



Universita' degli Studi di Napoli "Federico II"  
*Dipartimento di Ingegneria Chimica*

**An integrated network on thermal biomass  
conversion for power, heat and transport fuels**

## **ThermalNet**

Work Package: **WP2F**

WP Title: **Science and Modeling**

WP Leader: **Colomba Di Blasi**

Presentation by **Antonio Galgano**

Intelligent Energy  Europe

**ThermalNet**  
PyNe/GasNet/CombNet



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## WP 2F

## Objectives

**Introduction** - The design and development of practical biomass conversion systems is complicated by: variability of chemico-physical properties, huge number of chemical products, interaction between chemical and physical processes, need to control pollutants emissions. A comprehensive assessment about the actual scientific knowledge on thermochemical conversion processes is not available and the results achieved in one sector are unknown to the other despite the inter-relation.

**Objectives** - reviewing the current state of the scientific understanding in biomass pyrolysis, gasification and combustion, thus improving the exploitation of these results in technology implementation.

**Tasks** - The WP2F comprises the following the tasks: (1) literature review, (2) review about ongoing research, (3) assessment of industrial needs.



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## Application form for Scientists

Scientist Information	Institution name, Institution address, Contact person(s), Contact's phone and e-mail
Technology	<ul style="list-style-type: none"><li>•Pyrolysis</li><li>•Gasification</li><li>•Combustion</li></ul>
Level of Research	<ul style="list-style-type: none"><li>•Fundamentals and laboratory experimentation</li><li>•Applied research</li><li>•Demonstration</li></ul>
Funding	<ul style="list-style-type: none"><li>•Public</li><li>•Private</li></ul>



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## Research topics: Pyrolysis

Specify (if appropriate)	
P1 Feedstocks	P10 Product upgrading
P2 Biomass components	P11 Biorefinery
P3 Pre-treatments	P12 Chemicals production/recovery
P4 Drying	P13 Natural or added catalysts
P5 Physical properties: feedstocks, char	P14 Dynamics of minor species: N, S, Cl, other
P6 Chemical kinetics	P15 Model development
P7 Carbonization Fast pyrolysis Co-pyrolysis Other	P16 Numerical simulation
P8 Plant optimization	P17 Economic aspects
P9 Chemical Characterization of liquid products	P18 Bio-oil combustion/gasification



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## Research topics: Gasification

Specify (if appropriate)	
G1 Feedstocks	G10 Gas cleaning
G2 Pre-treatments	G11 Product upgrading
G3 Drying	G12 Natural or added catalysts
G4 Physical properties: feedstocks, char	G13 Dynamics of minor species: N, S, Cl, other
G5 Chemical kinetics	G14 Model development
G6 Fixed bed Fluidized bed Entrained bed Co-gasification Other	G15 Numerical simulation
G7 Plant optimization	G16 Economic aspects
G8 Char reactivity	G17 Life Cycle Assessment (LCA)
G9 Ash behaviour	



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## Research topics: Combustion

Specify (if appropriate)	
C1 Feedstocks	C10 Gas cleaning
C2 Pre-treatments	C11 Natural or added catalysts
C3 Drying	C12 Dynamics of minor species: N, S, Cl, other
C4 Physical properties: feedstocks, char	C13 Pollutants abatement
C5 Chemical kinetics	C14 Model development
C6 Fixed bed Fluidized bed Entrained bed Co-combustion Other	C15 Numerical simulation
C7 Plant optimization	C16 Economic aspects
C8 Char reactivity	C17 Life Cycle Assessment (LCA)
C9 Ash behaviour	



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## Application form for Industries

Company Information	Company name, Company address, Contact person(s), Contact's phone and e-mail
Technology	Pyrolysis, Gasification, Combustion
Topics to be investigated	Feedstocks; Biomass components; Pre-treatments; Drying; Physical properties; Chemical kinetics; Carbonization; Fast pyrolysis; Co-pyrolysis; Fixed bed; Fluidized bed; Entrained bed; Co-gasification; Plant optimisation; Chemical characterization of liquid products; Char reactivity; Ash behaviour; Gas cleaning; Product upgrading; Chemicals production/recovery; Natural or added catalysts; Dynamics of minor species; Pollutants abatement; Model development; Numerical simulation; Economic aspects; Bio-oil combustion; Life Cycle Assessment
Suggested topics	
Specify issues to be investigated	



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## To Scientists

Number of questionnaires sent:

**215 + Newsletter**

Number of questionnaires filled in:

**38**

## To Industries

Number of questionnaires sent:

**50 + Newsletter**

Number of questionnaires filled in:

**16**

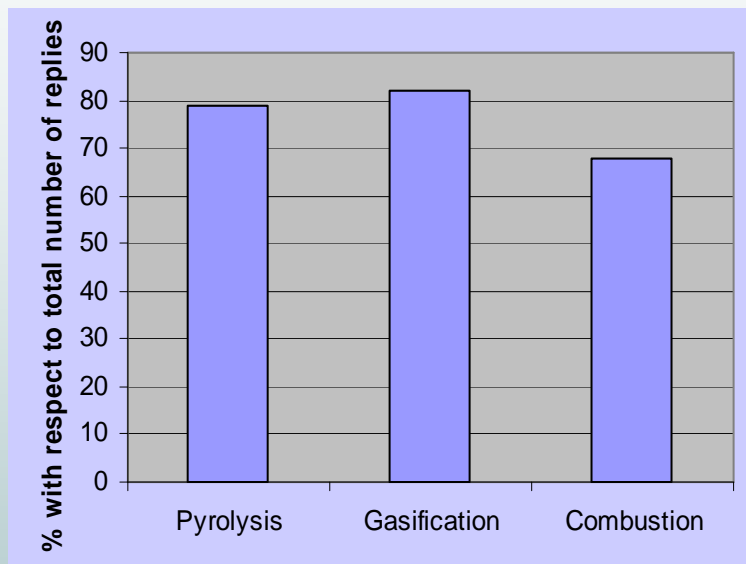


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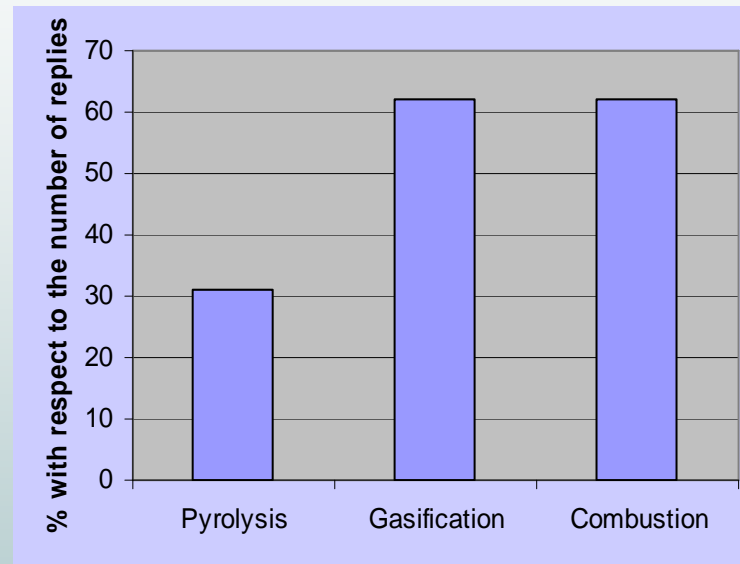
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### Technology

Scientists



Industries

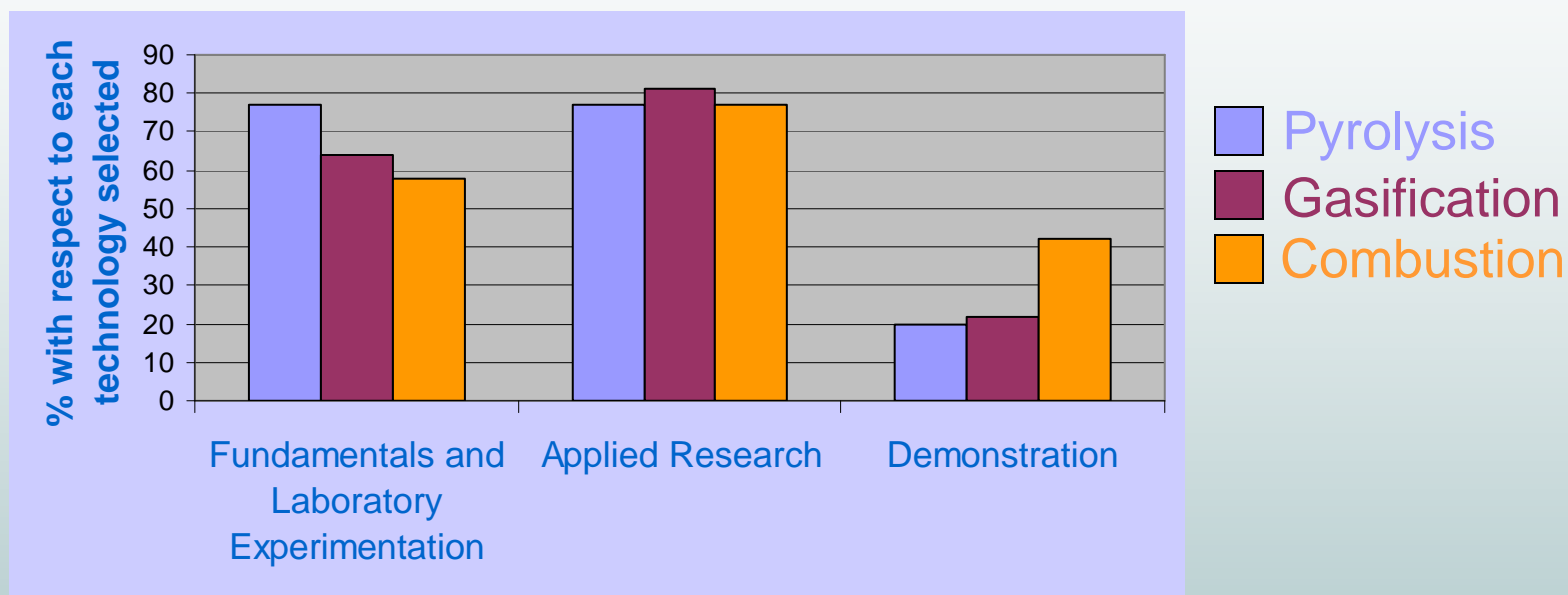


- The interest of scientists for the three conversion technologies is roughly the same
- Scientists are generally involved in two or all the three conversion technologies, in a larger extent with respect to industrial researchers.
- Industrial research focuses more on gasification and combustion, rather than on pyrolysis



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## Scientists: Level of Research

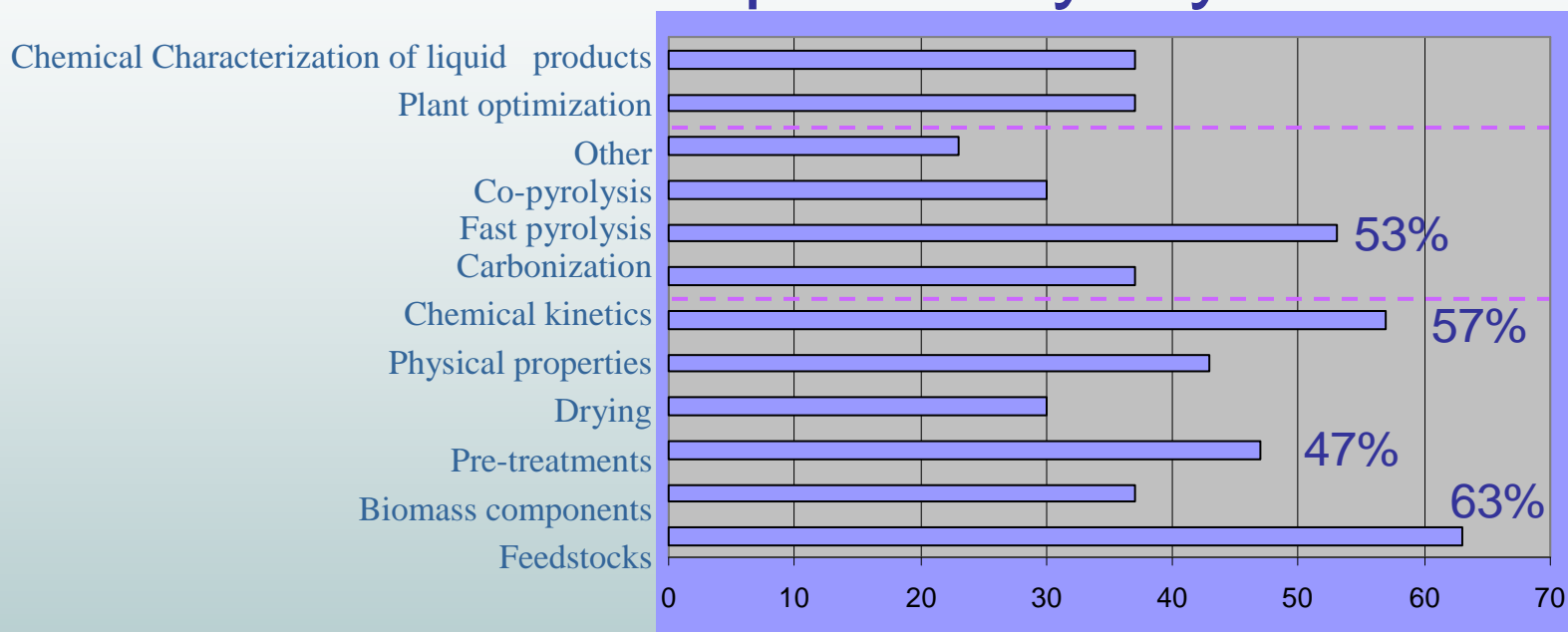


- Scientists are generally involved in two or all the three levels of research for all of the three conversion technologies
- The main research areas for all the three technologies are: a) Fundamentals and Laboratory Experimentation; b) Applied Research
- Research at a demonstration level is roughly double for combustion with respect to pyrolysis and gasification



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# Research Topics - Pyrolysis/1



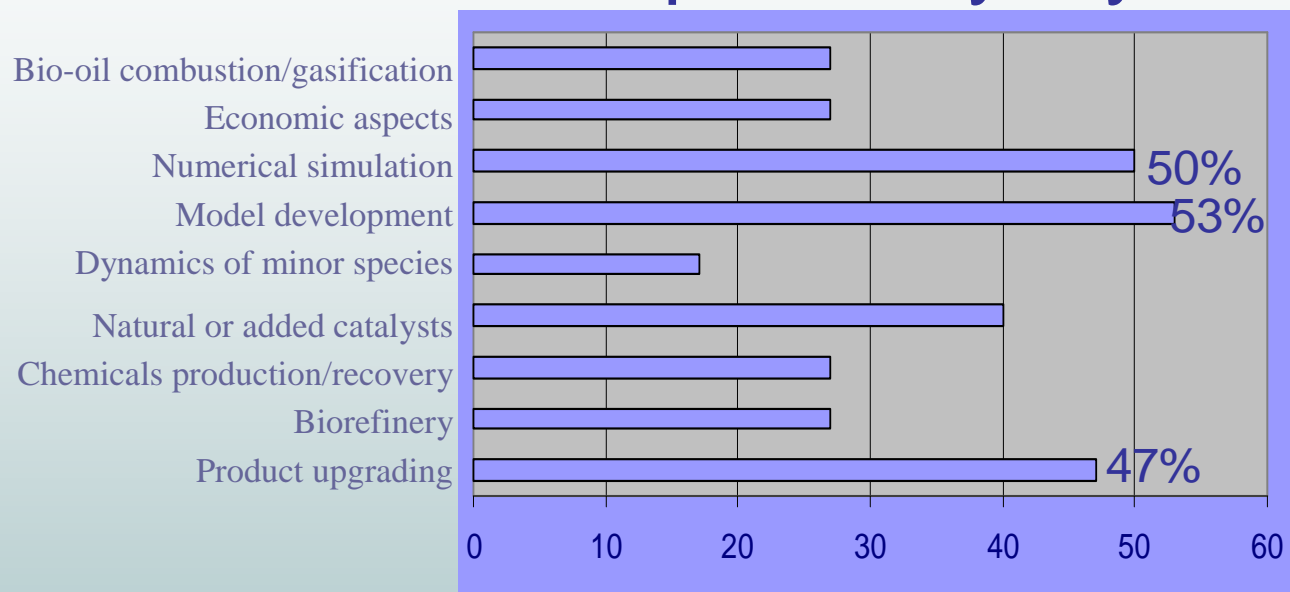
Percentages are evaluated with respect to the number of scientists with research activities in pyrolysis

Research activities on physical properties include feedstocks (77%) and char (100%)



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## Research Topics – Pyrolysis/2



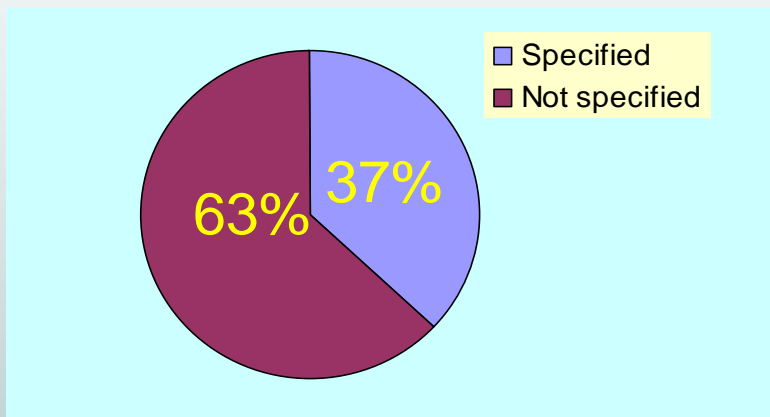
Percentages are evaluated with respect to the number of scientists with research activities in pyrolysis



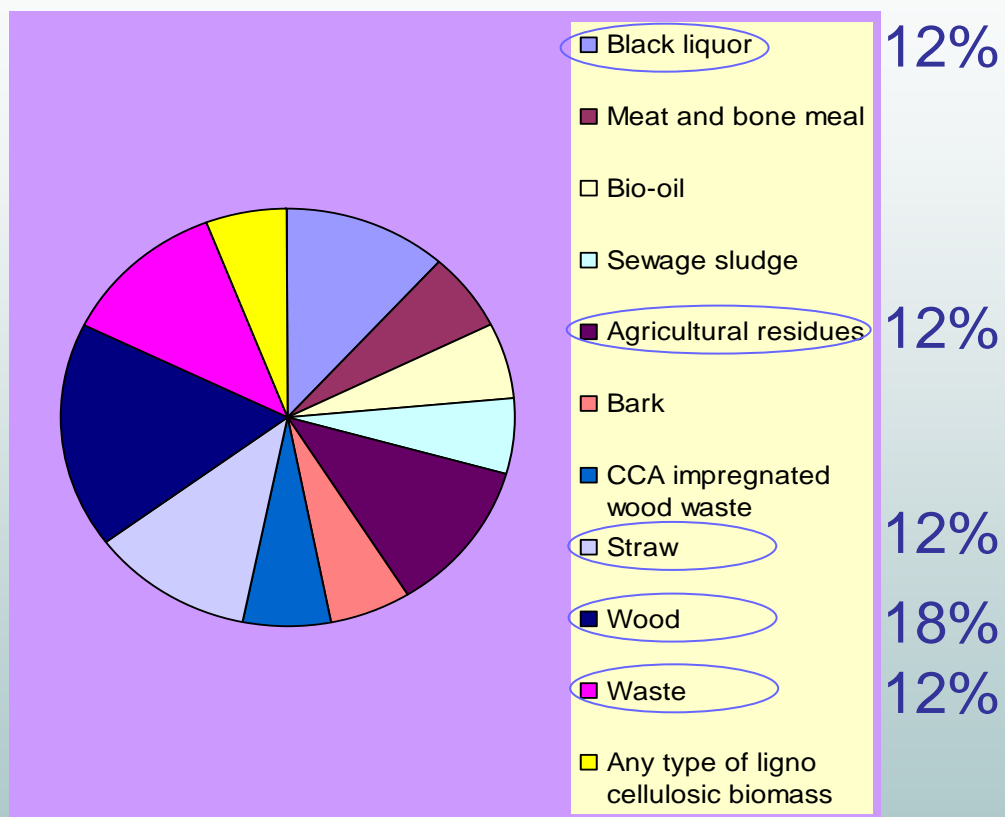
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### Pyrolysis – Feedstocks



Percentage of scientists who specify this topic



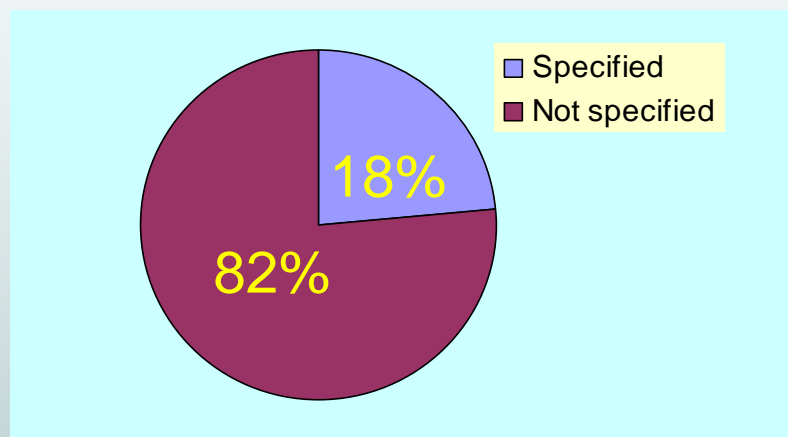
Percentages are evaluated with respect to the number of specified feedstocks



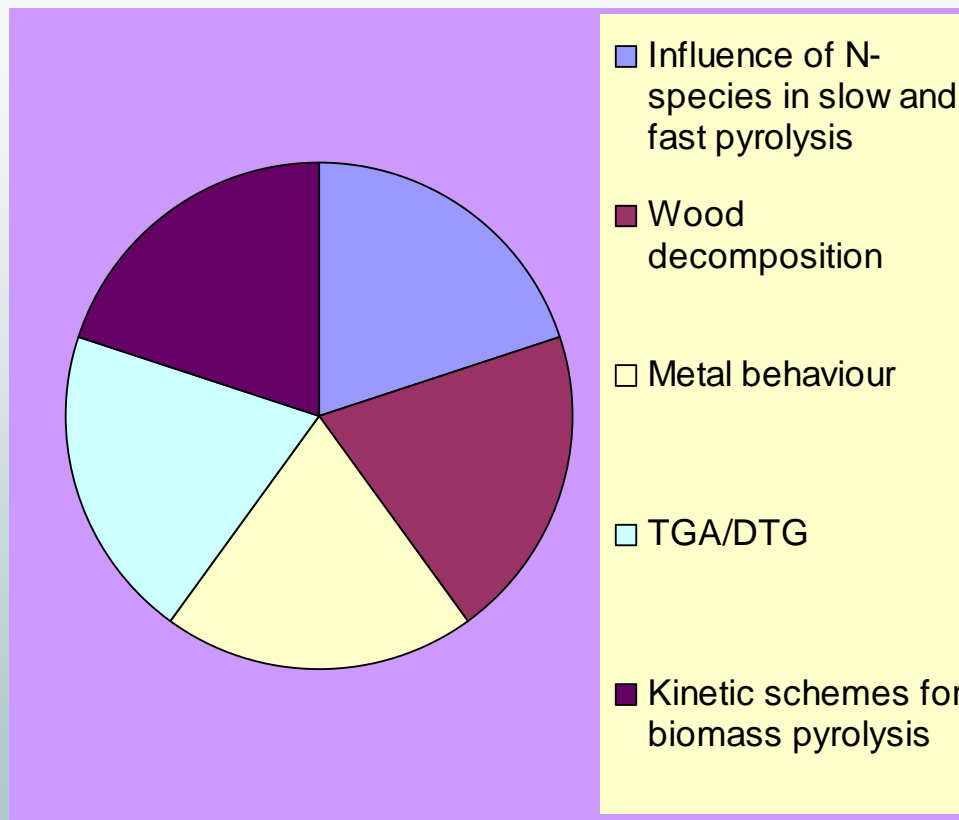
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### Pyrolysis – Chemical kinetics



Percentage of scientists who specify this topic

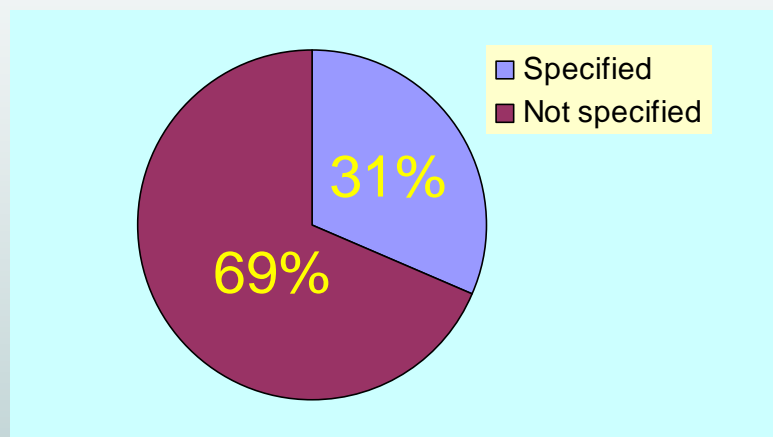




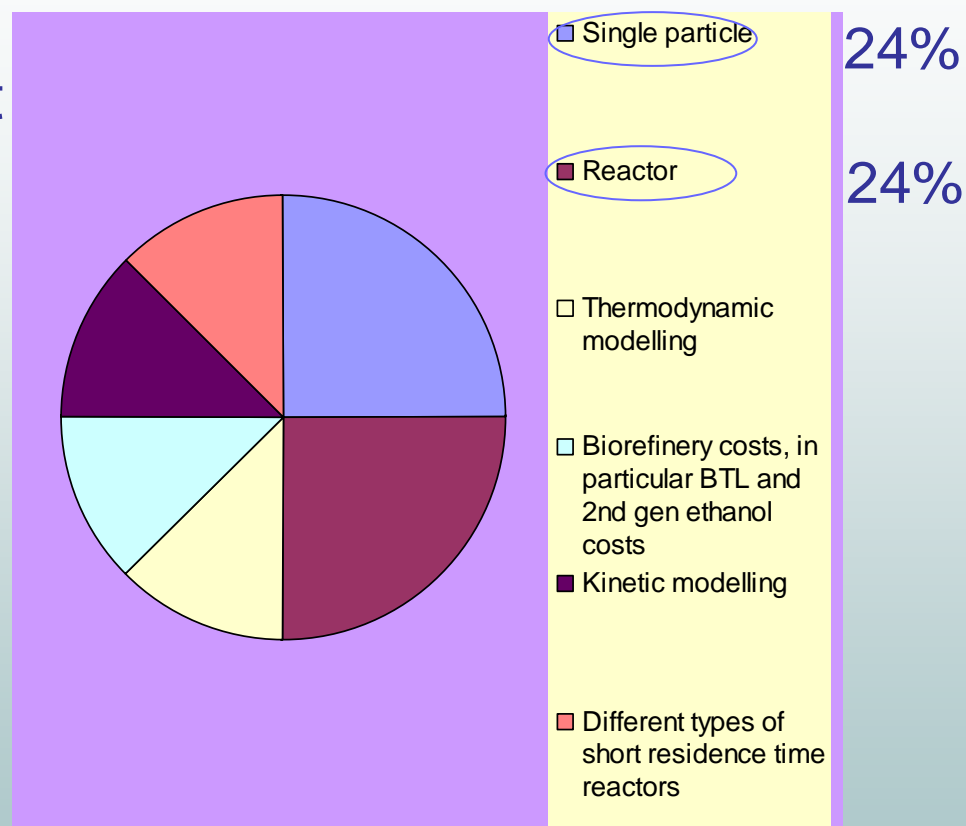
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### Pyrolysis – Model development



Percentage of scientists who specify this topic



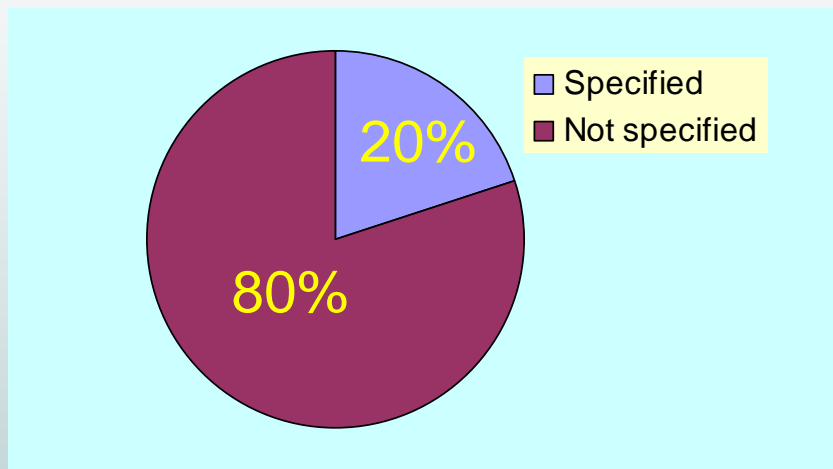
Percentages are evaluated with respect to the number of specified aspects



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### Pyrolysis – Numerical simulation



#### Specifications

Aspen Plus

Own code

Different types of short residence time reactors

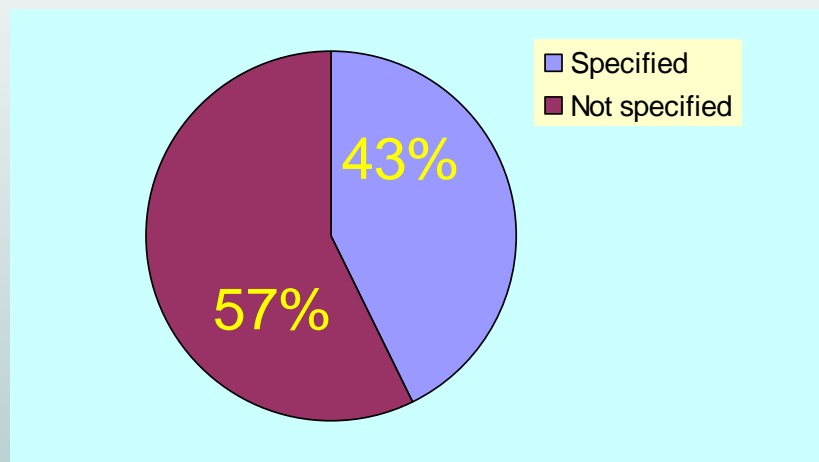
Percentage of scientists who specify this topic



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### Pyrolysis – Pre-treatments



Percentage of scientists who specify this topic

#### Specifications

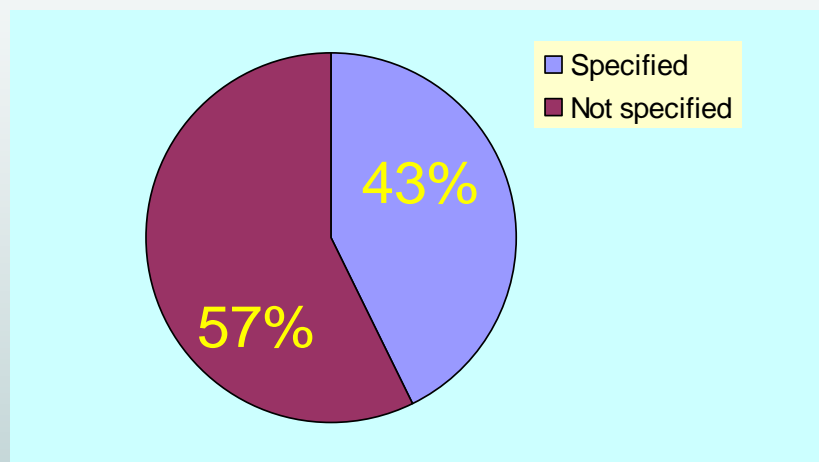
- Densification technologies
- Impregnation
- Washing
- Leaching
- Impregnation with different inorganic catalysts
- Energetical densificaton
- Briquetting
- Agglomeration
- Comminution



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### Pyrolysis – Product upgrading



Percentage of scientists who specify this topic

Specifications	%
In situ filtration of vapours	12.5
Hydrodeoxygenation of bio-oil	25
Fractionation	12.5
Separation of metal containing carbon product in pure carbon and metals + minerals	12.5
Upgrading of bio-oils	12.5
Thermal stability and transformation of condensable vapours	12.5
Char dust briquetting and agglomeration	12.5

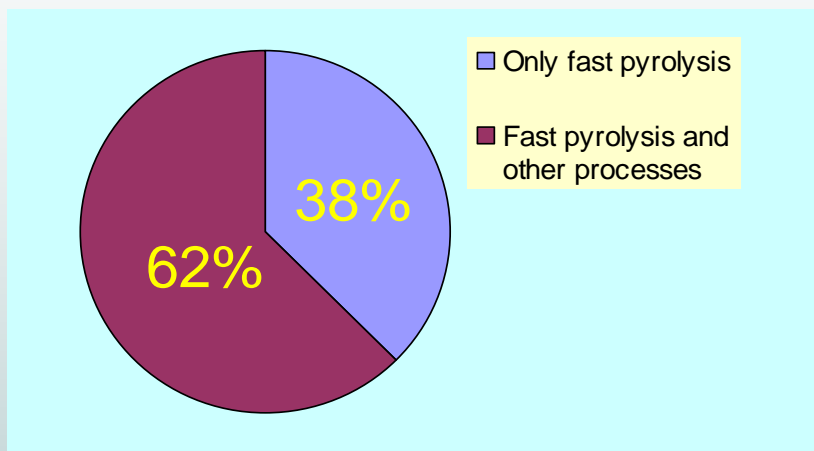
Percentages are evaluated with respect to the number of specified aspects



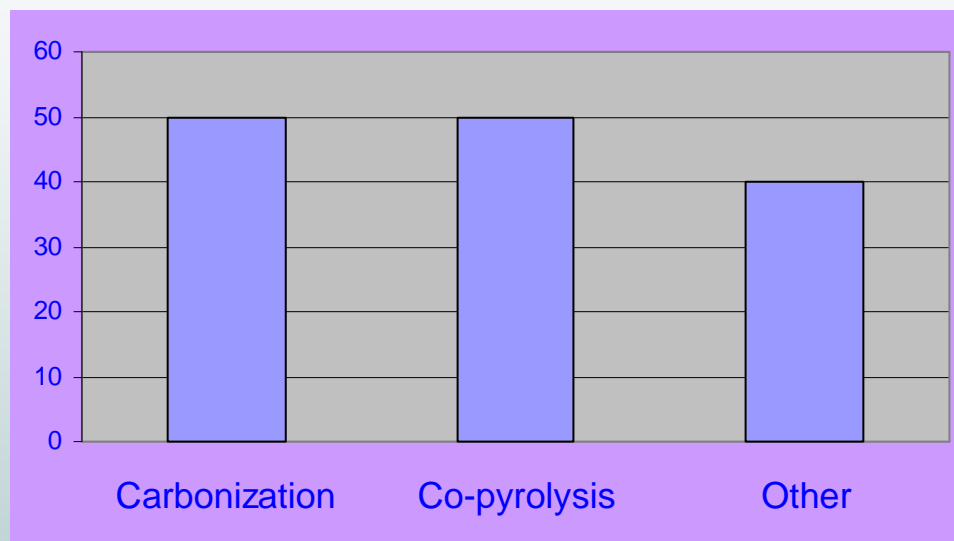
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### Pyrolysis – Fast pyrolysis



Percentages are evaluated with respect to the number of scientists with activities on this topic



Percentages are evaluated with respect to the number of scientists with activities on fast pyrolysis and other processes

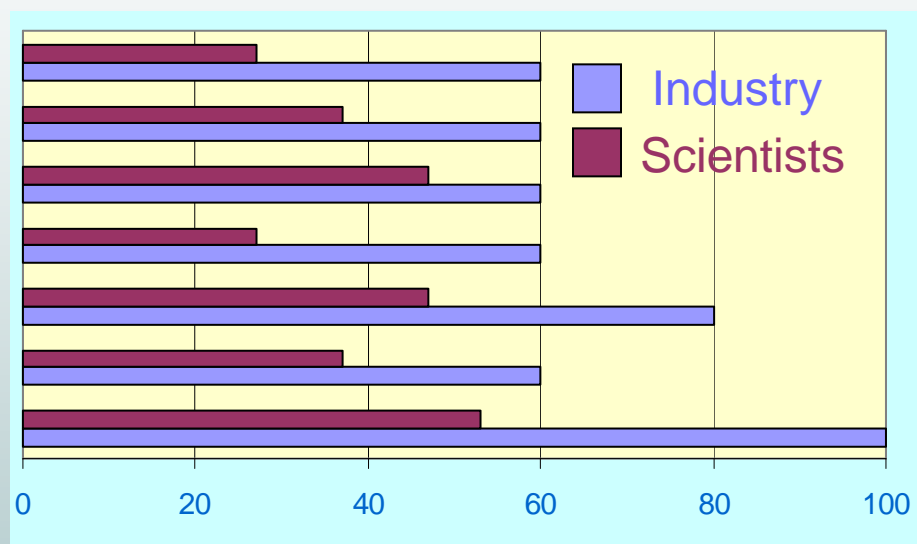
Specifications for "other" refer essentially to **slow pyrolysis**



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## Industry – Pyrolysis/1

Bio-oil combustion/gasification  
Chemical characterization of liquid  
Pre-treatments  
Economic aspects  
Product upgrading  
Plant optimization  
Fast pyrolysis



Topics of interest for industry are studied by scientists only partially



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### Industry – Pyrolysis/2

Issues to be investigated:

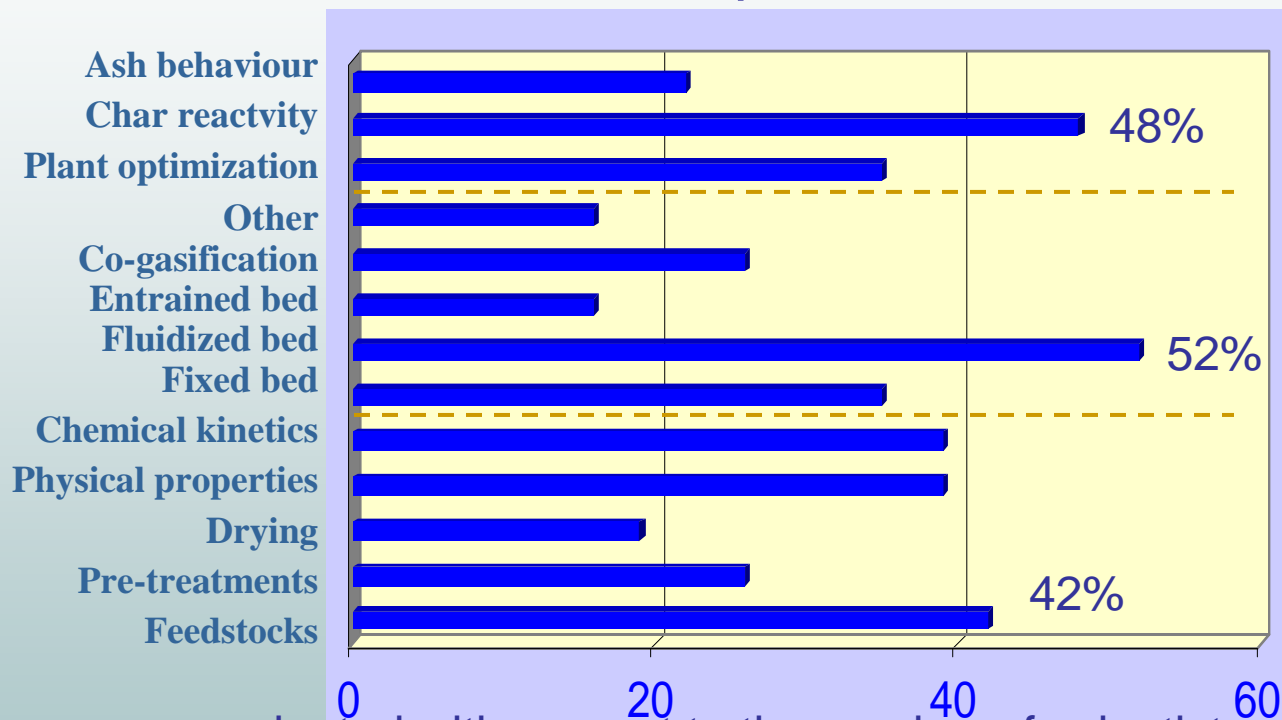
- Ablative pyrolysis
- Change of product quality depending on type of feedstock pre-treatment. Economic aspects
- Product treatments to achieve bio oil specification/composition as required for further utilisation in conventional refineries. Economic aspects
- Various feedstocks, physical oil upgrading, combustion in Diesel engine
- ATEX requirements and legislative compliance for thermal processes
- LCA of carbon sequestration potential of pyrolysis chars
- Quick assessment of tars in producer gas that can be done in minutes onsite, not in a remote lab



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### Research Topics - Gasification/1



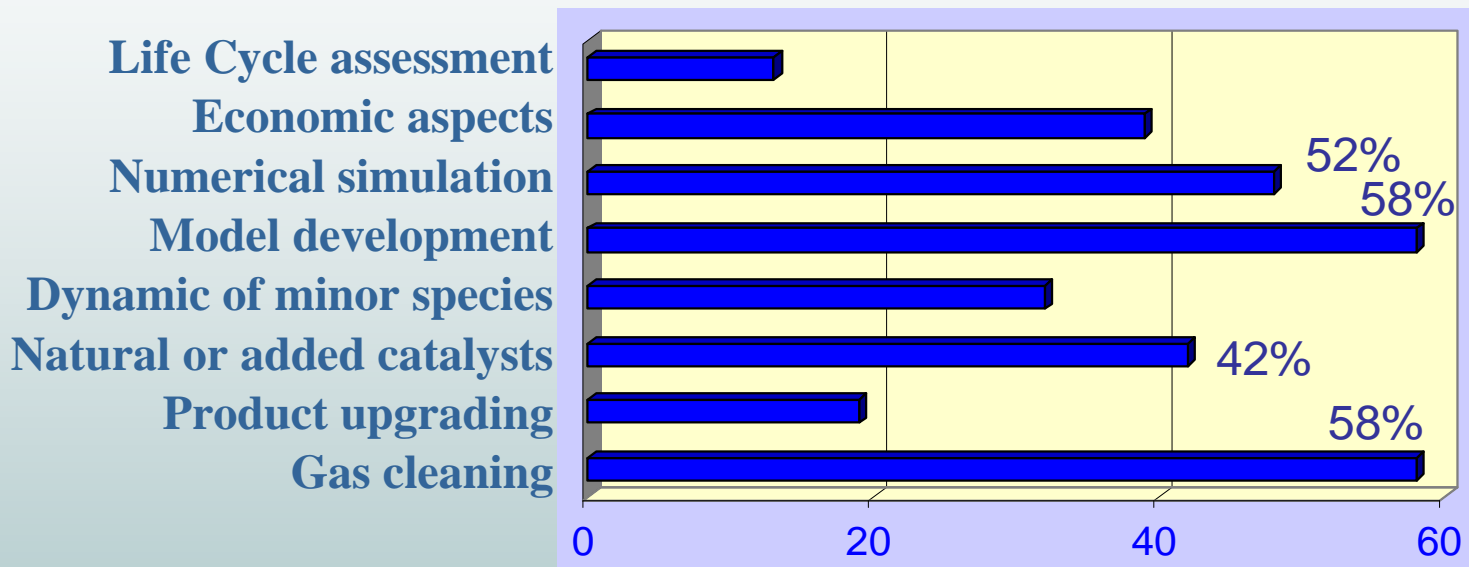
Percentages are evaluated with respect to the number of scientists with research activities in gasification

Research activities on physical properties include feedstocks (83%) and char (83%)



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Research Topics - Gasification/2

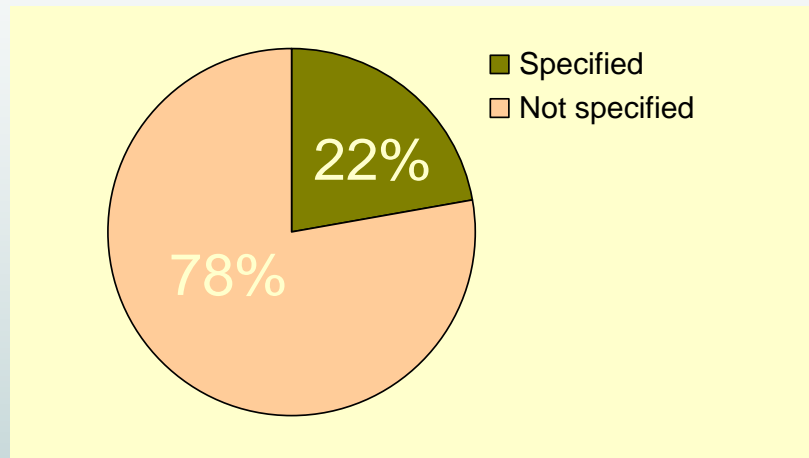


Percentages are evaluated with respect to the number of scientists with research activities in gasification



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### Gasification – Gas cleaning



Percentage of scientists who specify this topic

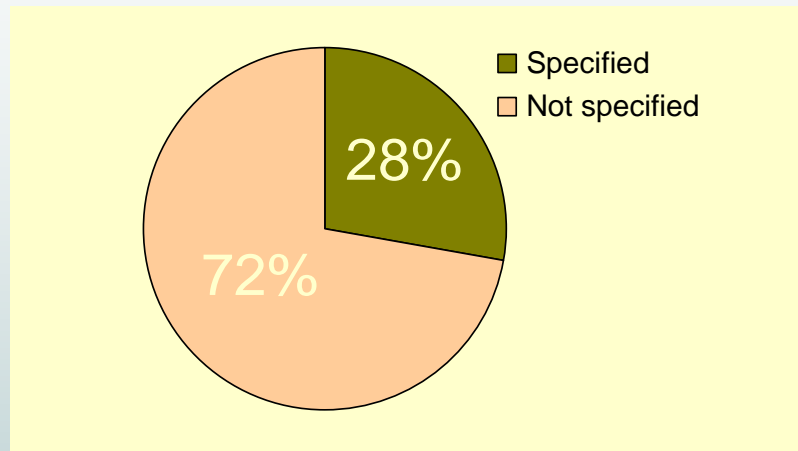
#### **Specifications**

- High temperature gas filtration
- Developments on OLGA tar removal
- Selection of catalytic processes
- Sorbent selection/testing for S and Cl
- Thermal cracking – methods of vapours traces analysis
- Technology assessment for removal of particles and tars



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### Gasification – Model development



Percentage of scientists who specify this topic

#### *Specifications*

- CFBG modeling
- Atomization of a bio-oil into a plasma
- Hydrothermal biomass gasification models
- Kinetic modelling
- Different types of short residence time reactors
- Research in connection with industry scale fluidized bed

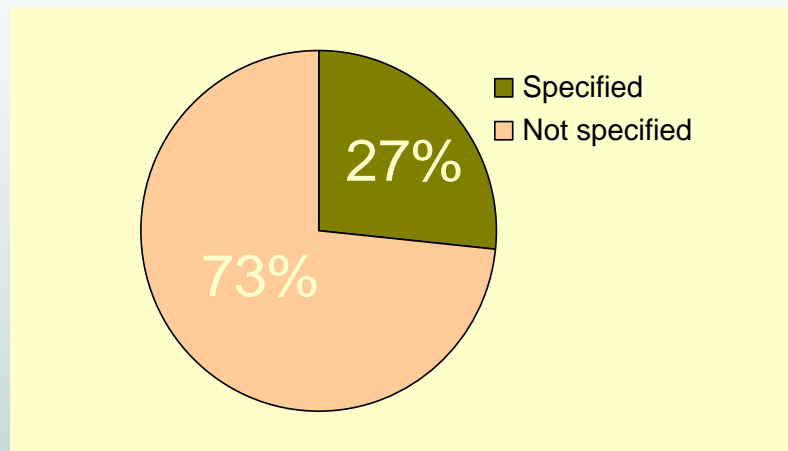


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### Gasification – Numerical simulation

#### Specifications



- CFBG modeling
- Aspen Plus
- NS of formation in a plasma-aided gasifier
- NS of a continuous flow supercritical biomass gasification reactor
- Different types of short residence time reactors
- Research in connection with industry scale fluidized bed

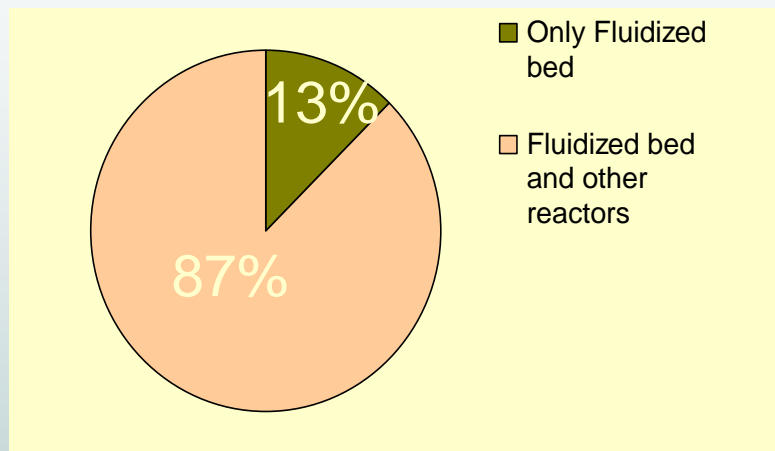
Percentage of scientists who specify this topic



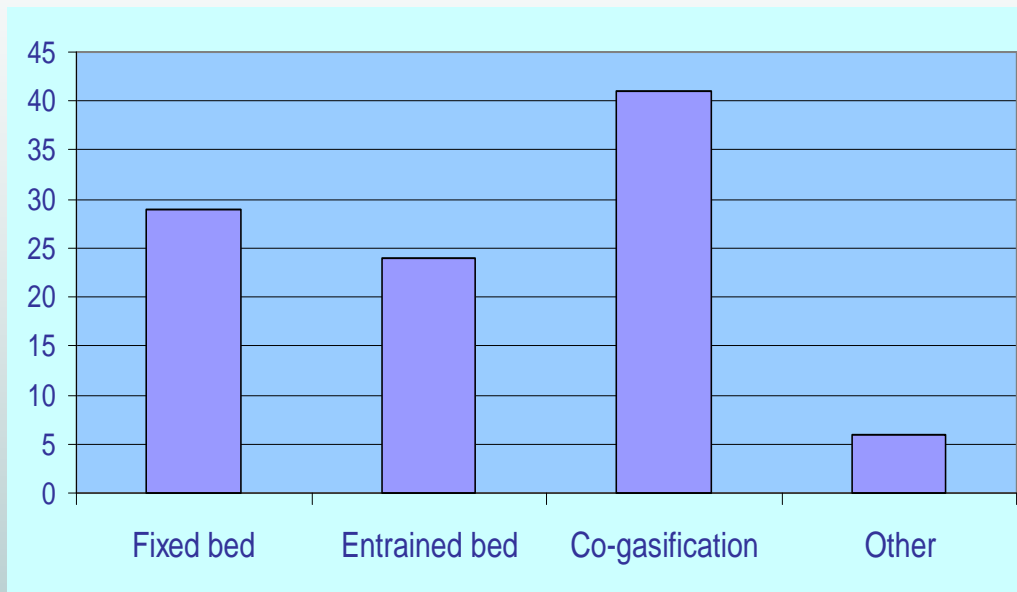
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### Gasification – Fluidized bed



Percentages are evaluated with respect to the number of scientists with activities on this topic



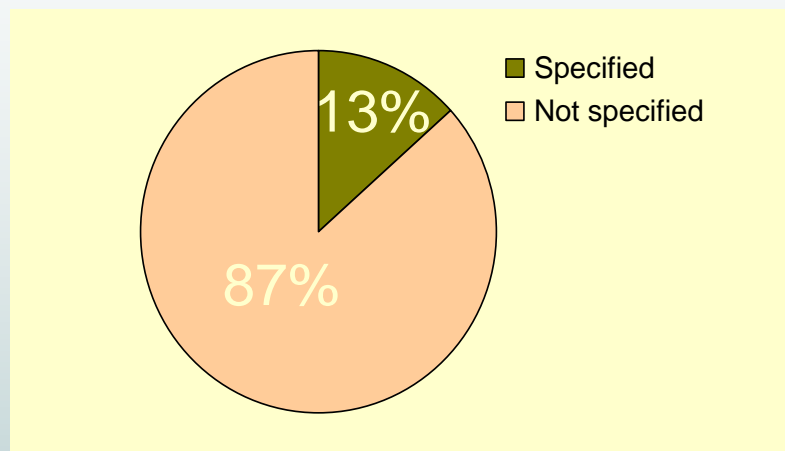
Percentages are evaluated with respect to the number of scientists who use fluidized beds and other reactors



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### Gasification – Char reactivity



Percentage of scientists who specify this topic

#### Specifications

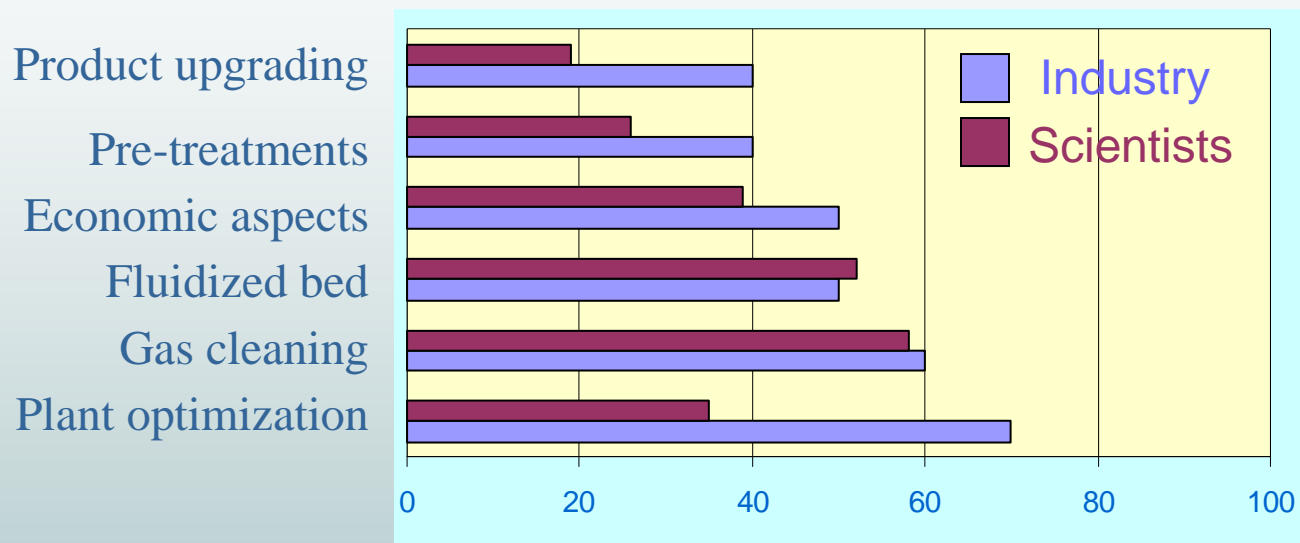
TGA/DTG

Research in connection with industry scale fluidized bed



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### Industry – Gasification/1



- The difference between industrial needs and topics of interest for scientists is lower in gasification than in pyrolysis
- Some topics of interest for industry require further investigation by scientists: plant optimization, pre-treatments and product upgrading



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### Industry – Gasification/2

Issues to be investigated:

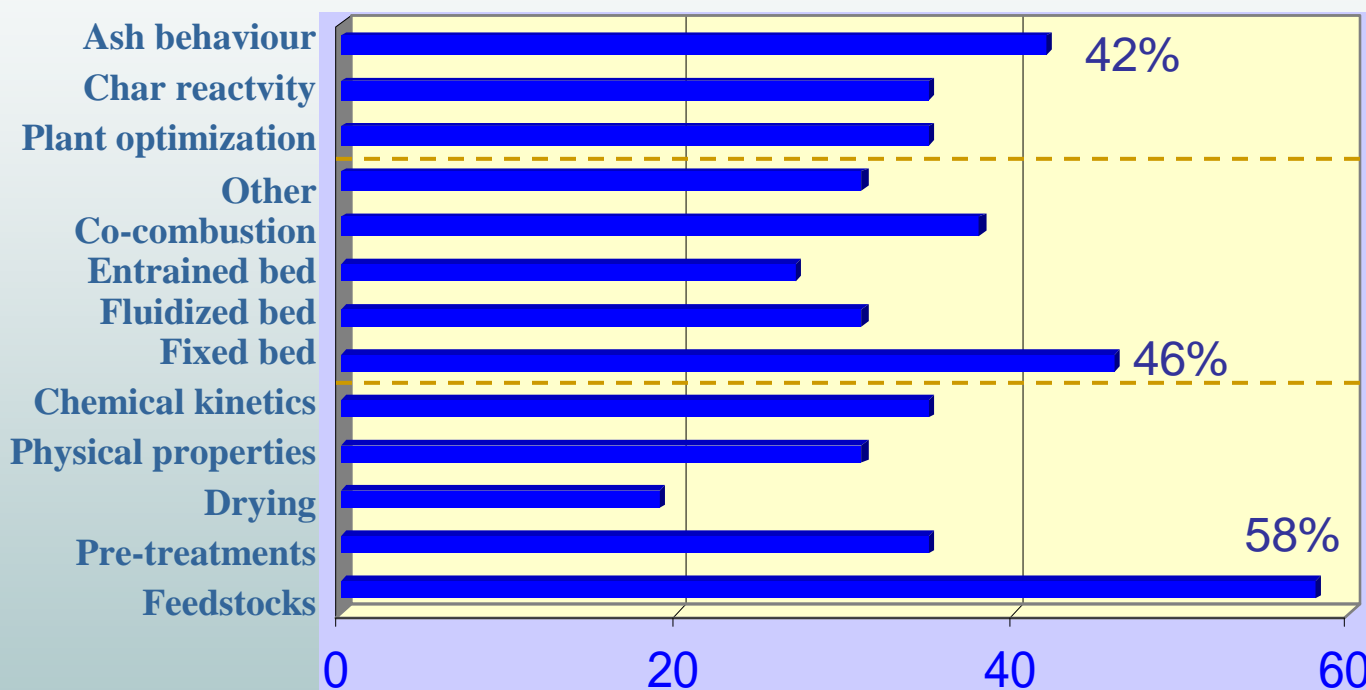
- Multistage gasification with external direct dryer, external pyrolysis, partial tar combustion and char gasification
- Technical, environmental and health aspects of by-products: (i.e. ashes)
- Emissions
- Ash behaviour and composition, fusion temperatures, bed agglomeration, etc.
- ATEX requirements and legislative compliance for thermal processes
- LCA of carbon sequestration potential of gasification chars
- Gas/air mixing for gas engines running on producer gas – no good commercial suppliers of systems for gasification
- Quick assessment of tars in producer gas that can be done in minutes onsite, not in a remote lab
- Tar and char conversion using air and riched air, heat recover from syngas, clean minimizing liquid waste production, define economic aspects and LCA



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### Research Topics - Combustion/1



Percentages are evaluated with respect to the number of scientists with research activities in combustion

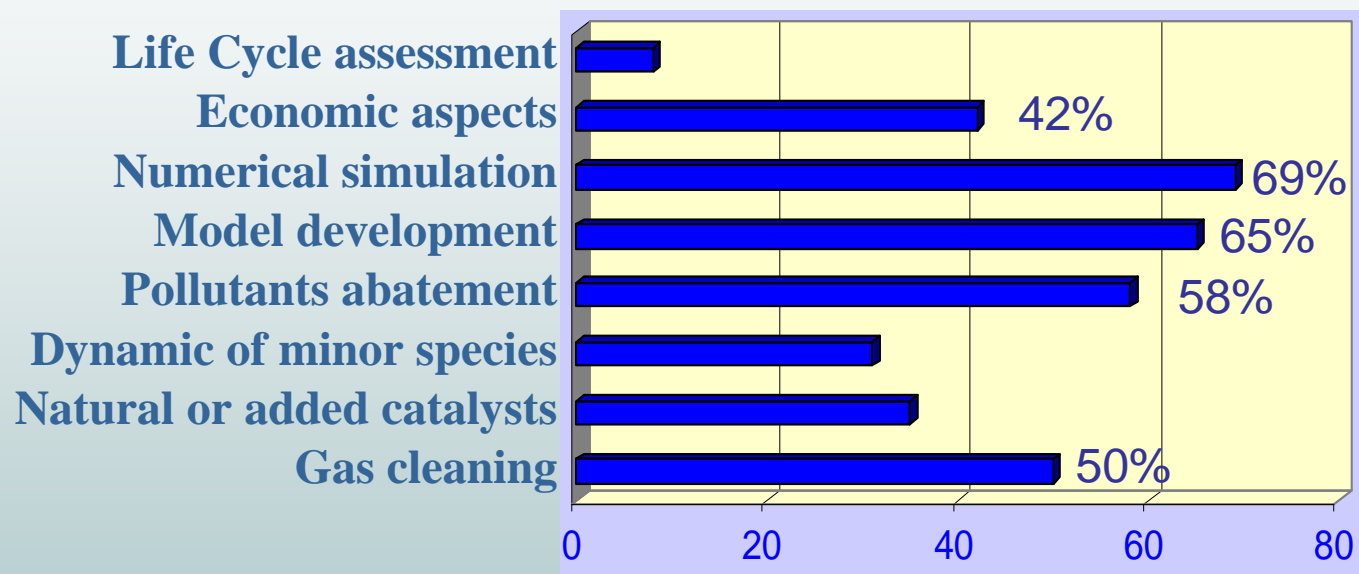
Research activities on physical properties include feedstocks (88%) and char (88%)



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### Research Topics - Combustion/2

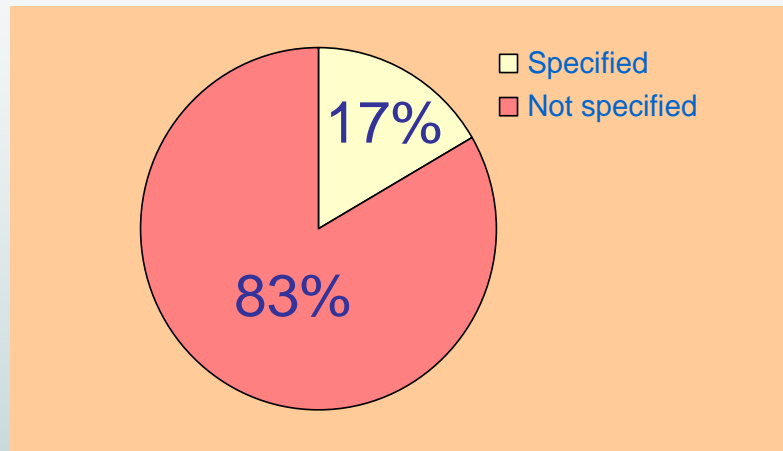


Percentages are evaluated with respect to the number of scientists with research activities in combustion



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### Combustion – Numerical simulation



Percentage of scientists who specify this topic

#### **Specifications**

NS biofuel oxidation and turbulent combustion

Kinetic model and particle model

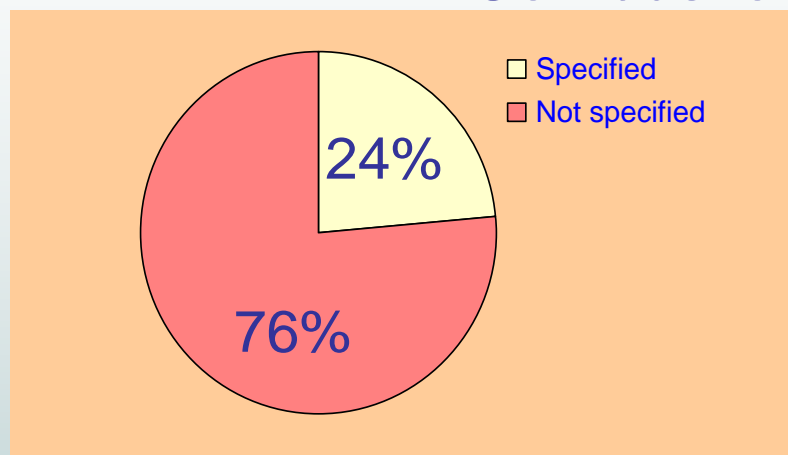
Optimization of combustion design by CFD modeling



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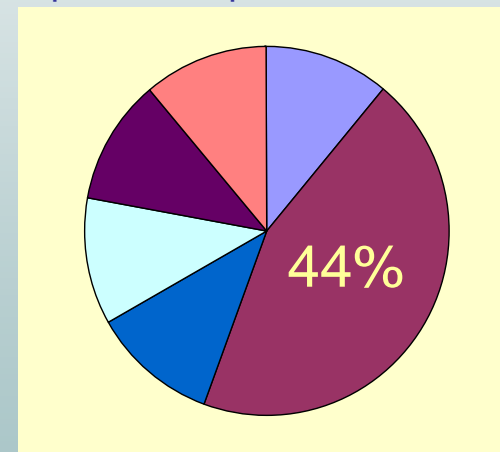
### Combustion – Model development



Percentage of scientists who specify this topic

Percentages are evaluated with respect to the number of specified aspects

- Kinetic models
- Integrated assessment of whole systems
- Engineering models
- CFD
- Turbulent combustion modelling of biofuels under high pressure conditions
- Particle model

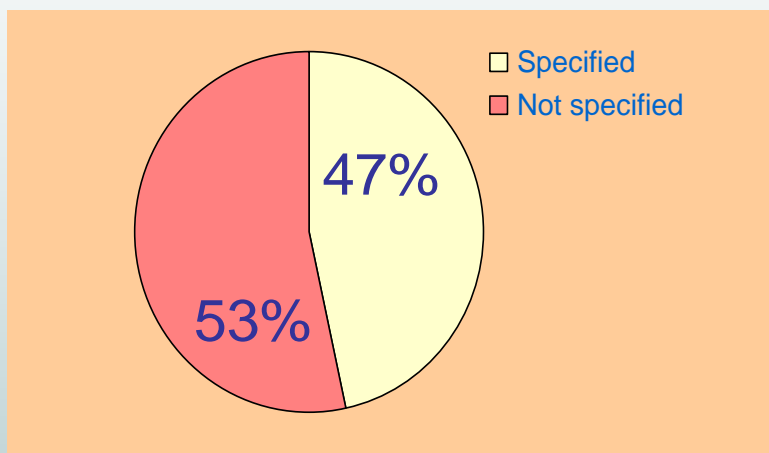




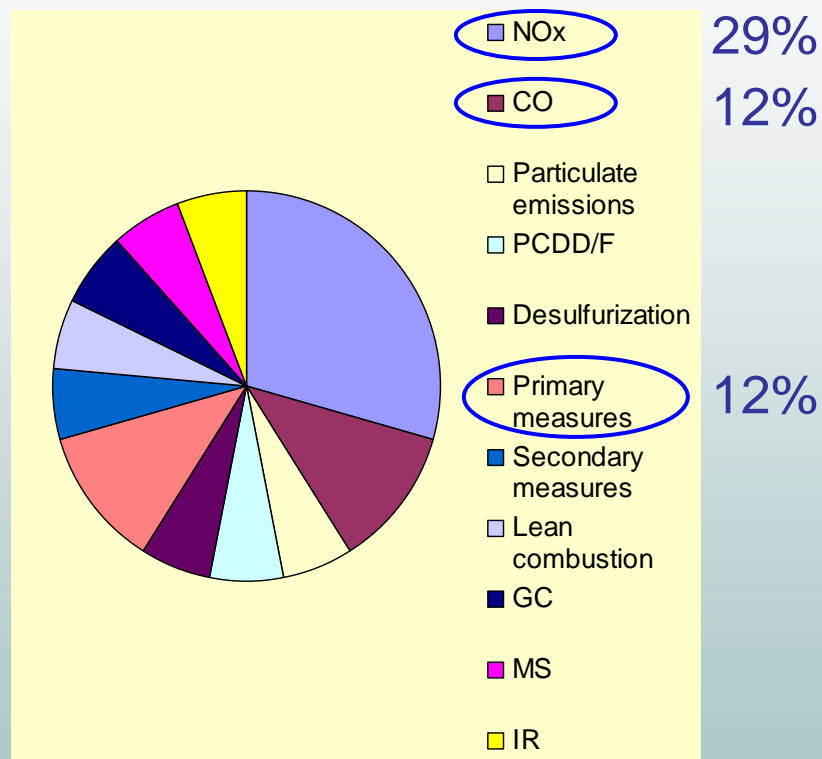
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### Combustion – Pollutants abatement



Percentage of scientists who specify this topic



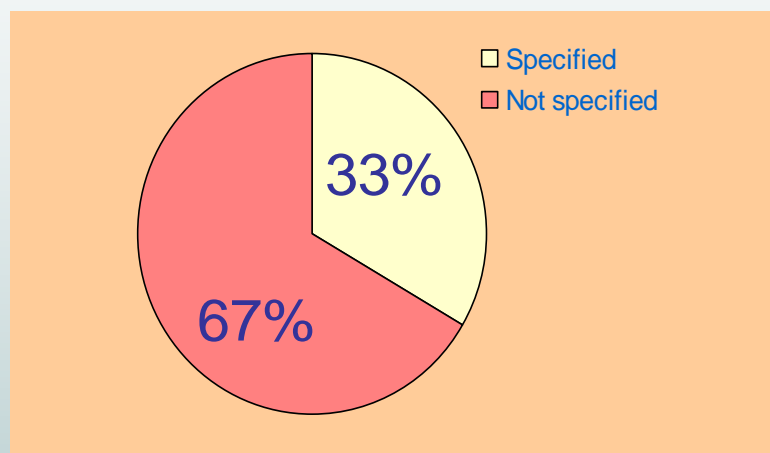
Percentages are evaluated with respect to the number of specified aspects



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### Combustion – Feedstocks



Percentage of scientists who specify this topic

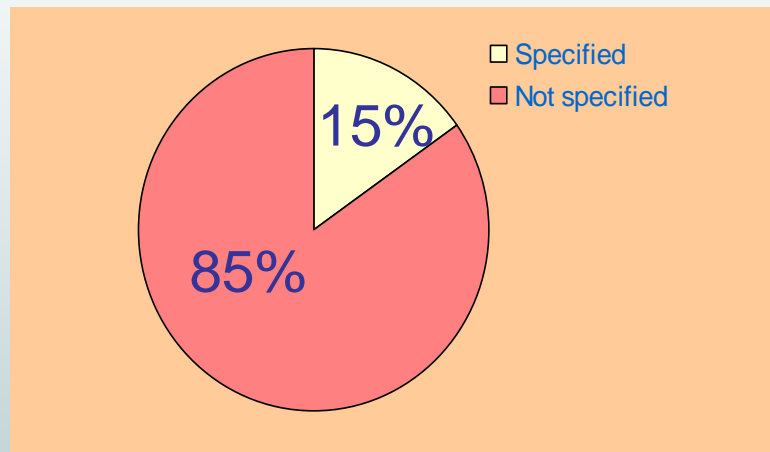
Specifications	%
Wood	22
Straw	11
Waste	11
Coal	11
Coke	11
Integrated assessment of whole systems	11
Physical and chemical characterization with ash analyses	11
Supply strategies	11

Percentages are evaluated with respect to the number of specified aspects



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## Combustion – Gas cleaning



Percentage of scientists who specify this topic

### Specifications

#### Desulfurization

Catalyzed and non catalyzed NO reduction, fundamentals of SNCR and SCR

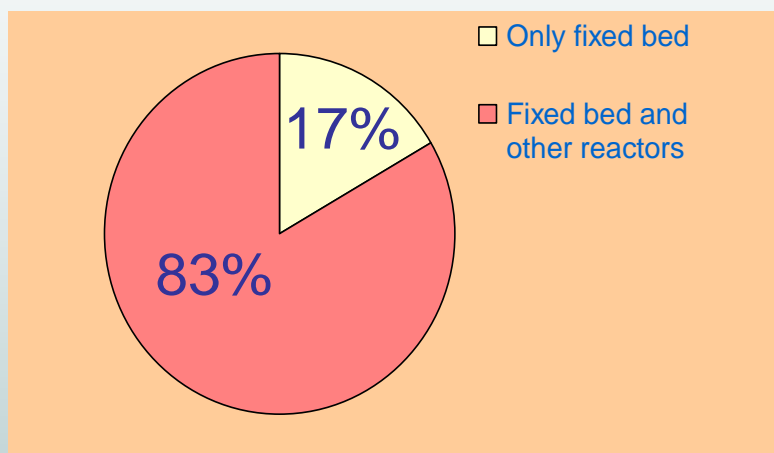
PM abatement: Fundamentals of particle characteristics and particle removal technologies



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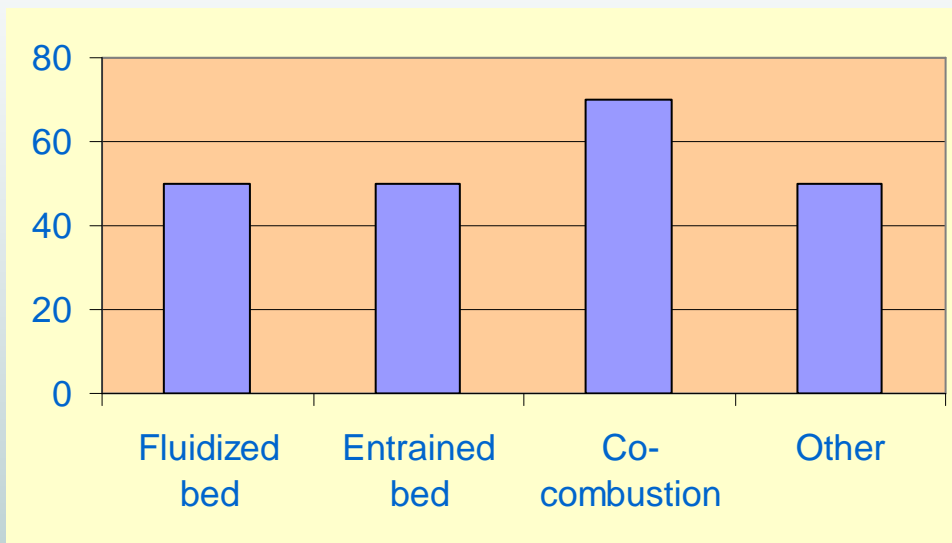
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### Combustion – Fixed bed



Percentages are evaluated with respect to the number of scientists with activities on this topic

Most of fixed bed reactors are grate furnaces

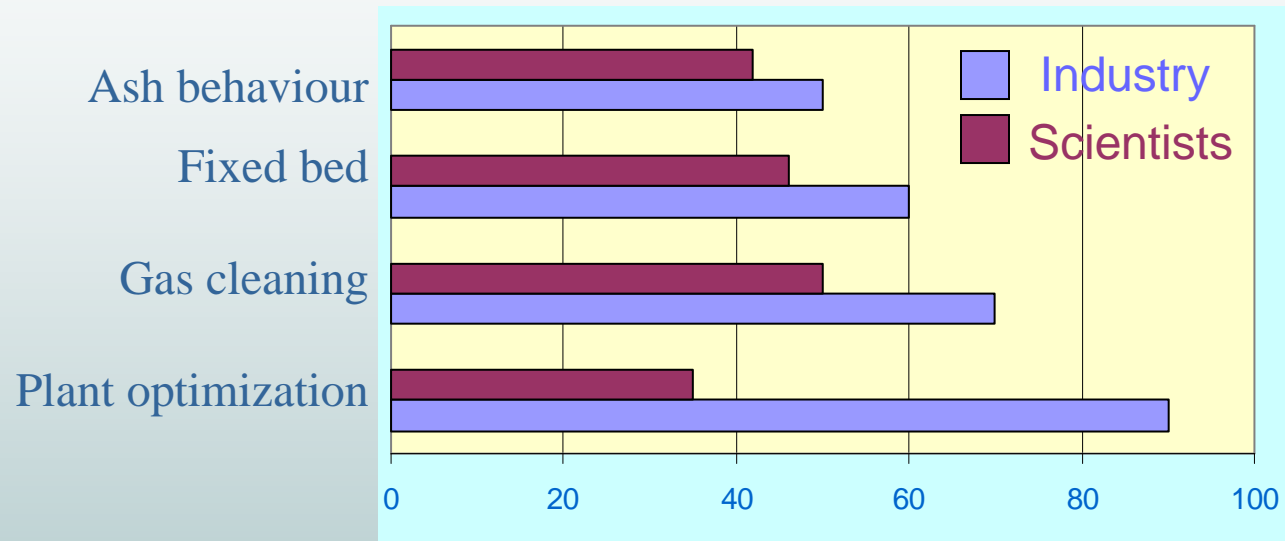


Percentages are evaluated with respect to the number of scientists who use fixed beds and other reactors



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### Industry – Combustion/1



Some topics of interest for industry require further investigation by scientists, in particular plant optimization and gas cleaning



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### Industry – Combustion/2

Issues to be investigated:

- Emissions
- Formation of particles in biomass combustion
- Characterization of aerosols with respect to precipitation design optimization with modeling of flow dynamics and kinetics
  - a) with respect to particle reduction
  - b) with respect to Nox reduction
- Development and implementation of advanced control technologies technical, environmental and health aspects of by-products: (i.e. ashes)
- Drying and milling of biomass
- Advanced co-firing in large coal boilers
- Biomass ash behaviour and mixed coal/biomass ash behaviour boiler tube
- Corrosion due to co-firing
- Combustion of the solid residues from biofuel production processes
- Particulate matter analysis

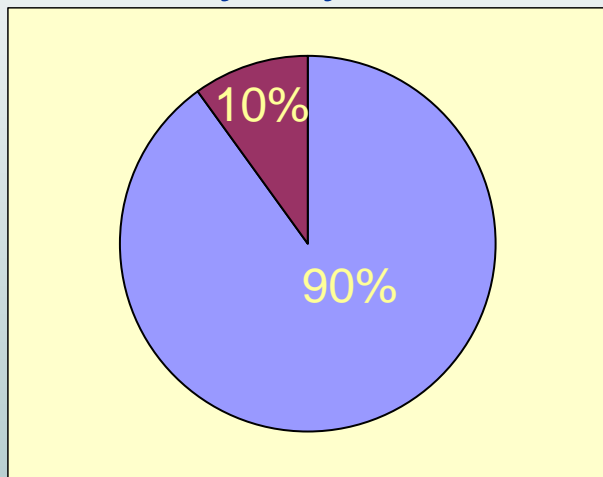


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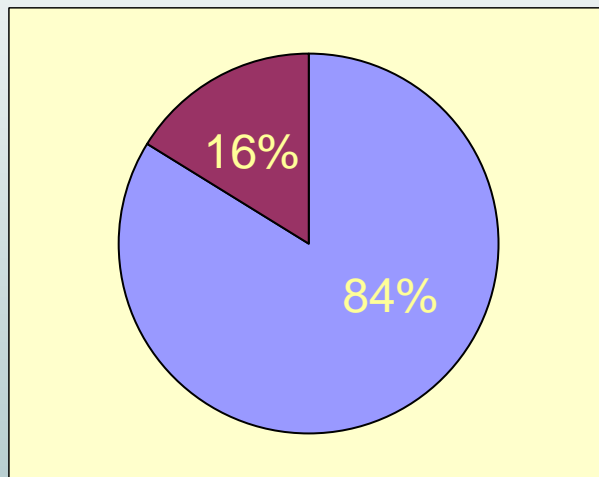
## Dipartimento di Ingegneria Chimica

### Funding

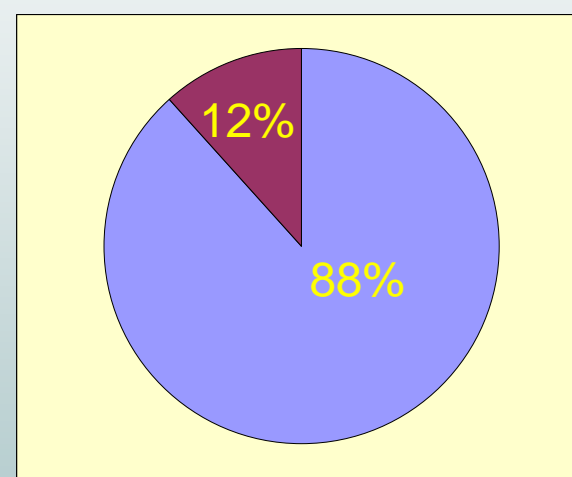
#### Pyrolysis



#### Gasification



#### Combustion



Useful answers  
Data not provided

A percentage between 10-16% do not answer to the question

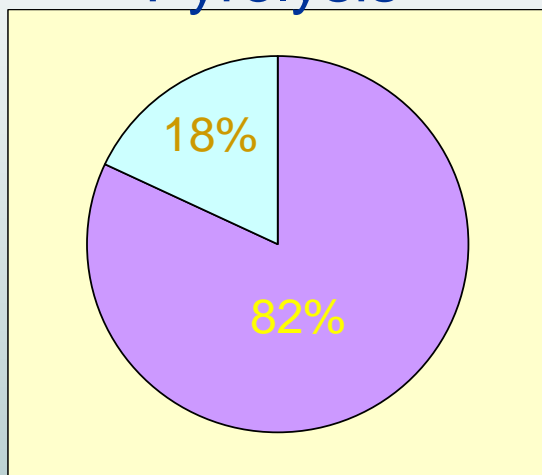


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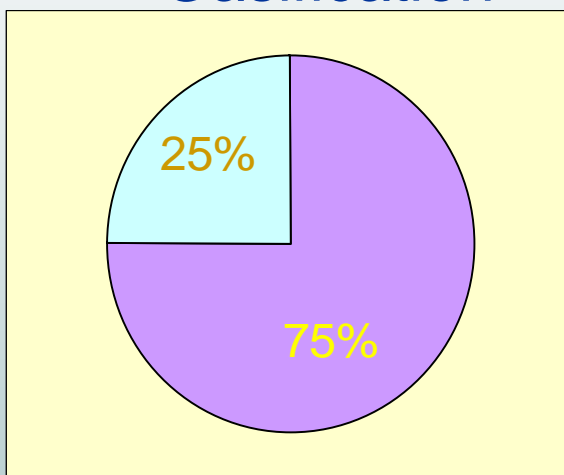
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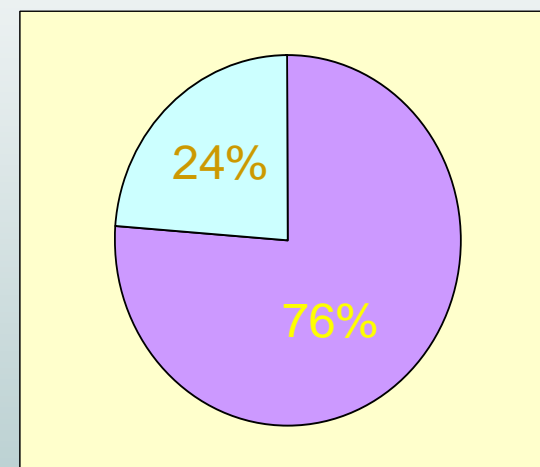
#### Pyrolysis



#### Gasification



#### Combustion



Private  
Public

- Most of research is funded by public financing
- Private funds seem to favour gasification and combustion technology



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### Conclusions/1

- A questionnaire has been prepared and distributed to researchers and industries for the collection of information about ongoing research and the assessment of industrial needs
- The interest of scientists for the three conversion technologies is roughly the same
- The main research levels for all the three technologies are: a) Fundamentals and Laboratory Experimentation; b) Applied Research
- Research at a demonstration level is larger for combustion with respect to pyrolysis and gasification
- The principal research topics for pyrolysis are: feedstocks, chemical kinetics, fast pyrolysis, model development, Numerical simulation, pre-treatments and product upgrading.
- The principal research topics for gasification are: gas cleaning, model development, numerical simulation, fluidized bed and char reactivity
- The principal research topics for combustion are: numerical simulation, model development, pollutants abatment
- Most of research is funded by public financing
- Private funds seem to favour gasification and combustion technology



## Universita' degli Studi di Napoli "Federico II" *Dipartimento di Ingegneria Chimica*

### Conclusions/2

- Industrial research focuses more on gasification and combustion, rather than on pyrolysis
- The following topics need to be investigated more by research groups:
  - pyrolysis:** fast pyrolysis, product upgrading, bio-oil combustion/gasification, chemical characterization of liquid, economic aspects and plant optimization
  - gasification:** plant optimization, pre-treatments and product upgrading
  - combustion:** plant optimization and gas cleaning