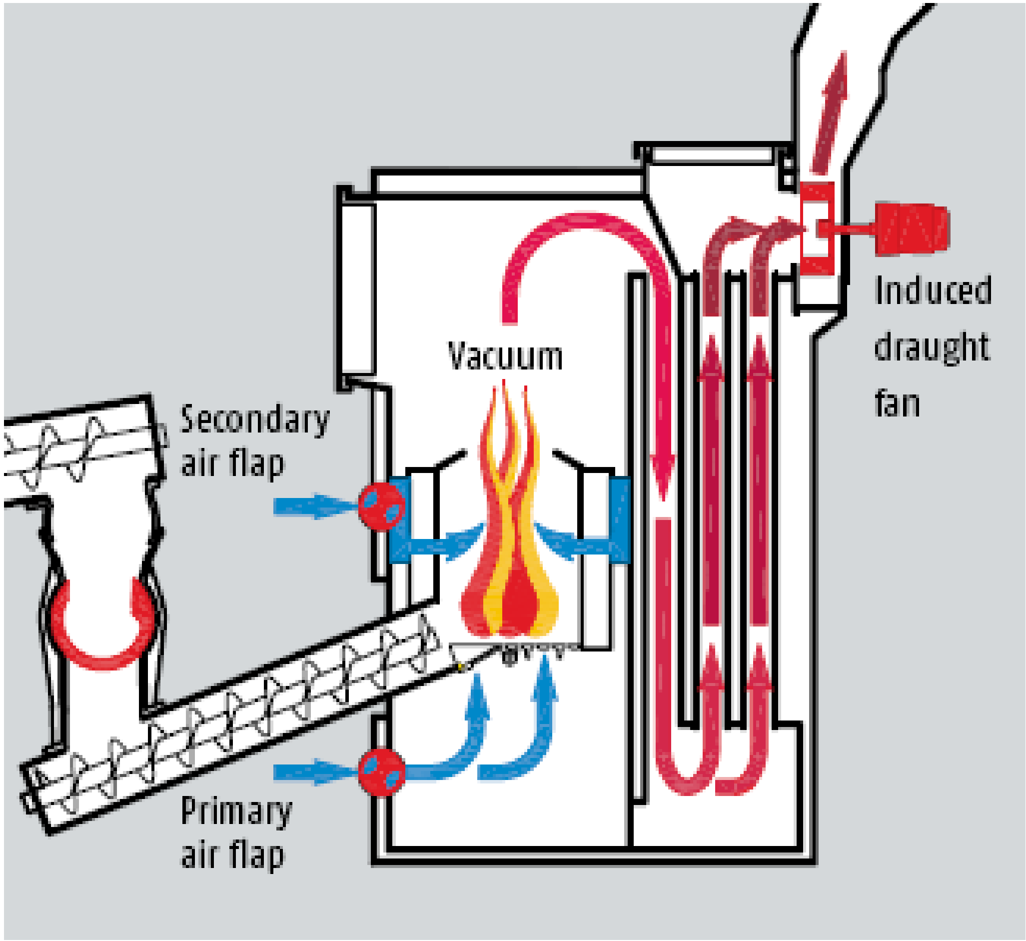
# Gaseous emissions

- $CO_2$
  - Released during any biomass combustion process
  - Greenhouse gas contributor
- CO
  - Mostly through inefficient combustion
  - Health problems at high levels in enclosed environments
- $NO_x$
  - Environmental and health concerns
- $SO_x$
  - Environmental and health concerns

# Emission reduction strategies

- Primary measures
  - Air staging
  - Temperature control: keep combustion chamber temps below ash melting point + decreased thermal NOx
  - Additives: elements which increase ash melting point
  - Mixtures: low N with high N fuel
- Secondary measures
  - Electrostatic precipitators
  - Ceramic filters
  - Improved boiler design

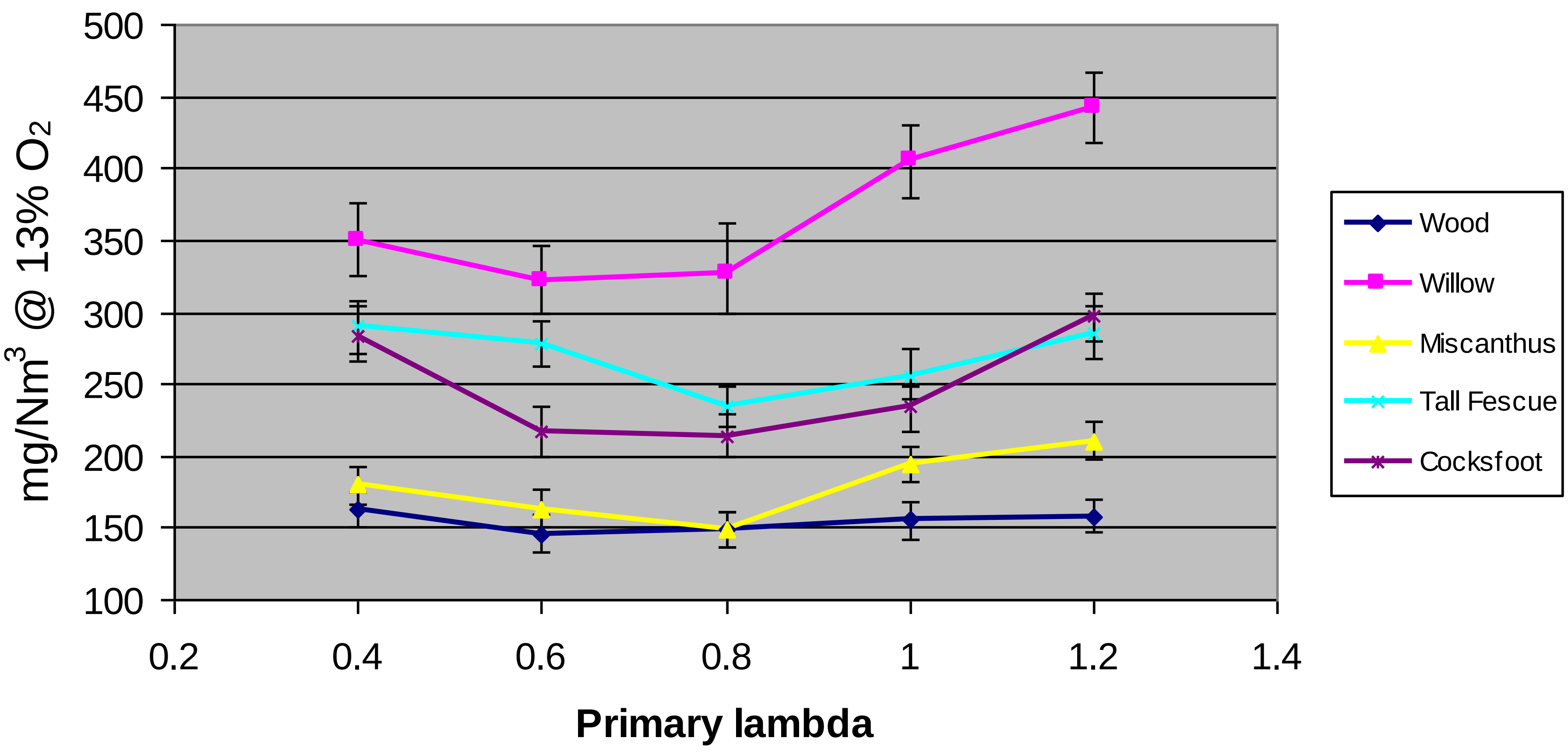
# Air Staging


Vacuum
Secondary air flap
Induced draught fan
Primary air flap

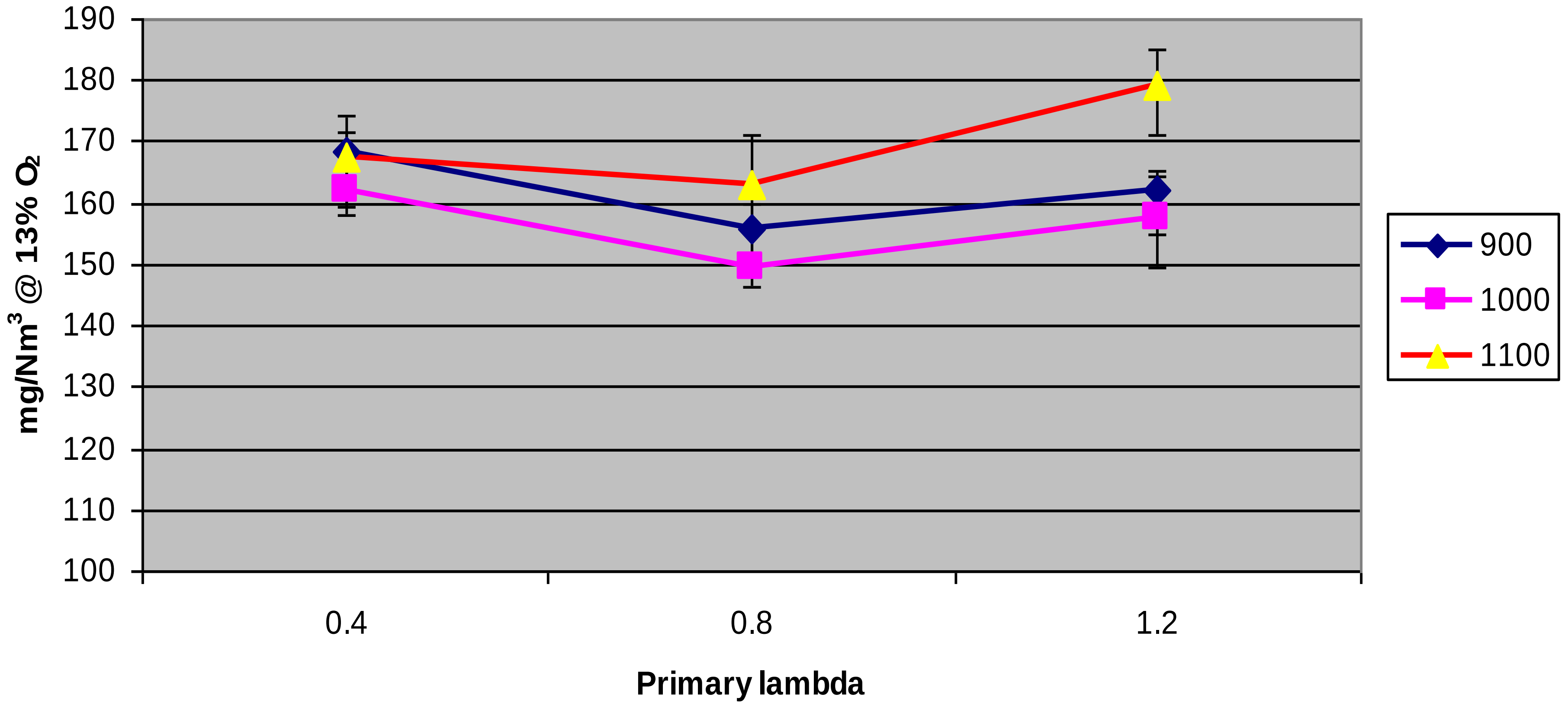
## Chemical Comparisons

| | Wood | Willow | Cocksfoot | Tall Fescue | Miscanthus |
|---|---|---|---|---|---|
| **Calorific Value (MJ/kg)** | 20.09 | 19.52 | 18.42 | 18.36 | 18.59 |
| **Ash Content (%)** | 0.31 | 2.22 | 6.12 | 4.96 | 2.5 |
| **Chlorine Content (%)** | 0.13 | 0.18 | 0.35 | 0.32 | 0.142 |
| **Sulphur Content (%)** | 0.006 | 0.022 | 0.075 | 0.125 | 0.066 |
| **Nitrogen Content (%)** | 0.1599 | 0.4994 | 0.63 | 0.699 | 0.331 |
| **Carbon Content (%)** | 50.18 | 48.73 | 48.04 | 48.71 | 48.83 |
| **Hydrogen Content (%)** | 6.08 | 5.85 | 5.67 | 5.94 | 6.30 |

# NOx reduction by air staging



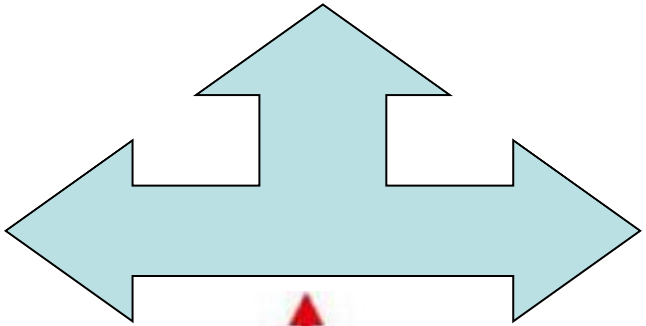
# Effect of temperature on NOx emissions (wood)



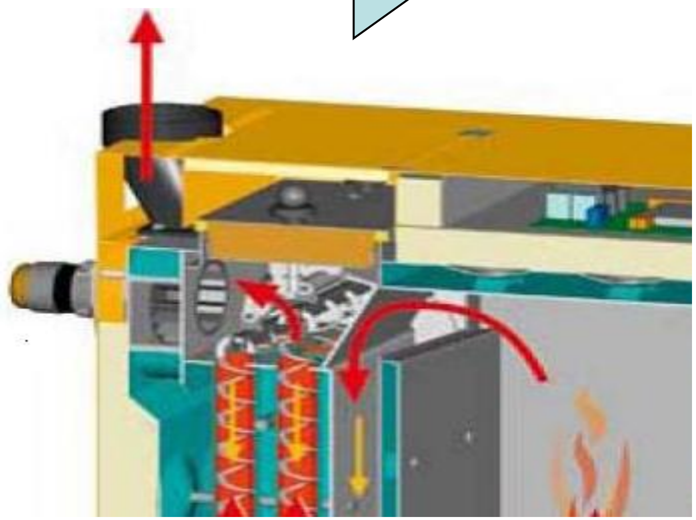
# Emissions

Gaseous

Large
particulates



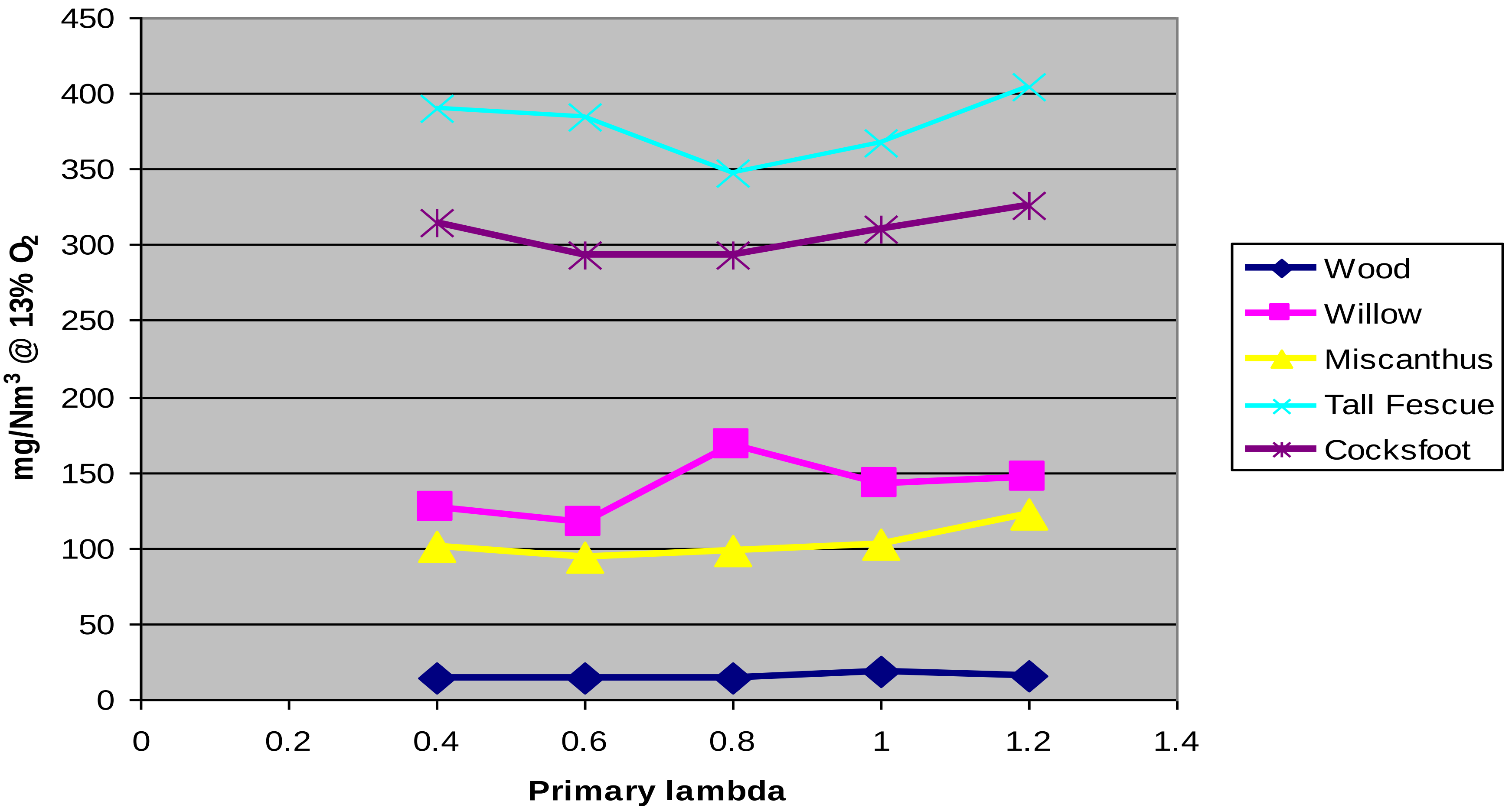
Aerosols



# Particulate emissions

- >1µm: Fly ash, soot, heavy particles
  - Indicator of a badly performing boiler
  - Nuisance value
- <1µm: aerosols:
  - Health implications
  - Dioxins
  - PAHs
- In Ireland currently not considered an issue on domestic scale.
- Central Europe and Scandinavia a lot of research into health effects ongoing.

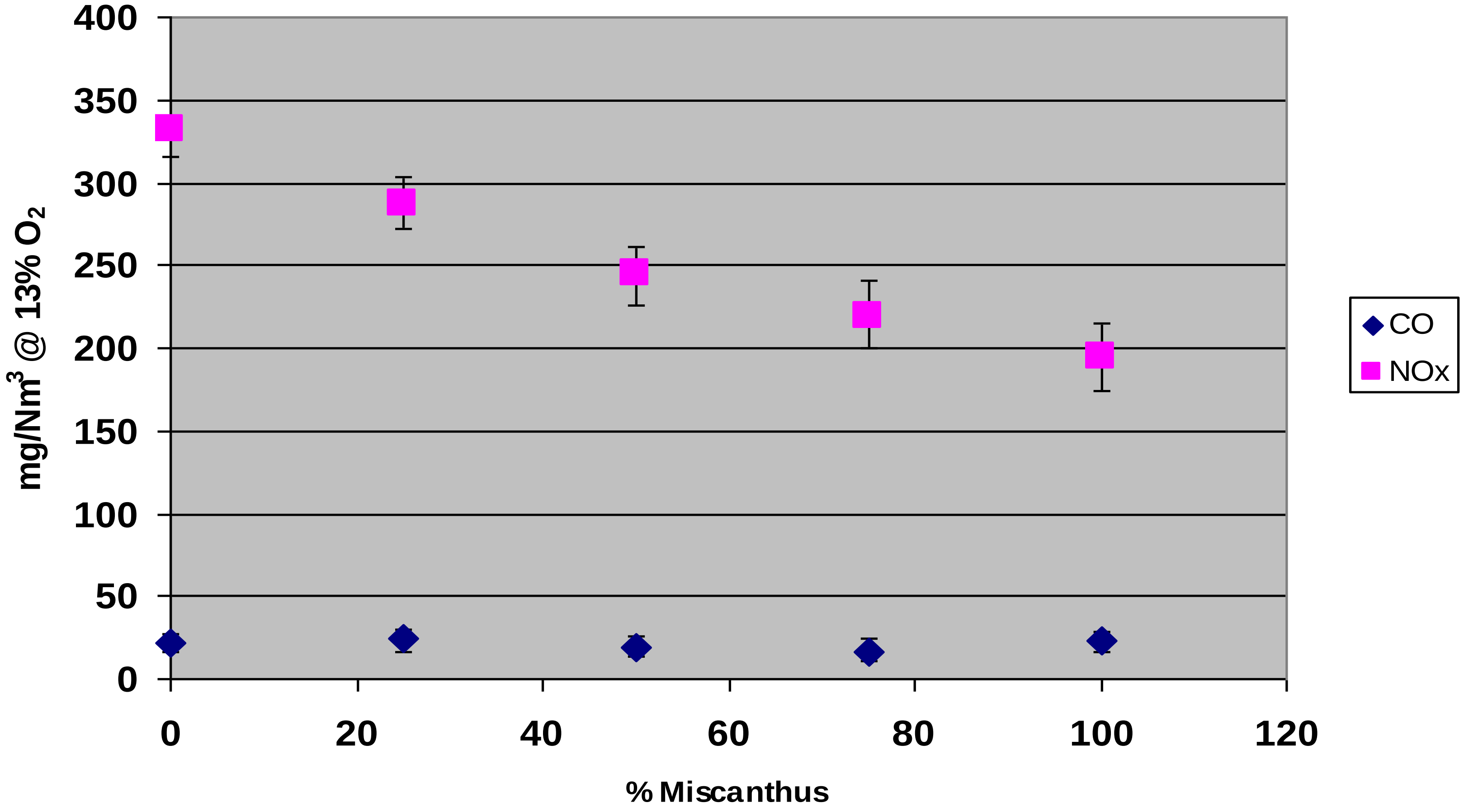
# Primary dust emission reduction measures: Air Staging



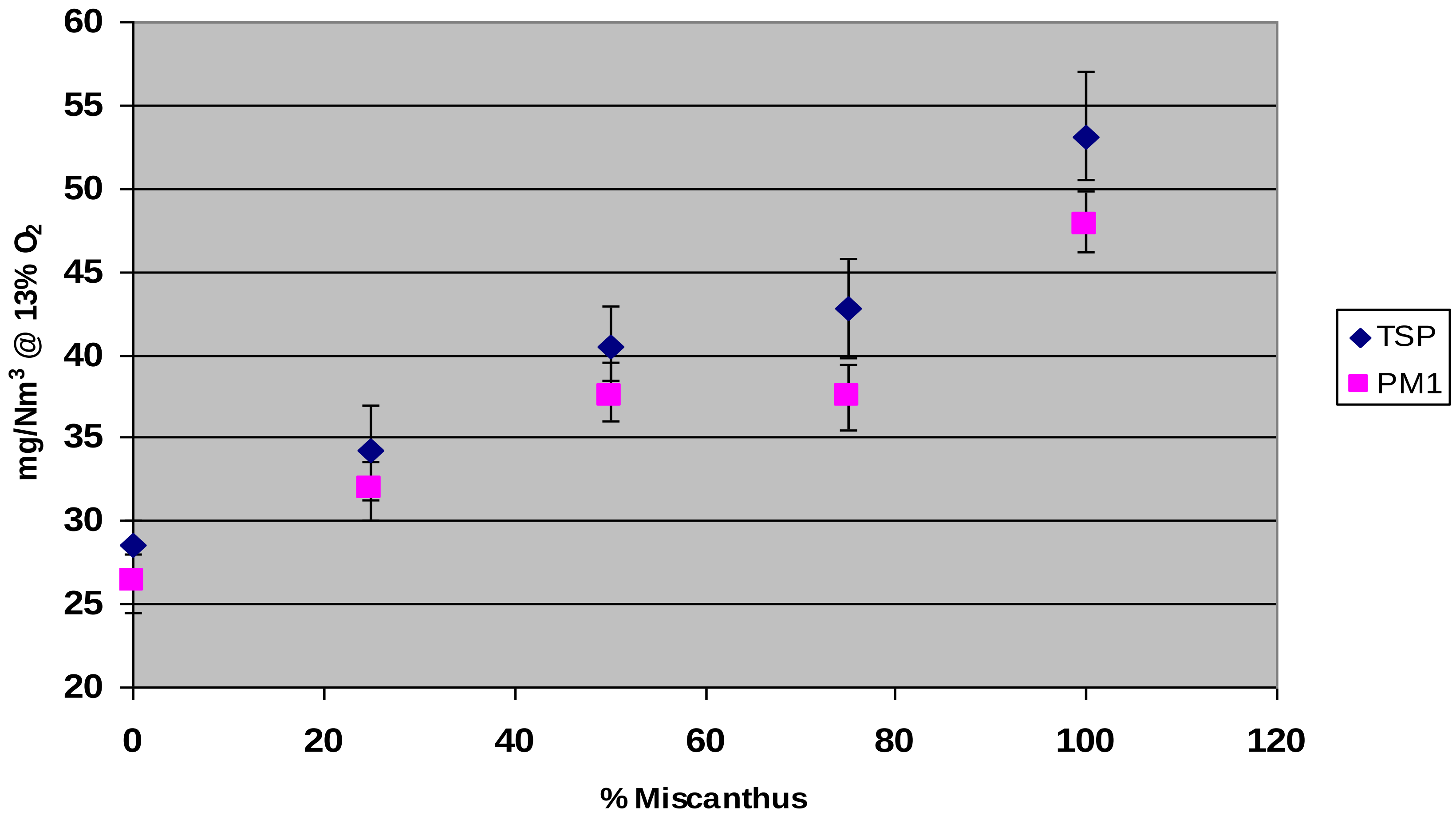
# Mixtures and additives

- Peat and Miscanthus
  - Blending to achieve best characteristics of both materials
- Tall Fescue and kaolin
  - Kaolin increases ash melting point and thus decreases particulate emissions

# Peat and Miscanthus: NOx



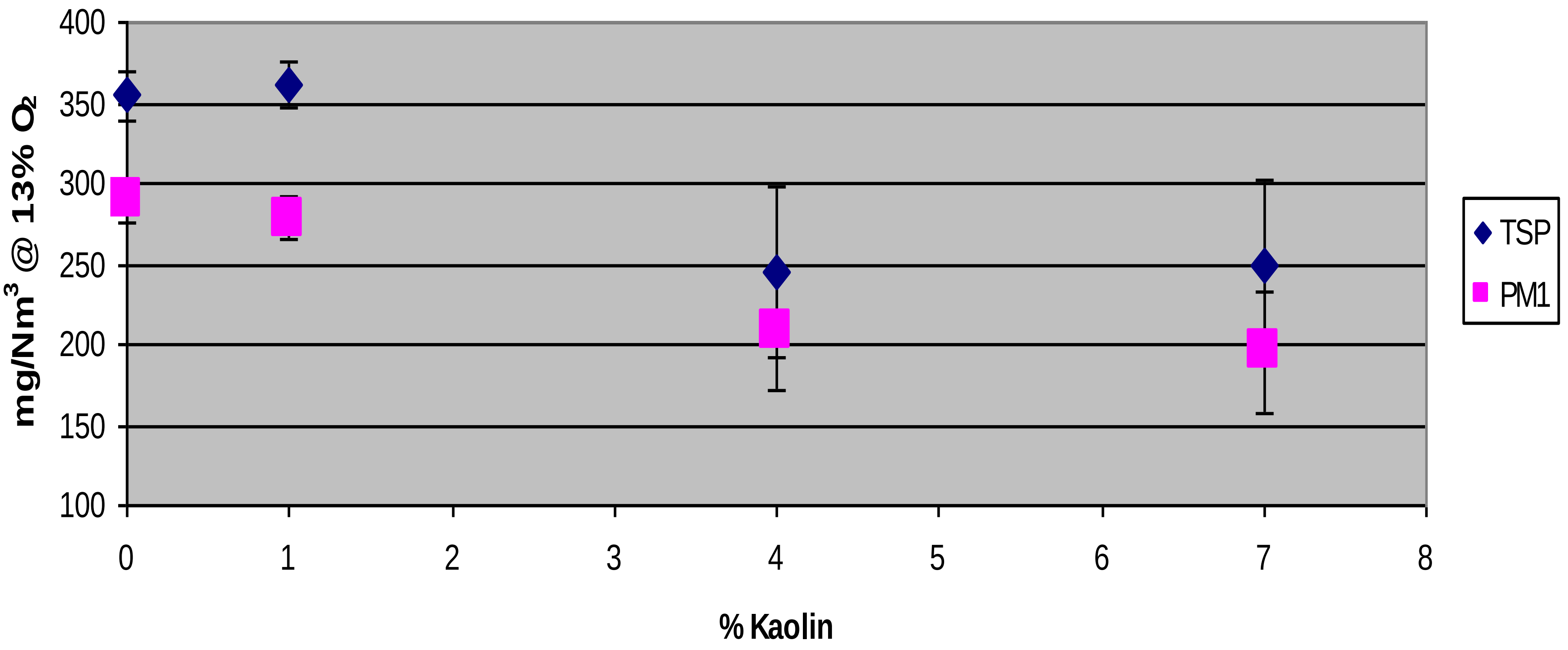
# Peat and Miscanthus: Particulates



# Tall Fescue Ash

# Effect of kaolin addition

# Effect of kaolin addition



# Blending and additives conclusions

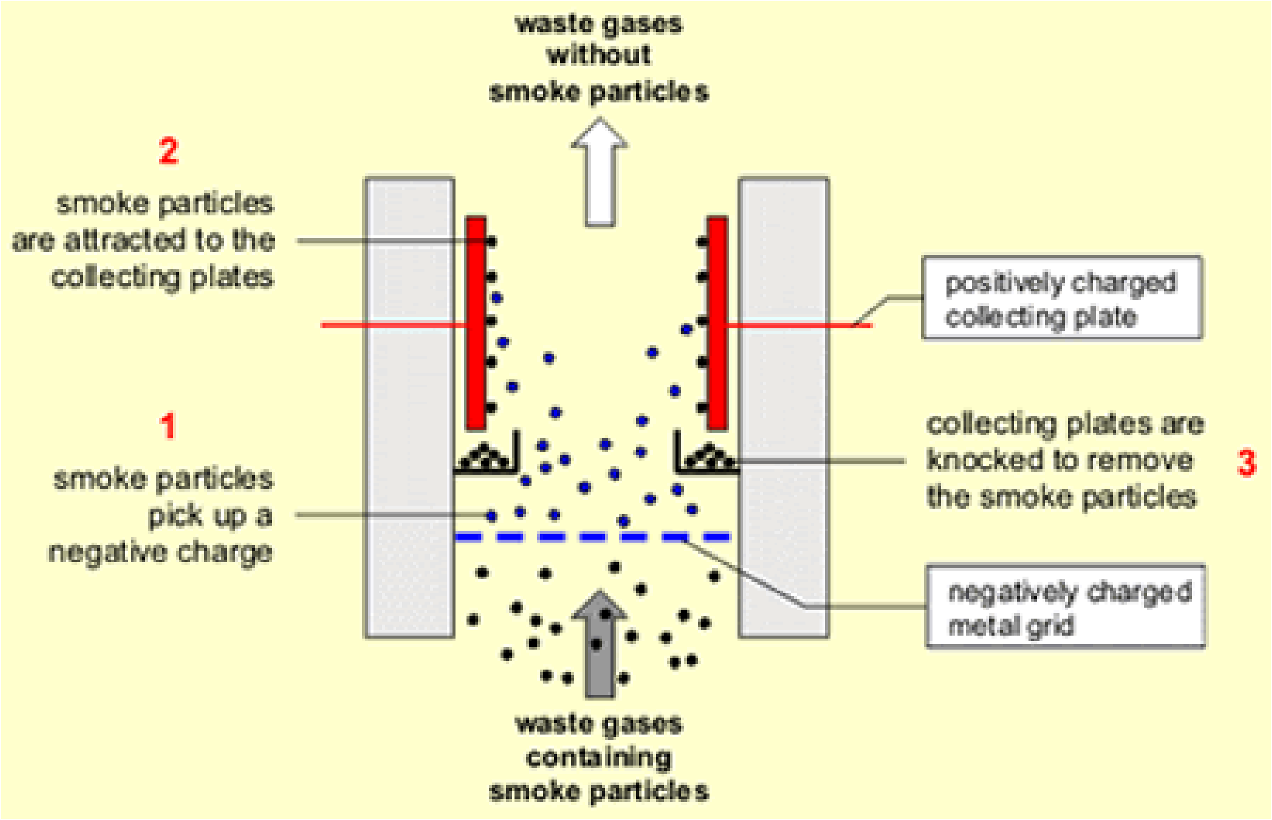
- Both blending and additives have the potential to greatly reduce particulate emissions from energy grass combustion and enable combustion of biomass with low ash melting temperatures
- However, especially for kaolin, issues with ash volume mean more research into boiler/grate types is necessary
- From an Irish perspective, blends of wood/peat with energy grasses are of great interest to maximise our scarce wood resource and help reduce usage of dwindling peat supplies.

# General Primary emission reduction strategy conclusions

- Primary lambda kept below 1 (exact value boiler but not fuel dependent)
- Flue gas recirculation below the grate should be applied to reduce ash melting and hence decrease PM1 emissions
- Temperature in the primary combustion chamber should be kept at a suitable level for the fuel
- Large potential in the appropriate use of blending and additives

# Secondary PM reduction measures

## Electrostatic precipitators (ESPs)




Emissions
Flue Gas
35 kW

# ESP comparisons

# ESP conclusions

- Can achieve very high efficiencies when used in correct operating conditions.
- Will be required to meet future standards where alternative fuels are combusted.
- Expense a major issue

# Biomass Utilisation

- Teagasc research has looked at numerous alternative fuels on a domestic scale as discussed
- It has been shown that all these materials can be
  - Pelleted
  - Combusted
  - Emissions reduced
- Multifuel boilers are available that can handle these fuels
  - Specialised steel/ceramic bodies
  - Flue gas recirculation
  - Specialised grates
  - Ability to control combustion environment/temperature

# Biomass Utilisation

- Many industrial units (> 100kW) (both heat only and CHP) in operation and in planning
  - Willow
  - Miscanthus
  - Straw
- Large Scale – electricity production
  - Bord Na Mona peat burning stations have included willow and miscanthus
  - Many straw burning power stations in Europe especially Denmark and coming online in UK

# Overall Conclusions

- Biomass combustion and utilisation is a very complex and challenging area.
- Ireland well behind central and northern Europe in terms of biomass utilisation.
- Research conducted in association with world renowned experts in the field has given Teagasc great knowledge and expertise in these challenging areas which can hopefully be passed on to and developed with all interested parties

# Acknowledgements

Department of Agriculture, Food and the Marine
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- http://www.teagasc.ie/energy/research/BiomassCombustion.asp