IEA Bioenergy

IEA Bioenergy Agreement
Task 19
'Biomass Combustion'

Project 'Modelling'

Results of questionnaire on modelling thermal conversion of biomass

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1. Summary

This document is the intermediary result of IEA Bioenergy Task 19's activity on Modelling. This Task activity aims to produce an inventory of various projects on modelling thermal conversion of biomass and stimulate information exchange amongst these actors.

Initially, a questionnaire has been distributed to the 15 individual Task members, who distributed them in their respective countries. 36 responses have been received from various organisations and entered in a database which allowed for proper analysis of the results.

The models are used for all kinds of purposes, varying between experimentation and application. This is usually done on a process level to better understand and design the process and calculate the emissions. Dynamic physical/chemical and CFD models are the most common types of model. In many cases, pyrolysis, gasification and combustion processes are combined in the same model.

It is interesting to note that most models are based on wood as a fuel. In the calculation, properties of the biomass (sometimes also kinetic data) and the combustion air are usually required to calculate combustion temperature and emissions.

The majority of the models (56%) are programmed in Fortran and run under UNIX or some version of MS Windows. Typically, these models are commercially available or calculation can be done by order.

Most of the researchers (89%) are interested in co-operation with others in order to exchange information and improve their model. It has therefore been evaluated if a relatively large group could be defined with common interest. As a result, 10 models have been selected from 9 different organisations in 7 countries which all relate to biomass combustion and the calculation of emissions.

It is proposed to initiate co-operation amongst these respondents by a workshop in which the various models are presented and discussed by the makers. Furthermore, it may be interesting to compare and validate the results of various models in a test in which the emissions resulting from the combustion of a certain type of biomass in a specified boiler configuration are calculated by the various models. Of course, it is possible to invite other interested respondents to join such activities as well.

2. Table of contents

3. Questionnaire results

All 38 questionnaires returned were entered in a Microsoft Access database which includes respondent ID's, names, company's, addresses, project names and the answers to the questions. A report of this Access file is given in Appendix II.

In this document, the results of the questionnaire are analysed. Chapter 3.1 provides an overview of the answers of the full group of respondents. In 3.2, a second analysis is made to compare the answers between the respondents with equal types of modelled parts of the process. Subsequently, in 3.3 an analysis is made to compare the answers between the respondents with equal types of models. Chapter 3.4 shows who is modelling what, as well as the areas in which co-operation is wanted. A recommendation for a follow-up activity is given in chapter 4.

3.1 Overall analysis

The below analysis is based on the full set of respondents that include modelling (36).

3.1.1 Response

The number of questionnaires that were sent out is 56. Of these, 38 were returned. This is a relatively high response. 36 of the respondents have a project that include modelling.

3.1.2 State of development (question 1)

Nearly all models are between the development stage and the application stage. 21 models (58%) are in use as an application.

1. What is the state of development of the model?

a. definition of goals:	3%
b. definition of system boundaries:	0%
c. selection of model type:	0%
d. determination of model input:	3%
e. experimentation:	14%
f. development:	47%
g. implementation:	22%
h. validation:	42%
i. application:	58%
j. others:	0%

3.1.3 Type of model (question 2)

Dynamic physical / chemical models (31%) and CFD models (42%) are the most common types of models.

2. What is the model type?

a. expert/data based:	3%
b. stationary empirical:	11%
c. dynamic empirical:	17%
d. thermodynamic:	25%
e. stationary physical / chemical:	19%
f. dynamic physical / chemical:	31%
g. CFD:	42%
h. fuzzy logic:	0%
i. neural network:	3%
j. others:	8%

3.1.4 Application of model (question 3)

Most of the models are used for fundamental understanding of the physics (44%), process design (75%) and calculation of emissions (42%).

3. What is the application of the model?

a. fundamental understanding physics:	44%
b. process design:	75%
c. scaling up:	31%
d. selection suitable biomass:	8%
e. calculation of emissions:	42%
f. operator training:	11%
g. operator advise system:	3%
h. start-up/shut down simulation:	14%
i. economic evaluation:	14%
j. others:	8%

3.1.5 Scale of model (question 4)

Most of the models are on a process scale (33%), but there is a wide spread in scale ranging from micro scale to plant level.

4. What is the scale of the model?

a. micro scale (Kolgomorov):	8%
b. particles (0.5 mm):	19%
c. process:	33%
d. operation unit:	25%
e. system (combination of processes):	22%
f. plant (comb. of operation units):	19%
g. others:	8%

3.1.6 Parts of process (question 5)

All process parts mentioned in the questionnaire receive attention of the modellers. 39% of the respondents describe the drying process. The feed system is described by 11% of the respondents. 33% included the pyrolysis process, equally divided between fast and slow pyrolysis.

44% of the respondents describe the gasification process. Most of these gasification processes modelled are atmospheric. Combustion is described by most of the respondents (53%). Most combustion processes are grate combustion. 25% of the respondents modelled the flue gas cleaning part as well. Most cleaning systems described are wet scrubbers and (tar) cracking. The energy conversion is described by 25% of the respondents. Most energy conversion processes described are indirect turbines and gas motors, but other systems also occur. Only 6% of the respondents describe the control system in their models.

5. What parts of the process are modelled?

a. drying:	39%
b. feed system:	11%
c. pyrolysis:	33%
d. gasification:	44%
e. combustion:	53%
f. flue gas cleaning:	25%
g. energy conversion:	25%
h. control system:	6%

3.1.7 Kind of biomass (question 6)

A large part of the models is based on wood (61%). Some models can cope with various kinds of biomass (17%).

6. On what kind of biomass is the model based?

general	17%
wood	61%
MSW	8%
straw	11%
other	8%

3.1.8 Transport of biomass (question 7)

Most of the models do not describe the transport of the biomass through the system (39%). The models that describe the transport are mainly based on grates (28%).

7. How is the transport of the biomass modelled?

a. not modelled:	39%
b. grate:	28%
c. fluidised bed:	17%
d. packed bed:	14%
e. circulating fluidised bed:	8%
f. rotary kiln:	6%
g. others:	8%

3.1.9 Input variables (question 8)

The most important input variables are the composition and properties of the biomass and the air. Some models need kinetic data of e.g. the propagation of heat through biomass also.

8. What are the most important input variables of the model?

biomass composition / properties	53%
air composition / properties	42%
temperature	44%
pressure	17%
geometry	11%
kinetic data	17%

3.1.10 Output variables (question 9)

The most important output variables are the temperature and the composition and properties of the products. Some models calculate the rate of biomass conversion.

9. What are the most important output variables calculated by the model?

product composition / properties	53%
efficiencies	11%
temperature	50%
rate of conversion	25%
economics	3%

3.1.11 Programme language (question 10)

FORTRAN is the most used language to programme the models (56%).

10. What language is used to program the model?

a. no programme language used:	8%
b. fortran:	56%
c. basic / visual basic:	3%
d. pascal / object pascal:	6%
e. C / C++:	17%
f. others:	19%

3.1.12 Commercial package (question 11)

Most programmers do not use a commercial package in the analysis (39%). Of the commercial packages used, Excel, ACSL as well as many other packages such as Fluent, Delphi and Tascflow are used.

11. What commercial package is used?

a. no commercial package used:	39%
b. MS Excel:	11%
c. Matlab:	6%
d. Mathcad:	0%
e. ACSL:	11%
f. ASPEN:	6%
g. SPEED-UP:	0%
h. PC-TRAX:	0%
i. others:	44%

3.1.13 Operating system (question 12)

Most models work under UNIX (47%) or various kinds and versions of MS Windows. One model runs as a http server/client application on the internet.

12. Under what operating system does the model work?

a. UNIX:	47%
b. Linux:	11%
c. MS-DOS / MS Windows 3.11:	39%
d. MS Windows 95 / 98:	50%
e. MS Windows NT:	56%
f. Mac:	3%
g. VAX / VMS:	8%
h. others:	6%

3.1.14 User-interface (question 13)

(36%) of the models do not have a user-interface (data has to be entered by input file) while 47% can be run by keyboard and another 47% graphically (by mouse).

13 What is the set-up of the user-interface?

a. no user-interface (input file):	36%
b. keyboard:	47%
c. graphical (mouse controlled):	47%
d. others:	6%

3.1.15 Availability of model (question 14)

A large number of models is commercially available (33%) while for another 31%, calculations can be done by order.

14. What is the availability of the model?

a. free, with source code:	8%
b. free, without source code:	17%
c. commercial:	33%
d. not available, calculation by order:	31%
e. others:	22%

3.1.16 Literature references to the model (question 15)

23 of the models discussed are referred to in literature. A literature list is attached in Appendix II.

3.1.17 Interest in co-operation (question 16)

Nearly all respondents are interested in co-operation (93%). A major area of interest for co-operation with others is combustion (36%).

16 Do you have interest in co-operation?

No:	11%
Yes: in the below field	89%
combustion:	36%
pyrolysis:	11%
gasification:	14%
flue gas cleaning:	6%

3.2 Respondents with common process components modelled

The correlation between the parts of the process that were modelled and the answers to questions 2, 3, 4, 5 and 7 was evaluated. The results of this are given in Appendix III. It should be noticed that some respondents included more than one part of a process in their model and that the percentages given are based on the size of the group.

3.2.1 Parts of process

It is analysed if there is a relation between the various parts of the process modelled. It has to be noted that for some groups of respondents who model a specific process component, several other parts of the process are as well modelled. In such cases there is hardly any correlation between the answers to the questions and the specific group. From the analysis it can be concluded that

- The energy conversion process to steam or power is usually modelled in combination with other processes but there are some respondents who only modelled this part.
- Drying, pyrolysis, gasification and combustion process are mainly modelled as a combination of these processes.
- The groups of respondents that model the feed system or the control system is small. It is therefore difficult to give an good analysis about this group.
- The respondents that model the flue gas cleaning process also model other parts of the process. So, the flue gas cleaning process is mainly modelled in combination with other parts of the process. Consequently, there is a very weak correlation with the answers to the other questions.

3.2.2 Type of model

50% of the respondents that model pyrolysis use a dynamic physical / chemical model. CFD modelling is also widely used to model pyrolysis (42%). 44% of the respondents that model the gasification process use a CFD model, but other model types are also widely used. By far the largest number of the respondents that model combustion use a CFD model (63%).

3.2.3 Application of model

The main reason to model a part of the process is to design the process. The models of the respondents that include the drying, pyrolysis, gasification or combustion process are also made to understand the fundamental physics and to calculate emissions. The models of the respondents that include the energy conversion process are also used for thermodynamic optimisation.

3.2.4 Scale of model

The models that include the drying, pyrolysis, gasification or combustion process are mainly described as a combination of processes. The models that include the energy conversion process are mainly described as a combination of operation units.

3.2.5 Transport of biomass

Transport of the biomass is usually modelled with a grate in combination with a pyrolysis or combustion process.

3.3 Respondents with common model types used

An analysis has been made to compare the answers between the respondents with similar models. The response to questions 2, 3, 4 and 5 is compared for different types of model. The results of this analysis is given in Appendix IV. Again, it should be noticed that some respondents included more than one type of model and that the percentages given are based on the size of the group.

3.3.1 Type of model

First the variety in model types will be discussed. For many respondents there is more than one answer to this question, which implies that the correlation with answers to other questions may be weak. Similarly, the small number of respondents who use an expert/data based, stationary empirical, fuzzy logic or neural network model implies that it is difficult to accurately analyse these groups. There is a strong correlation between dynamic empirical and thermodynamic modelling. Also, stationary, dynamic physical, chemical and CFD models are hardly combined in one model.

3.3.2 Application of model

Nearly all models are used for process design. While several models are designed for specific applications, the empirical and thermodynamic models have various applications. Important applications of the physical / chemical models are the understanding of physics and process control. CFD models are mainly used for a better the understanding of the physics and the calculation of emissions (60%).

3.3.3 Scale of model

The empirical, thermodynamic and CFD models are mainly applied on a process scale. The stationary physical / chemical models are mainly applied on a process and operation unit scale. The dynamic physical / chemical models are mainly applied on a plant scale.

3.3.4 Parts of process

To describe the gasification process, empirical, thermodynamic and CFD models are most commonly used. In order to describe the combustion process, CFD models are mainly used (80%). Physical / chemical models are used to describe various parts of the process.

3.4 Respondents seeking co-operation

An desegregation of the respondents after the process parts that are modelled is given below. Their names and addresses are listed in the overview in Appendix II.

Respondent ID's	*Parts of process modelled*
2,4,10,11,13,14,18,19,22,28,29,33,35,36	drying
10,13,29,35	feed system
2,3,4,10,12,14,22,28,29,33,35,36	pyrolysis
3,4,6,9,10,11,15,18,22,24,27,28,30,31,35,36	gasification
1,3,4,5,6,7,10,13,14,15,20,21,22,24,32,35,36,37,38	combustion
5,9,10,13,17,20,22,28,35	flue gas cleaning
10,15,18,20,21,23,25,26,28,34	energy conversion
20,21	control system

Co-operation is sought by the below respondents in the following areas:

Respondent ID's	*Area of interest for co-operation*
1,3,4,5,6,7,10,13,24,25,27,33,36	combustion
2,3,10,22	pyrolysis
10,22,27,28	gasification
9,17	flue gas cleaning

Many of the modellers calculate the emissions resulting from the conversion of biomass. Below a desegregation is made according to the thermal conversion processes modelled (combustion, pyrolysis or gasification). All of these respondents are interested in co-operation, their names and addresses are provided in Appendix V.

ID's of respondents who calculate emissions and are interested in co-operation	*process modelled*
1,4,5,7,10,14,22,24,35,36	combustion
4,10,14,22,33,35,36	pyrolysis
4,9,10,22,24,35,36	gasification

From the above it is interesting to note that there are actually 10 respondents who all deal with both combustion and emission calculation and are interested to mutually exchange information. This could form the basis for future activities.

4. Follow up activities

An appropriate follow-up action for Task 19, resulting from the analysis of the questionnaires is the stimulation of co-operation within a large group of respondents with common interest. The most obvious group is the group that models the combustion process of wood to calculate the emissions. This group is large (11 respondents), has a small spread in model types and 10 of the respondents are willing to co-operate. These 10 respondents come from 9 different organisations in 7 countries (Austria, Switzerland, Italy, Denmark, Norway, Sweden, Finland). The results of the questionnaires on this specific group are given in Appendix V.

Co-operation amongst the respondents in this group may be initiated by a workshop in which the various models are presented and discussed by the makers. Furthermore, it may be interesting to compare and validate the results of various models in a test in which the emissions resulting from the combustion of a certain type of biomass in a specified boiler configuration are calculated by the various models.

Of course, it is possible to invite other interested respondents to join such activities as well.

Appendix I:

Questionnaire

Modelling of biomass thermal conversion

Questionnaire

General data

Name	:	Phone	:
Position	:	Fax	:
Company	:	E-mail	:
Address	:	Internet address:	

Name of project:

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1. What is the state of development of the model?
   - ☐ definition of goals
   - ☐ definition of system boundaries
   - ☐ selection of model type
   - ☐ determination of model input
   - ☐ experimentation
   - ☐ development
   - ☐ implementation
   - ☐ validation
   - ☐ application
   - ☐ others, e.g.:

2. What is the model type?
   - ☐ expert / data based
   - ☐ stationary empirical
   - ☐ dynamic empirical
   - ☐ thermodynamic
   - ☐ stationary physical / chemical
   - ☐ dynamic physical / chemical
   - ☐ CFD
   - ☐ fuzzy logic
   - ☐ neural network
   - ☐ others, e.g.:

3. What is the application of the model?
   - ☐ fundamental understanding physics
   - ☐ process design optimisation
     - ☐ thermodynamic
     - ☐ energetic
     - ☐ exergetic
     - ☐ process control
   - ☐ scaling up
   - ☐ selection suitable biomass
   - ☐ calculation of emissions
   - ☐ operator training
   - ☐ operator advice system
   - ☐ start-up and shut down simulation
   - ☐ economic evaluation
   - ☐ others, e.g.:

4. What is the scale of the model?

- ☐ micro scale (Kolgomorov)
- ☐ particles (0.5 mm)
- ☐ process
- ☐ operation unit
- ☐ system (combination of processes)
- ☐ plant (combination of operation units)
- ☐ others, e.g.:

5. What parts of the process are modelled?
   - ☐ drying
   - ☐ feed system
     - ☐ screw feeder
     - ☐ lock hoppers
     - ☐ others, e.g.:
   - ☐ pyrolysis
     - ☐ flash
     - ☐ slow
     - ☐ others, e.g.:
   - ☐ gasification
     - ☐ atmospheric
     - ☐ pressurised
     - ☐ air blown
     - ☐ oxygen blown
     - ☐ indirect heated
     - ☐ steam (reforming)
     - ☐ others, e.g.:
   - ☐ combustion
     - ☐ grate
     - ☐ underfeed stoker
     - ☐ fluidised bed
     - ☐ others, e.g.:
   - ☐ flue gas cleaning
     - ☐ wet scrubber
     - ☐ cyclone
     - ☐ hot gas cleaning
     - ☐ denox
     - ☐ (tar) cracking
     - ☐ others, e.g.:
   - ☐ energy conversion
     - ☐ indirect turbine
     - ☐ “closed loop” turbine
     - ☐ gas motor
     - ☐ IGCC
     - ☐ co-combustion boiler
     - ☐ steam cycle
     - ☐ others, e.g.:
   - ☐ control system

6. On what kind of biomass is the model based?

7. How is the transport of the biomass modelled?
   - ☐ not modelled
   - ☐ grate

- ☐ fluidised bed
- ☐ packed bed
- ☐ circulated fluidised bed
- ☐ rotary kiln
- ☐ others, e.g.:

8. What are the most important input variables of the model?

9. What are the most important output variables calculated by the model?

10. What language is used to program the model?
    - ☐ no programme language used
    - ☐ Fortran
    - ☐ Basic / Visual Basic
    - ☐ Pascal / Object Pascal
    - ☐ C / C++
    - ☐ others, e.g.:

11. What commercial package is used?
    - ☐ no commercial package used
    - ☐ MS Excel
    - ☐ Matlab
    - ☐ Mathcad
    - ☐ ACSL
    - ☐ ASPEN
    - ☐ SPEED-UP
    - ☐ PC-TRAX
    - ☐ others, e.g.:

12. Under what operating system does the model work?
    - ☐ UNIX
    - ☐ Linux
    - ☐ MS-DOS / MS Windows 3.11
    - ☐ MS Windows 95 / 98
    - ☐ MS Windows NT
    - ☐ Mac
    - ☐ VAX / VMS
    - ☐ others, e.g.:

response to questionnaire

sent out:	59
returned:	40
projects that include modelling:	38

1. state of development

a. definition of goals:	1	3%
b. definition of system boundaries:	0	0%
c. selection of model type:	0	0%
d. determination of model input:	1	3%
e. experimentation:	5	13%
f. development:	18	47%
g. implementation:	9	24%
h. validation:	16	42%
i. application:	22	58%
j. others:	0	0%

2. What is the model type?

a. expert/data based:	1	3%
b. stationary empirical:	4	11%
c. dynamic empirical:	6	16%
d. thermodynamic:	9	24%
e. stationary physical / chemical:	7	18%
f. dynamic physical / chemical:	12	32%
g. CFD:	16	42%
h. fuzzy logic:	0	0%
i. neural network:	1	3%
j. others:	3	8%

12 kinetic, multivariable response software

15 flow sheet

27 kinetic model is now being developed

3. Application of the model

a. fundamental understanding physics:	16	42%
b. process design:	27	71%
b1. thermodynamic:	11	29%
b2. energetic:	10	26%
b3. exergetic:	0	0%
b4. process control:	13	34%
c. scaling up:	11	29%
d. selection suitable biomass:	3	8%
e. calculation of emissions:	18	47%
f. operator training:	4	11%
g. operator advise system:	1	3%
h. start-up/shut down simulation:	5	13%
i. economic evaluation:	5	13%

j. others:	5	13%

3	ash management
9	process design optimation: selection of equipment
34	heat and fluid flow calculations
39	calculation of gas composition, behaviour of fuel bed
40	calculation of combustion process

4. Scale of the model

a. micro scale (Kolgomorov):	3	8%
b. particles (0.5 mm):	7	18%
c. process:	13	34%
d. operation unit:	10	26%
e. system (combination of procesess):	8	21%
f. plant (comb. of operation units):	7	18%
g. others:	3	8%

33	Single large particle 5-10 mm
36	large particles
37	Scale is dependent on the accuracy and computer limits

5. What parts of the process are modelled?

a. drying:	15	39%
b. feed system:	4	11%
b1. screw feeder:	1	3%
b2. lock hoppers:	1	3%
b3. others:	0	0%
		8%
c. pyrolysis:	12	32%
c1. fast:	5	13%
c2. slow:	6	16%
c3. others:	1	3%

33	fast pyrolysis process limited by heat conduction inside the particle

d. gasification:	16	42%
d1. atmopspheric:	11	29%
d2. pressurised:	3	8%
d3. air blown:	6	16%
d4. oxygen blown:	4	11%
d5. indirect heating:	1	3%
d5. steam reforming:	5	13%
d6. others:	0	0%

e. combustion:	21	55%
e1. grate:	11	29%
e2. underfeed stoker:	2	5%
e3. fluidised bed:	5	13%
e4. others:	6	16%

1	wood log combustion
25	suspension firing, co-utilisation, reburn, gas turbines with low CV fuel from gasification of biomass
36	fixed bed, moving bed (current/co-current)
37	gas combustion chamber below the grate (down-draught firing)
38	suspension firing
40	homogeneous gas phase combustion in the burnout zone of domestic wood stoves

f. flue gas cleaning:	9	24%
f1. wet scrubber:	4	11%
f2. cyclone:	2	5%
f3. hot gas cleaning:	1	3%
f4. denox:	1	3%
f5. (tar) cracking:	5	13%
f6. others:	2	5%

13	fabric filter
31	further purification for fuel cell applications

g. energy conversion:	9	24%
g1. indirect turbine:	4	11%
g2. "closed loop" turbine:	1	3%
g3. gas motor:	4	11%
g4. IGCC:	3	8%
g5. co-combnustion:	2	5%
g6. steam cycle:	2	5%
g7. others:	5	13%

6	direct gas turbine
13	hot water for district heating
18	heat recovery for CHP
23	catalytic combustion
26	combustion cycle

h. control system:	2	5%

6. on what kind of biomass is the model based?

general	6
MSW	1
sawdust, sludge, coal/biomass/waste blends, reburn	1
straw	2
sugar beet pulp	1
wood	15
wood, bark	1
wood, but other biomass can also be modeled	5
wood/straw	2
wood/straw/MSW	1

7. How is the transport of the biomass modelled?

a. not modelled:	15	39%
b. grate:	11	29%
c. fluidised bed:	6	16%
d. packed bed:	5	13%
e. circulating fluidised bed:	3	8%
f. rotary kiln:	2	5%
g. others:	3	8%

15	pneumatic/screw feeders
28	screw
36	moving bed

8. What are the most important input variables of the model?

1	fuel composition burning rate CO2 level temperatures
2	boundary conditions: temperature, pressure, heat flux particle: density, moisture content, size, etc.
3	Boiler design description Fuel properties Boiler operating conditions
4	properties chemical data of thermal degradation
5	Furnace geometry, air and flue gas injectors, mass and energy fluxes from fuel bed

7	Input to the combustion model: - Composition of biomass - Air ratio, distribution and velocity - depth of bed material in case of fluid bed Input to the emission model: - Composition of the flue gas (NOx, dust etc.)
9	Scale of installation, choice of equipment, equipment operational parameters
10	MORE THAN ONE MODEL: amount of biomass
11	- oxygen content in feed gas - type of biomass - moisture content of biomass
12	temperature, time, reactants, products, experimental variable in a factorial design
13	teacher: composition of biomass and heat load trainee: adjustment of prim. and sec. air, grate speed etc.
14	air flow rate and air inlet temperature, fuel properties
17	gas composition, flowrates and temperature reactor conditions
18	Biomass throughput Gasifier type Biomass moisture content before drying Dryer type Biomass moisture content after drying Mode of operation (power only, CHP) Air oxygen concentration
19	sugar beet composition and flow primary and secundary air flow and temperature natural gas flow
20	waste composition and flow prim and sec air flow and temperature grate speed flue gas recirculation flow and temperature
21	wood composition and flow primary and secundary air flow and temperature grate speed flue gas recirculation flow and temperature
22	heat/mass transfer coefficients, physical properties of biomass, kinetic constants
23	gas composition temperature pressure
24	- process conditions (temp, pressure) - furnace geometry and dimensions, fuel and air througput and geometry
25	particle size, composition, location of injection, number of inlet streams
26	- geometry of the combustion chamber of the gas engine - gas components
27	air flux, fuel composition and moisture content, equivalence ratio, input feedstock
28	biomass flow (incl water content) water addition air flow

29	pyrolysis data, straw flow, temperature outside the reactor, heating values of straw and hot gas
30	water flow reactivity data of T, [H2], [H2O], X temperature outside the reactor
32	BCs, fluidization velocity, pressure, temperature, particle size and density
33	wood density, water content, kinetic data, cp values BC: temperature, radiative flux incoming, heat transfer coefficient
34	gas absorbtion coefficient heat dynamics, thermal conductivities and dynamic viscosities
35	chemical input geometrical data operating conditions
36	particles of the media, chemical kinetics, composition, (fuel-gaseous phase), load
37	Gas mixture flows of primary and secundary air temperature of the gas flows and some surfaces
39	fuel composition, furnace geometry, wall temperatures
40	gas concentration, volume flow (velocities), temperature (gas+wall) of all inlets, geometry

9. What are the most important output variables of the model?

1	emission levels in different denominations conversion factors efficiencies
2	ultimate product yield distribution (char, volatiles, gases) internal temperature, density, pressure of the particle
3	Rates and properties of ash deposition Predicted velocities, temperatures, particle concentrations, burnout, gas composition
4	specific concentrations over fuel bed rate of conversion
5	Flow and temperature profiles over the furnace, composition of the flue gas in different sections of the furnace, residence time distributio/n of gas and particles in the furnace are main present aims. Moreover the use of the output data as input data for NOx reduction kinetic calculations with Chemkin and/or with Fluent (postprocessing) are intended.
6	Biomass particle trajectories
7	Output of the combustion model: - combustion parameters, e.g. oxygen contents Output of the emission model: - Composition of the flue gas (NOx, dust etc.)
9	performance, economics
10	various
11	reactor model: -cold gas efficiency -reactor temperatures - gas composition process model: - overall efficiency

12	product yields
13	Mimic diagram with all relevant parameters of the plant
14	pyrolysis and combustion rate combustion temperatures
15	plant efficiency and plant capacity
17	gas outlet composition, temperature and concentration profiles in the reactor
18	Power output Heat output Plant capital cost (total and by item) Electricity cost
19	flue gas flow, temperature and composition in furnace and dryer mass and temperature profiles over the dryer temperature and composition of dried sugar beet
20	flue gas flow, temperature and composition steam production fraction unburned waste mass and temperature profiles over the grate
21	flue gas flow, temperature and composition steam production fraction unburned waste mass and temperature profiles over the grate
22	temperature and specific progress, gas composition, liquid yields, etc.
23	gas composition temperature pressure
24	- concentrations of minor and major components - geometrical distribution of flow, temperature and concentration
25	flame stability, temperature, particle velocity and trajectory, volatile release, NOx, O2
26	- knock behaviour of the engine - detection of knock spots - information about the knock intensity
27	temp. profile and generator gas composition
28	bed height flows gas composition power and heat output
29	pyrolysis rate, output temperature
30	temperature distribution effective char conversion rate
32	Local gas and particle velocities, voidage, cooling-tube erosion
33	temperature
34	temperature, heat fluxes
35	velocity and turbulence temperature species particle distribution, momentum and temperature emission levels

36	temperature profiles (gas, solid) and concentrations (CO, CO2, CxHy, O2, H2O, H2, C) as function of time
37	Flow pattern and mixing Gas concentrations Temperatures
39	gas composition released by the fuel bed, combustion behaviour of different fuels
40	gas concentration + temperature fields in the burnout zone, mixing between combustible gases and air

10. What language is used to program the model?

a. no programme language used:	3	#Naam?
b. Fortran:	22	58%
c. Basic / visual basic:	1	3%
d. pascal / object pascal:	2	5%
e. C / C++:	6	16%
f. Others:	7	8%

5	Fluent 5 (Fluent UNS) is written in C/C++. Submodels developed at the Technical University of Graz, Work Group Thermal Biomass Utilization, to be implemented in Fluent 5, will also be written in C/C++. The model concerning fixed-bed biomass combustion (drying, volatilization, char combustion) on the grate will be developed with Chemkin Digital Visual Fortran and Visual C++.
6	NUMECA proprietory
9	Javascript, HTML
27	MATLAB
28	SIL (simulation language by Niels Houbak ET DTU)
29	SIL (simulation language by Niels Houbak ET DTU)
30	SIL (simulation language by Niels Houbak ET DTU)

11. What commercial package is used

a. no commercial package used:	15	39%
b. MS Excel:	4	11%
c. Matlab:	2	5%
d. Matcad:	0	0%
e. ACSL:	4	11%
f. ASPEN:	2	5%
g. SPEED-UP:	0	0%
h. PC-TRAX:	0	0%
i. Others:	18	47%

2	DASSL
3	MS Visual C++ and OpenGL

4	for CFD: TASCFLOW
5	Fluent (Fluent 5, Gambit), Chemkin. Additional programmes: Digital Visual Fortran, Visual C++ (see also 10.), Microsoft Excel.
6	NUMECA proprietory
7	not used, but output can be read into these packages
9	Delphi
11	SPENCE (from KEMA)
12	sirius (multivariable data analysis)
13	PC-DYSIM from RYSØ, DK
17	modest
24	chemkin, fluent
25	CINAZ
26	- CFD-CODE FIRE (AVL List GmbH, Graz, Austria) - Engine cycle calculation software MOSES II (TU Graz)
31	VPSE PRO
36	Fluent, Limex, Phoenics
39	developed model will be coupled with FLUENT
40	ALOLOS programme, developed by IVD

12. Under what operating system does the model work?

a. UNIX:	19	50%
b. Linux:	4	11%
c. MS DOS/MS Windows 3.11:	14	37%
d. MS Windows 95/98:	18	47%
e. MS Windows NT:	20	53%
f. Mac:	1	3%
g. VAX/VMS:	3	8%
h. others, e.g.:	2	5%

9	http server/browser client (e.g. Netscape or MS Internet Explorer)
34	All with a Fortran compiler

13. What is the user interface?

a. no user interface (file-input):	15	39%
b. keyboard:	17	45%
c. graphical (mouse controlled):	17	45%
d. others:	2	5%

9	browser
37	graphical is under development

14. What is the availability of the model?

a. free, with source code:	3	8%
b. free, without source code:	6	16%
c. commercial:	14	37%
d. not available, calculation by order:	12	32%
e. others:	8	21%

3	Probably widely available for free without the source code, but this decision has yet to be made
4	not decided yet
9	accessible through internet after retrieval of user ID and password
14	not available yet
18	availability depends on particular interest
22	literature
32	e.g.: through research co-operation
37	for research only, a small fee for documentation and administration is required. See www.cranfield.ac.uk/sme/sofie

15. Are there references to literature in which the model is described?

1	PhD. thesis: Theoretical and experimental studies on emissions from wood combustion, by Øyvind Skreiberg
2	PhD thesis of Morten G. Grønli: A theoretical and experimental study of the thermal degradation of biomass
3	It derives much of its fundamental backbone from a coal model that has been described several times under the names (in order of development) ADLVIC, TADIM, and SAFE
4	For model of decomposition of wood: not yet For CFD applications: 1) Bruch, C.; Nussbaumer, Th.: CFD Modelling of Wood Furnaces. Biomass for Energy and Industry. 10th European Conference and Technology Exhibition, June 8-11, 1998, Würzburg, Germany, 1366-1369 2) Bruch, Ch.; Nussbaumber, Th.: verbrennungsmodellierung mit CFD zur optimierten Gestaltung von Holzfeuerungen. Innovationen bei Holzfeuerungen und Wärmekraftkopplung, 5. Holzenergiesymposium, 16. Oktober 1998 ETH Zürich, Bundesambt für Energie, Bern 1998, 189-202

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	WEISSINGER Alexander, OBERNBERGER Ingwald, Günter LÄNGLE, Alfred STEURER, 1998:. NOx - reduction by primary measures for grate furnaces in combination with in-situ measurements in the hot primary combustion zone and chemical kinetic simulations. In: Proceedings of the 10th European Bioenergy Conference, June 1998, Würzburg, Germany, C.A.R.M.E.N. (ed), Rimpar, Germany
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10	Solantausta, Y., Bridgwater, A., Beckman, D., Electricity production by advanced biomass power systems. Espoo 1996, VTT Research Notes 1729. 115 p. + app. 79 p.
	Koljonen, Timo; Solantausta, Yrjö; Salo, Kari; Horvath, Andras. IGCC Power Plant integrated to a Finnish pulp and paper mill. IEA Bioenergy. Techno-economic analysis activity. 1999. VTT, Espoo. 77 p. + app. 4 p. VTT Tiedotteita - Meddelanden - Research Notes : 1954. ISBN 951-38-5425-6.
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12	yes, but not this application

14	several
15	Combined gasification of coal and straw, final report, june 1995 (clean coal technology programme, EU-DGXII)
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15. Do you have interest in cooperation?

Yes:	34	89%
No:	4	11%

1	Combustion of wood
2	Drying and pyrolysis of wood
3	Are currently cooperating with the Univ. of Aalborg (Denmark) on description of grate. Would be happy to cooperate with others on any aspect of the model.
4	experimental data for validation comparison to other models for packed bed combustion
5	Modeling of fixed-bed combustion on grate systems (drying, volatilization, char combustion); CFD modeling of gas phase combustion in fixed bed furnaces; exchange of experience concerning reaction and flow models used.
6	biomass combustion in gas turbines
7	Thermodynamic conversion of biofuels and waste
9	Experts in gas cleaning systems
10	All thermochemical biomass conversion processes
12	chemical reaction modelling
13	- 3D modelling of combustion process on grate - experiences in conversion to full Windows platform
17	reactor modelling for hot gas cleaning
18	Bio-energy plant/system modelling

22	pyrolysis and gasification of biomass and waste
24	combustion and gasification emission chemistry
25	experimental: - characterisation of flat-flame turbulence, high temp. H/E - combustion in a 0.5 MW furnace, suspension fired, oil, solid, gas - analysis of gas, temperature, and heavy metals. modelling: - fuel combustion - emissions - heavy metal partitioning - reburn - stack dispersion
26	3-D and 0-D engine cycle simulation and calculation
27	- gasification of biomass - kinetic measurement of thermodynamical conversion of biomass (pyrolysis, gasification) - combustion of biomass; a 20 kWth turbulence chamber is available at our institute - tar cracking: simulation and experimental - modelling of biomass conversion
28	gasification
30	reactivity expressions R(T,[H2], [H2O], X,..)
32	Physical sub-models and numerical modelling
33	Cooperaration within the project "Combustion of Biomass" at CECOST. For experiments: cooperation within the Physical Chemistry Division at Göteborg University
35	modelling measuring velocity, concentration, particle size and particle velocity
36	Computer simulation of firing systems
39	application and validation of the model
40	- Experimental and numerical investigations of the combustion process in small scale wood heaters or other biomass fired furnaces - Applications of the ALOLOS code on different firing systems

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Project: CHP gas turbine directly by a biomass gasifier (JOULE 970144)

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Project: Improved energy generation based on biomass FBC with minimum emission (Joule 980200)

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Project: Hydrogen-rich gas from biomass steam gasification (EC-JOULE)

No model was developed within this project

9 *Name:* H.J. Koele *Position:* Process Engineer

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Project: Development of an integrated small scale combined heat and power (CHP) fixed bed gasific system fuelled by standard gasifier fuel: expert system on producer gas cleaning

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Project: IEA Bioenergy Task 22: Techno-economic assessments for bioenergy applications

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Project: Gasification of biomass with oxygen rich air in a reverse-flow, slagging gasifier

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Project: Aqueous thermal conversion of biomass to hydrocarbons in the fluid fuel range

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Project:

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Project:

16 *Name:* Mr. Van der Drift *Position:*

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Project: Conversion of Biomass - Prediction and solution methods for ash agglomeration and related problems

No model was developed within this project

17	*Name:*	Dr. Pella Simell	*Position:*	Research Scientist
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	Email:	pekka.simell@vtt.fi	*Internet:*	www.vtt.fi/ene
	Project:	Catalytic upgrading of gas by biomass gasification: application to small scale fuel cell electricity (JOR3-CT95-0053)		

18	*Name:*	John Brammer	*Position:*	Research Assistant
	Company	Aston University		
	Address:	Birmingham B4 7ET United Kingdom		
	Phone:	+44 121 359 3611	*Fax:*	+44 121 359 6814
	Email:	j.g.brammer@aston.ac.uk	*Internet:*	http://www.ceac.aston.ac.uk/erg
	Project:	Study of biomass gasifier-engine systems with integrated drying for power and CHP		

19	*Name:*	L.B.M. van Kessel	*Position:*	Scientific Researcher
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	Email:	l.b.m.vanKessel@mep.tno.nl	*Internet:*	www.mep.tno.nl
	Project:	sugar beet pulp dryer simulator		

20	*Name:*	L.B.M. van Kessel	*Position:*	Scientific Researcher
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	Project:	waste incinerator simulator		

21 *Name:* L.B.M. van Kessel *Position:* Scientific Researcher

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Project: wood incinerator simulator

22 *Name:* Prof. C. Di Blasi *Position:* Professor

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Italy

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Email: diblasi@unina.it *Internet:*

Project: Fixed bed gasification of agricultural residues (JOR3-CT95-021)

23 *Name:* G. Martin *Position:* head of department

Company division Génie des procédés, Institute Français du Pétrole

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"René Navarre"-Solaize
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Email: gerardhenri.martin@ifp.fr *Internet:*

Project: ULECAT

24 *Name:* Pia Kilpinen *Position:* Associate Professor

Company Åbo Akademi University, Combustion Research Group

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Finland

Phone: +35 8 2 2154681 *Fax:* +35 8 2 2154780

Email: pia.kilpinen@abo.fi *Internet:*

Project: Development of selective oxidation technology for NOx emission reduction reduction in gasification power plants

25	*Name:*	Prof. Lockwood	*Position:*	chair in combustion
	Company	Imperial College, Dept. Mechanical Engineering		
	Address:	Exhibition Road UK-SW7 2BX London United Kingdom		
	Phone:	+44 1 715947032	*Fax:*	+44 1 715815495
	Email:	f.lockwood@ic.ac.uk	*Internet:*	
	Project:	Application of utilisation and emissions of biomass residues from industrial combustors (ENDASH)		

26	*Name:*	Robert Di Beran	*Position:*	Head Thermodynamic Calculations
	Company	TU Graz, Institute for internal combustion engines and thermodynamics		
	Address:	Kopernikusgasse 24 Graz, Austria		
	Phone:	+43 316 8737210	*Fax:*	+43 316 8737712
	Email:	beran@vkma.tu-graz.ac.at	*Internet:*	www.tu-graz.ac.at
	Project:	Turbulence chamber gasification, with combustion-optimized gas engine and turbulence chamber treatment (development of components), gas engine part. Gasification and treatment was carried out by TU Berlin, Mr. F. Pfab		

27	*Name:*	F. Pfab	*Position:*	Researcher
	Company	Technical University Berlin, Institute for Energy Engineering		
	Address:	Sekr. RDH 9 Fasanenstr. 89 10623 Berlin Germany		
	Phone:	+ 49 30 314-25972	*Fax:*	+ 49 30 314 -2215
	Email:	evt1dfdb@sp.zrz.tu-berlin.de	*Internet:*	http://www.tu-berlin.de/fb6/ifet/rdh/index.html
	Project:	Turbulence chamber gasification, with combustion-optimized gas engine and turbulence chamber treatment (development of components),. Gasification and treatment part		

28	*Name:*	B. Gøbel, J.D. Bastian, U. Henriksen	*Position:*	
	Company	Dept. of Energy Engineering, Technical University of Denmark		
	Address:	2800 Lyngby Denmark		
	Phone:	+45 45254172	*Fax:*	+45 45935761
	Email:	GB@et.dtu.dk; JDB@et.dtu.dk; UH	*Internet:*	
	Project:	Dynamic mathematical model of a 400 kW two stage gasifier		

29	*Name:*	Lars Fenger and Susanne Dahl	*Position:*	master thesis students
	Company	Dept. of Energy Engineering, Technical University of Denmark		
	Address:	2800 Lyngby Denmark		
	Phone:	+45 45254172	*Fax:*	+45 45935761
	Email:	UH@et.dtu.dk	*Internet:*	
	Project:	Analysis of externally heated pyrolysis unit heated by exhaust heat from an IC engine		

30	*Name:*	Ulrik Henriksen	*Position:*	Associate research professor
	Company	Dept. of Energy Engineering, Technical University of Denmark		
	Address:	2800 Lyngby Denmark		
	Phone:	+45 45254172	*Fax:*	+45 45935761
	Email:	UH@et.dtu.dk	*Internet:*	
	Project:	Modelling a macro TGA reactor for char gasification		

31	*Name:*	Dr. A. Heinzel	*Position:*	
	Company	Fraunhofer-Gesells. Zur Förder. Der Ang. Forschung e. V. (DE)		
	Address:	Oltmannsstrasse 5 DE-79100 Freiburg Germany		
	Phone:	+49 76 145880	*Fax:*	+49 76 14588320
	Email:	heinzel@ise.fhg.de	*Internet:*	www.ise.fhg.de
	Project:	Solid biomass gasification for fuel cells		

32	*Name:*	Alf-Erik Almstedt	*Position:*	Professor
	Company	Dept of Thermo- and Fluid Dynamics, Chalmers University of Technology		
	Address:	S-412 96 Göteborg Sweden		
	Phone:	+46-31-772 1407	*Fax:*	+46-31-18 09 76
	Email:	affe@tfd.chalmers.se	*Internet:*	http://tfd.chalmers.se/~affe/
	Project:	Basic Research on Pressurized Fluidized Bed Combustion		

33 *Name:* Bellais Michel *Position:* PhD student

Company KemikTeknologie KTH

Address: Teknikringen 42
S-10044 Sotckholm
Sweden

Phone: +46 8 7906602 *Fax:* +46 8 108579

Email: michel@bet.kth.se *Internet:*

Project: Pyrolysis of large biomass particles

34 *Name:* Thomas Nilsson *Position:* PhD Student

Company Lund Institute of Technology (LTH)

Address: box 118
22100 Lund
Sweden

Phone: +46 46 2224813 *Fax:* +46 46 2228612

Email: thomas.nilsson@vok.lth.se *Internet:* www.vok.lth.se

Project:

35 *Name:* Fuchs Laszlo *Position:* Professor

Company Lund Institute of Technology (LTH)

Address: box 118
22100 Lund
Sweden

Phone: +46-46 2224300 *Fax:* +46-46 2224717

Email: Lazlo.Fuchs@vok.lth.se *Internet:* http://www.fm.vok.lth.se/

Project: Modelling of the combustion of biomass

36 *Name:* Ao. univ-Prof. Dr. Harald Raupenstrauch *Position:* Professor

Company University of Technology, Institute for Apparatus Design, Particle Technology and Combustion Technology

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8010 Graz
Austria

Phone: +43 316 873 7497 *Fax:* +43 316 873 7492

Email: raupe@amvt.tu-graz.ac.th *Internet:*

Project:

37	*Name:*	Anders Lönnermark	*Position:*	M.Sc.
	Company	SP Swedish National Testing and Research Institute		
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	Phone:	+46 33 165691	*Fax:*	+46 33 417759
	Email:	anders.lonnermark@sp.se	*Internet:*	www.sp.se/fire/
	Project:	CFD modelling of small scale biomass-fired boilers		

38	*Name:*	Awais Man	*Position:*	Research Manager
	Company	Cinar Ltd		
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	Phone:	+44-171-5812245	*Fax:*	+44-171-5812265
	Email:	awais@cinar.co.uk	*Internet:*	www.cinar.demon.co.uk
	Project:	Modelling for higher energy efficiency and lower NO emissions from biomass fuel systems		

39	*Name:*	Jenny Larfeldt	*Position:*	
	Company	TPS		
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	Phone:	+46-155-221308	*Fax:*	+44-155-221398
	Email:	jenny.larfeldt@tps.se	*Internet:*	www.tps.se
	Project:	Optimised combustion of wood and wood-waste fuels in a stoker fired boiler		

40	*Name:*	Dipl. Ing Roland Berger	*Position:*	Head of dept. Chemical Engineering
	Company	IVD, Un. of Stuttgart		
	Address:	Pfaffenwaldring 23 D-70550 Stuttgart Germany		
	Phone:	+49-711-6853492	*Fax:*	+49-711-6853491
	Email:	berger@ivd.uni-stuttgart.de	*Internet:*	www.ivd.uni-stuttgart.de
	Project:	Newly designed wood burning systems with low emissions and high efficiency		

Questions 1 to 4

1: status of development

ID	a	b	c	d	e	f	g	h	i	j
1								✓		
2								✓		
3						✓				
4						✓	✓			
5						✓				
6							✓			
7							✓	✓	✓	
9						✓	✓			
10									✓	
11					✓	✓		✓		
12					✓	✓		✓	✓	
13									✓	
14						✓				
15									✓	
17						✓	✓			
18						✓			✓	
19									✓	
20									✓	
21						✓				
22									✓	
23									✓	
24									✓	
25							✓	✓	✓	
26							✓	✓	✓	
27						✓				
28	✓								✓	
29									✓	
30									✓	
31								✓		
32						✓		✓	✓	
33					✓	✓				
34								✓		

2: model type

ID	a	b	c	d	e	f	g	h	i	j
1			✓							
2						✓				
3							✓			
4						✓	✓			
5							✓			
6							✓			
7							✓			
9	✓	✓			✓					
10										
11		✓	✓	✓						
12				✓						✓
13						✓				
14					✓					
15										✓
17		✓			✓					
18		✓			✓					
19						✓				
20						✓				
21						✓				
22						✓	✓			
23				✓						
24					✓		✓			
25							✓			
26			✓	✓			✓			
27				✓	✓					✓
28			✓	✓		✓				
29			✓	✓	✓					
30			✓	✓		✓				
31				✓						
32							✓			
33						✓				
34							✓			

3: application of the model

ID	a	b	b1	b2	b3	b4	c	d	e	f	g	h	i	j
1									✓					
2	✓	✓	✓			✓								
3	✓	✓					✓	✓			✓		✓	✓
4		✓		✓					✓					
5		✓	✓			✓	✓		✓					
6		✓				✓								
7									✓					
9		✓							✓				✓	✓
10		✓	✓				✓		✓				✓	
11	✓	✓	✓	✓			✓							
12	✓													
13										✓				
14		✓				✓			✓					
15		✓	✓	✓									✓	
17	✓	✓				✓	✓							
18		✓	✓	✓									✓	
19		✓				✓				✓		✓		
20		✓				✓				✓		✓		
21		✓				✓				✓		✓		
22	✓	✓		✓		✓	✓	✓	✓			✓		
23		✓	✓				✓		✓					
24	✓								✓					
25	✓	✓	✓				✓		✓					
26		✓	✓	✓		✓								
27	✓	✓				✓								
28		✓	✓	✓		✓		✓				✓		
29	✓	✓		✓		✓	✓							
30	✓						✓							
31		✓		✓										
32	✓	✓												
33									✓					
34	✓													✓

4: scale of the model

ID	a	b	c	d	e	f	g
1				✓			
2		✓					
3					✓		
4					✓		
5			✓				
6			✓				
7			✓				
9			✓	✓			
10					✓	✓	
11			✓	✓			
12			✓				
13						✓	
14		✓					
15					✓		
17				✓			
18						✓	
19						✓	
20						✓	
21						✓	
22					✓		
23				✓			
24			✓				
25	✓	✓					
26		✓	✓				
27			✓				
28			✓		✓	✓	
29				✓			
30	✓	✓					
31			✓		✓		
32			✓				
33							✓
34				✓			

35					✓	✓	✓	✓	✓								✓				✓	✓	✓	✓			✓		✓						✓	✓			✓		
36						✓		✓	✓							✓	✓				✓	✓							✓									✓			✓
37				✓	✓	✓		✓	✓								✓					✓							✓									✓			✓
38								✓									✓		✓		✓															✓					
39						✓	✓									✓													✓					✓				✓			
40								✓	✓								✓												✓					✓			✓				

Question 5

5: parts of the process that are modelled

ID	a	b	b 1	b 2	b 3	c	c 1	c 2	c 3	d	d 1	d 2	d 3	d 4	d 5	d 6	d 7	e	e 1	e 2	e 3	e 4	f	f 1	f 2	f 3	f 4	f 5	f 6	g	g 1	g 2	g 3	g 4	g 5	g 6	g 7
1																		✓				✓															
2	✓					✓	✓	✓																													
3						✓				✓								✓																			
4	✓					✓	✓	✓		✓	✓							✓	✓	✓																	
5																		✓	✓				✓		✓												
6										✓		✓						✓	✓																		✓
7																		✓			✓																
9										✓	✓												✓	✓	✓			✓									
10	✓	✓		✓		✓	✓			✓	✓	✓	✓	✓				✓			✓		✓	✓		✓		✓		✓	✓		✓	✓		✓	
11	✓									✓	✓																										
12						✓		✓																													
13	✓	✓																✓	✓				✓						✓								✓
14	✓					✓												✓	✓	✓																	
15										✓	✓	✓	✓	✓		✓		✓	✓		✓									✓	✓	✓		✓	✓	✓	
17																							✓				✓	✓									
18	✓									✓	✓		✓	✓																✓			✓				✓
19	✓																																				
20																		✓	✓				✓	✓						✓	✓						
21																		✓	✓											✓	✓						
22	✓					✓				✓	✓		✓	✓		✓		✓	✓				✓					✓									
23																																					✓
24										✓								✓																			
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26																														✓			✓				✓
27										✓	✓		✓																								
28	✓					✓		✓		✓	✓					✓							✓	✓						✓			✓				

29	✓	✓	✓			✓		✓																													
30										✓	✓				✓	✓																					
31										✓																		✓	✓								
32																		✓			✓																
33	✓					✓	✓		✓																												
34																														✓					✓		
35	✓	✓				✓				✓								✓					✓														
36	✓					✓	✓	✓		✓	✓		✓			✓		✓	✓			✓															
37																		✓				✓															
38																		✓			✓	✓															
39	✓																	✓	✓																		
40																		✓				✓															

Question 6 to 10

ID	*6. fuel*	*7: transport of biomass* a	b	c	d	e	f	g	*10: language* a	b	c	d	e	f
1	wood	✓								✓				
2	wood	✓								✓				
3	wood, but other biomass can also be modeled		✓	✓	✓	✓							✓	
4	wood, but other biomass can also be modeled		✓										✓	
5	wood		✓											✓
6	wood	✓												✓
7	general			✓						✓			✓	
9	wood	✓										✓		✓
10	wood, but other biomass can also be modeled			✓		✓			✓					
11	wood, but other biomass can also be modeled	✓										✓		
12	general	✓							✓				✓	
13	wood/straw/MSW		✓							✓				
14	straw		✓							✓				
15	wood/straw							✓		✓				
17	general	✓								✓			✓	
18	wood	✓									✓			
19	sugar beet pulp						✓			✓				
20	MSW		✓							✓				
21	wood		✓							✓				
22	wood			✓	✓					✓				

23	wood	✓								✓				
24		✓								✓				
25	sawdust, sludge, coal/biomass/waste blends, r	✓								✓				
26	general	✓								✓				
27	wood					✓								✓
28	wood		✓					✓						✓
29	wood/straw						✓							✓
30	straw				✓									✓
31														
32	general			✓						✓				
33	wood	✓							✓					
34	wood				✓					✓				
35	wood		✓	✓	✓					✓				
36	wood, bark		✓					✓		✓				
37	general	✓								✓			✓	
38														
39	wood, but other biomass can also be modeled		✓							✓				
40	wood	✓								✓				

Questions 11 to 16

	11: commercial package									*12: operating system*								*13: user interface*				*14: availability*					*16: co-op?*
ID	*a*	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*a*	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*	*e*	
1		✓										✓	✓	✓				✓	✓	✓		✓	✓				✓
2									✓			✓	✓	✓				✓							✓		✓
3									✓				✓	✓						✓						✓	✓
4	✓								✓	✓								✓								✓	✓
5		✓							✓					✓				✓	✓	✓				✓	✓		✓
6									✓							✓			✓	✓				✓			✓
7									✓	✓	✓	✓	✓	✓					✓	✓					✓		✓
9	✓								✓								✓			✓	✓					✓	✓
10						✓							✓							✓				✓			✓
11		✓							✓			✓							✓	✓					✓		
12	✓								✓			✓	✓	✓				✓		✓				✓			✓
13									✓			✓	✓	✓						✓				✓			✓
14	✓											✓	✓	✓				✓								✓	✓
15					✓					✓		✓	✓	✓					✓						✓		

17	☐	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐	☑
18	☐	☑	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑	☑	☐	☐	☐	☐	☑	☑	☐	☐	☐	☐	☐	☑	☑
19	☐	☐	☐	☐	☑	☐	☐	☐	☐	☑	☐	☐	☑	☑	☐	☐	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐	☑
20	☐	☐	☐	☐	☑	☐	☐	☐	☐	☑	☐	☐	☑	☑	☐	☐	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐	☑
21	☐	☐	☐	☐	☑	☐	☐	☐	☐	☑	☐	☐	☑	☑	☐	☐	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐	☑
22	☑	☐	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	☐	☑	☑
23	☑	☐	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	☑	☐	☑
24	☐	☐	☐	☐	☐	☐	☐	☐	☑	☑	☐	☐	☐	☐	☐	☑	☐	☑	☐	☐	☐	☐	☐	☑	☑	☐	☑
25	☐	☐	☐	☐	☐	☐	☐	☐	☑	☑	☐	☐	☐	☑	☐	☐	☐	☐	☑	☐	☐	☐	☐	☑	☐	☐	☑
26	☐	☐	☐	☐	☐	☐	☐	☐	☑	☑	☐	☑	☑	☑	☐	☐	☐	☑	☑	☐	☐	☐	☐	☐	☑	☐	☑
27	☐	☐	☑	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☑	☐	☑
28	☑	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐	☐	☑
29	☑	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐	☐	☑
30	☑	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐	☐	☑
31	☐	☐	☐	☐	☐	☑	☐	☐	☑	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐
32	☑	☐	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	☐	☑	☑
33	☐	☐	☑	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☑	☐	☐	☑	☐	☐	☐	☐	☑
34	☑	☐	☐	☐	☐	☐	☐	☐	☐	☑	☑	☑	☑	☑	☑	☑	☑	☐	☑	☐	☐	☐	☑	☐	☐	☐	☑
35	☑	☐	☐	☐	☐	☐	☐	☐	☐	☑	☑	☐	☐	☑	☐	☐	☐	☑	☑	☐	☐	☑	☐	☐	☐	☐	☑
36	☐	☐	☐	☐	☐	☐	☐	☐	☑	☑	☐	☐	☐	☐	☐	☐	☐	☑	☐	☑	☐	☐	☐	☐	☑	☐	☑
37	☑	☐	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐	☐	☐	☑	☐	☑	☐	☑	☐	☐	☑	☐
38	☑	☐	☐	☐	☐	☐	☐	☐	☐	☑	☑	☑	☑	☑	☐	☐	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐	☑
39	☐	☐	☐	☐	☐	☐	☐	☐	☑	☑	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☑	☑	☐	☑
40	☑	☐	☐	☐	☐	☐	☐	☐	☑	☑	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☑	☐	☐	☑

13. What is the set-up of the user-interface?

- ☐ no user-interface (input file)
- ☐ keyboard
- ☐ graphical (mouse controlled)
- ☐ others, e.g.:

14. What is the availability of the model?

- ☐ free, with source code
- ☐ free, without source code
- ☐ commercial
- ☐ not available, calculation by order
- ☐ others, e.g.:

15. Are there references to literature in witch the model is described?

16. Do you have interest in co-operation?

- ☐ No
- ☐ Yes. On what field?

Appendix II:

Results of the questionnaires

Appendix III:

Type, application and scale of model, parts of the process modelled and transport of the biomass for the various respondents, desegregated by process components modelled

	processes modelled (question 5)							
	drying	feed system	pyro-lysis	gasifi-cation	combus tion	flue gas cleaning	energy conver-sion	control system
number of respondents:	14	4	12	16	19	9	9	2
2. type of model								
a. expert/data based:	0	0	0	1	0	1	0	0
b. stationary empirical:	2	0	0	3	0	2	1	0
c. dynamic empirical:	3	1	2	3	1	1	2	0
d. thermodynamic:	3	1	3	5	0	1	2	0
e. stationary physical / chemical:	3	1	2	4	2	2	1	0
f. dynamic physical / chemical:	**8**	1	**6**	5	6	4	3	2
g. CFD:	4	1	5	**7**	**12**	3	3	0
h. fuzzy logic:	0	0	0	0	0	0	0	0
i. neural network:	0	0	0	0	1	0	0	0
j. others:	0	0	1	2	1	0	1	0
3. application of model								
a. fundamental understanding physics:	6	2	**7**	**8**	7	3	2	0
b. process design optimisation:	**12**	3	**10**	**14**	**14**	**8**	**8**	2
b1. thermodynamic:	6	2	4	6	4	4	**6**	0
b2. energetic:	7	2	5	**8**	4	3	4	0
b3. exergetic:	0	0	0	0	0	0	0	0
b4. process control:	6	1	5	4	6	5	4	2
c. scaling up:	5	3	5	6	5	5	2	0
d. selection suitable biomass:	2	0	3	3	2	2	1	0
e. calculation of emissions:	7	2	**7**	7	**11**	5	2	0
f. operator training:	2	1	0	0	3	2	2	2
g. operator advise system:	0	0	1	1	1	0	0	0
h. start-up/shut down simulation:	3	0	2	2	3	3	3	2
i. economic evaluation:	2	1	2	5	3	2	3	0
j. others:	0	0	1	2	1	1	1	0
4. scale of model								
a. micro scale (Kolgomorov):	1	1	1	2	1	1	1	0
b. particles (0.5 mm):	3	1	3	2	3	1	2	0
c. process:	2	0	2	**7**	5	3	2	0
d. operation unit:	3	1	2	3	3	2	1	0
e. system (combination of processes):	5	2	**6**	**8**	6	4	3	0
f. plant (comb. of operation units):	5	2	2	3	4	4	**5**	2
g. others:	2	0	2	1	2	0	0	0
5. parts of process								
a. drying:	14	4	**10**	**8**	7	5	3	0
b. feed system:	4	4	3	2	3	3	1	0
c. pyrolysis:	10	3	12	7	7	4	2	0
d. gasification:	8	2	**7**	16	9	5	4	0
e. combustion:	7	3	**7**	**9**	19	6	4	2
f. flue gas cleaning:	5	3	4	5	6	9	3	1
g. energy conversion:	3	1	2	4	4	3	**9**	2
h. control system:	0	0	0	0	2	1	2	2
7. transport of biomass								
a. not modelled:	4	0	3	5	4			
b. grate:	**6**	2	**6**	5	**9**			
c. fluidised bed:	3	2	4	4	6			
d. packed bed:	2	1	3	4	3			
e. circulating fluidised bed:	1	1	2	3	2			
f. rotary kiln:	2	1	1	0	0			
g. others:	2	0	2	3	2			
	0	0	0	0	0			

Appendix IV:

Type, application and scale of model and parts of the process modelled for the various respondents, desegregated by model type

	Model type (question 2)								
	expert/ data based	stationary empirical	dynamic empirical	thermo dynamic	stationary physical	dynamic physical	CFD	neural network	others
number of respondents:	1	4	6	9	7	11	15	1	3
2. type of model									
a. expert/data based:	1	1	0	0	1	0	0	0	0
b. stationary empirical:	1	4	1	1	3	0	0	0	0
c. dynamic empirical:	0	1	6	**5**	1	2	1	0	0
d. thermodynamic:	0	1	**5**	9	2	2	1	0	2
e. stationary physical / chemical:	1	3	1	2	**7**	0	1	0	1
f. dynamic physical / chemical:	0	0	2	2	0	**11**	3	0	0
g. CFD:	0	0	1	1	1	3	**15**	1	0
h. fuzzy logic:	0	0	0	0	0	0	0	0	0
i. neural network:	0	0	0	0	0	0	1	1	0
j. others:	0	0	0	2	1	0	0	0	3
3. application of model									
a. fundamental understanding physics:	0	2	3	**5**	**4**	4	**9**	1	2
b. process design optimisation:	1	**4**	4	**7**	**6**	**8**	**11**	0	2
b1. thermodynamic:	0	2	3	4	1	2	4	0	1
b2. energetic:	0	2	4	**5**	2	3	4	0	1
b3. exergetic:	0	0	0	0	0	0	0	0	0
b4. process control:	0	1	3	4	**4**	**6**	4	0	1
c. scaling up:	0	2	3	4	2	2	5	0	0
d. selection suitable biomass:	0	0	1	1	0	2	2	0	0
e. calculation of emissions:	1	1	1	1	3	4	**9**	0	0
f. operator training:	0	0	0	0	0	4	0	0	0
g. operator advise system:	0	0	0	0	0	0	1	0	0
h. start-up/shut down simulation:	0	0	1	1	0	5	1	0	0
i. economic evaluation:	1	2	0	0	2	0	1	0	1
j. others:	1	1	0	0	1	0	2	0	0
4. scale of model									
a. micro scale (Kolgomorov):	0	0	1	1	0	1	2	0	0
b. particles (0.5 mm):	0	0	2	2	1	2	4	1	0
c. process:	1	2	3	**6**	**3**	1	**6**	0	2
d. operation unit:	1	3	3	3	**3**	1	3	0	0
e. system (comb. of processes):	0	0	1	2	0	3	4	0	1
f. plant (comb. of operation units):	0	1	1	1	1	**5**	0	0	0
g. others:	0	0	0	0	0	2	2	0	0
5. parts of process									
a. drying:	0	2	3	3	3	**8**	4	0	0
b. feed system:	0	0	1	1	1	1	1	0	0
c. pyrolysis:	0	0	2	3	2	6	5	0	1
d. gasification:	1	3	3	**5**	**4**	5	7	0	2
e. combustion:	0	0	1	0	2	6	**12**	1	1
f. flue gas cleaning:	1	2	1	1	2	4	3	0	0
g. energy conversion:	0	1	2	2	1	3	3	0	1
h. control system:	0	0	0	0	0	2	0	0	0

Appendix V:

Questionnaire results of group that models wood combustion to calculate emissions

response to questionnaire

sent out:	13
returned:	13
projects that include modelling:	13

1. state of development

a. definition of goals:	0	0%
b. definition of system boundaries:	0	0%
c. selection of model type:	0	0%
d. determination of model input:	1	8%
e. experimentation:	2	15%
f. development:	7	54%
g. implementation:	4	31%
h. validation:	6	46%
i. application:	8	62%
j. others:	0	0%

2. What is the model type?

a. expert/data based:	0	0%
b. stationary empirical:	0	0%
c. dynamic empirical:	1	8%
d. thermodynamic:	0	0%
e. stationary physical / chemical:	2	15%
f. dynamic physical / chemical:	4	31%
g. CFD:	9	69%
h. fuzzy logic:	0	0%
i. neural network:	0	0%
j. others:	0	0%

3. Application of the model

a. fundamental understanding physics:	4	31%
b. process design:	8	62%
b1. thermodynamic:	3	23%
b2. energetic:	3	23%
b3. exergetic:	0	0%
b4. process control:	3	23%
c. scaling up:	4	31%
d. selection suitable biomass:	1	8%
e. calculation of emissions:	13	100%
f. operator training:	0	0%
g. operator advise system:	0	0%
h. start-up/shut down simulation:	1	8%
i. economic evaluation:	1	8%
j. others:	2	15%

39	calculation of gas composition, behaviour of fuel bed

40	calculation of combustion process

4. Scale of the model

a. micro scale (Kolgomorov):	1	8%
b. particles (0.5 mm):	2	15%
c. process:	4	31%
d. operation unit:	4	31%
e. system (combination of procesess):	4	31%
f. plant (comb. of operation units):	1	8%
g. others:	2	15%

36	large particles
37	Scale is dependent on the accuracy and computer limits

5. What parts of the process are modelled?

a. drying:	7	54%
b. feed system:	2	15%
b1. screw feeder:	0	0%
b2. lock hoppers:	1	8%
b3. others:	0	0%
		15%
c. pyrolysis:	6	46%
c1. fast:	3	23%
c2. slow:	2	15%
c3. others:	0	0%
d. gasification:	6	46%
d1. atmopspheric:	4	31%
d2. pressurised:	1	8%
d3. air blown:	3	23%
d4. oxygen blown:	2	15%
d5. indirect heating:	0	0%
d5. steam reforming:	2	15%
d6. others:	0	0%
e. combustion:	13	100%
e1. grate:	6	46%
e2. underfeed stoker:	2	15%
e3. fluidised bed:	2	15%
e4. others:	4	31%

1	wood log combustion
36	fixed bed, moving bed (current/co-current)

37	gas combustion chamber below the grate (down-draught firing)
40	homogeneous gas phase combustion in the burnout zone of domestic wood stoves

f. flue gas cleaning:	4	31%
f1. wet scrubber:	1	8%
f2. cyclone:	1	8%
f3. hot gas cleaning:	1	8%
f4. denox:	0	0%
f5. (tar) cracking:	2	15%
f6. others:	0	0%
g. energy conversion:	1	8%
g1. indirect turbine:	1	8%
g2. "closed loop" turbine:	0	0%
g3. gas motor:	1	8%
g4. IGCC:	1	8%
g5. co-combnustion:	0	0%
g6. steam cycle:	1	8%
g7. others:	0	0%
h. control system:	0	0%

6. on what kind of biomass is the model based?

general	2
straw	1
wood	5
wood, bark	1
wood, but other biomass can also be modeled	3

7. How is the transport of the biomass modelled?

a. not modelled:	4	31%
b. grate:	6	46%
c. fluidised bed:	4	31%
d. packed bed:	2	15%
e. circulating fluidised bed:	1	8%
f. rotary kiln:	0	0%
g. others:	1	8%

36	moving bed

8. What are the most important input variables of the model?

1	fuel composition burning rate CO2 level temperatures
4	properties chemical data of thermal degradation
5	Furnace geometry, air and flue gas injectors, mass and energy fluxes from fuel bed
7	Input to the combustion model: - Composition of biomass - Air ratio, distribution and velocity - depth of bed material in case of fluid bed Input to the emission model: - Composition of the flue gas (NOx, dust etc.)
10	MORE THAN ONE MODEL: amount of biomass
14	air flow rate and air inlet temperature, fuel properties
22	heat/mass transfer coefficients, physical properties of biomass, kinetic constants
24	- process conditions (temp, pressure) - furnace geometry and dimensions, fuel and air througput and geometry
35	chemical input geometrical data operating conditions
36	particles of the media, chemical kinetics, composition, (fuel-gaseous phase), load
37	Gas mixture flows of primary and secundary air temperature of the gas flows and some surfaces
39	fuel composition, furnace geometry, wall temperatures
40	gas concentration, volume flow (velocities), temperature (gas+wall) of all inlets, geometry

9. What are the most important output variables of the model?

1	emission levels in different denominations conversion factors efficiencies
4	specific concentrations over fuel bed rate of conversion
5	Flow and temperature profiles over the furnace, composition of the flue gas in different sections of the furnace, residence time distributio/n of gas and particles in the furnace are main present aims. Moreover the use of the output data as input data for NOx reduction kinetic calculations with Chemkin and/or with Fluent (postprocessing) are intended.
7	Output of the combustion model: - combustion parameters, e.g. oxygen contents Output of the emission model: - Composition of the flue gas (NOx, dust etc.)
10	various

14	pyrolysis and combustion rate combustion temperatures
22	temperature and specific progress, gas composition, liquid yields, etc.
24	- concentrations of minor and major components - geometrical distribution of flow, temperature and concentration
35	velocity and turbulence temperature species particle distribution, momentum and temperature emission levels
36	temperature profiles (gas, solid) and concentrations (CO, CO2, CxHy, O2, H2O, H2, C) as function of time
37	Flow pattern and mixing Gas concentrations Temperatures
39	gas composition released by the fuel bed, combustion behaviour of different fuels
40	gas concentration + temperature fields in the burnout zone, mixing between combustible gases and air

10. What language is used to program the model?

a. no programme language used:	1	#Naam?
b. Fortran:	10	77%
c. Basic / visual basic:	0	0%
d. pascal / object pascal:	0	0%
e. C / C++:	3	23%
f. Others:	1	8%

5	Fluent 5 (Fluent UNS) is written in C/C++. Submodels developed at the Technical University of Graz, Work Group Thermal Biomass Utilization, to be implemented in Fluent 5, will also be written in C/C++. The model concerning fixed-bed biomass combustion (drying, volatilization, char combustion) on the grate will be developed with Chemkin Digital Visual Fortran and Visual C++.

11. What commercial package is used

a. no commercial package used:	6	46%
b. MS Excel:	2	15%
c. Matlab:	0	0%
d. Matcad:	0	0%
e. ACSL:	0	0%
f. ASPEN:	1	8%
g. SPEED-UP:	0	0%
h. PC-TRAX:	0	0%
i. Others:	7	54%

4	for CFD: TASCFLOW
5	Fluent (Fluent 5, Gambit), Chemkin. Additional programmes: Digital Visual Fortran, Visual C++ (see also 10.), Microsoft Excel.

7	not used, but output can be read into these packages
24	chemkin, fluent
36	Fluent, Limex, Phoenics
39	developed model will be coupled with FLUENT
40	ALOLOS programme, developed by IVD

12. Under what operating system does the model work?

a. UNIX:	9	69%
b. Linux:	2	15%
c. MS DOS/MS Windows 3.11:	3	23%
d. MS Windows 95/98:	4	31%
e. MS Windows NT:	6	46%
f. Mac:	0	0%
g. VAX/VMS:	1	8%
h. others, e.g.:	0	0%

13. What is the user interface?

a. no user interface (file-input):	10	77%
b. keyboard:	5	38%
c. graphical (mouse controlled):	5	38%
d. others:	1	8%

37	graphical is under development

14. What is the availability of the model?

a. free, with source code:	2	15%
b. free, without source code:	2	15%
c. commercial:	5	38%
d. not available, calculation by order:	5	38%
e. others:	4	31%

4	not decided yet
14	not available yet
22	literature

37	for research only, a small fee for documentation and administration is required. See www.cranfield.ac.uk/sme/sofie

15. Are there references to literature in which the model is described?

1 PhD. thesis: Theoretical and experimental studies on emissions from wood combustion, by Øyvind Skreiberg

4 For model of decomposition of wood: not yet

For CFD applications:
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15. Do you have interest in cooperation?

Yes:	12	92%
No:	1	8%

1	Combustion of wood
4	experimental data for validation comparison to other models for packed bed combustion
5	Modeling of fixed-bed combustion on grate systems (drying, volatilization, char combustion); CFD modeling of gas phase combustion in fixed bed furnaces; exchange of experience concerning reaction and flow models used.
7	Thermodynamic conversion of biofuels and waste
10	All thermochemical biomass conversion processes
22	pyrolysis and gasification of biomass and waste

24	combustion and gasification emission chemistry
35	modelling measuring velocity, concentration, particle size and particle velocity
36	Computer simulation of firing systems
39	application and validation of the model
40	- Experimental and numerical investigations of the combustion process in small scale wood heaters or other biomass fired furnaces - Applications of the ALOLOS code on different firing systems

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Project: Fixed bed gasification of agricultural residues (JOR3-CT95-021)

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Project: Modelling of the combustion of biomass

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Project: CFD modelling of small scale biomass-fired boilers

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Project: Optimised combustion of wood and wood-waste fuels in a stoker fired boiler

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Project: Newly designed wood burning systems with low emissions and high efficiency

Questions 1 to 4

ID	1: status of development a	b	c	d	e	f	g	h	i	j	2: model type a	b	c	d	e	f	g	h	i	j	3: application of the model a	b	b1	b2	b3	b4	c	d	e	f	g	h	i	j	4: scale of the model a	b	c	d	e	f	g
1								✓					✓																✓									✓			
4						✓	✓									✓	✓					✓		✓					✓										✓		
5						✓											✓					✓	✓			✓	✓		✓								✓				
7							✓	✓	✓								✓												✓								✓				
10									✓													✓	✓				✓		✓				✓						✓	✓	
14						✓									✓							✓				✓			✓							✓					
22									✓							✓	✓				✓	✓		✓		✓	✓	✓	✓			✓							✓		
24									✓						✓		✓				✓								✓								✓				
35					✓	✓	✓	✓	✓								✓				✓	✓	✓	✓			✓		✓						✓	✓			✓		
36						✓		✓	✓							✓	✓				✓	✓							✓									✓			✓
37				✓	✓	✓		✓	✓								✓					✓							✓									✓			✓
39						✓	✓									✓													✓					✓				✓			
40								✓	✓								✓												✓					✓			✓				

Question 5

5: parts of the process that are modelled

ID	a	b	b1	b2	b3	c	c1	c2	c3	d	d1	d2	d3	d4	d5	d6	d7	e	e1	e2	e3	e4	f	f1	f2	f3	f4	f5	f6	g	g1	g2	g3	g4	g5	g6	g7
1																		✓				✓															
4	✓					✓	✓	✓		✓	✓							✓	✓	✓																	
5																		✓	✓				✓		✓												
7																		✓			✓																
10	✓	✓		✓		✓	✓			✓	✓	✓	✓	✓				✓			✓		✓	✓		✓		✓		✓	✓		✓	✓		✓	
14	✓					✓												✓	✓	✓																	
22	✓					✓				✓	✓		✓	✓		✓		✓	✓				✓					✓									
24										✓								✓																			
35	✓	✓				✓				✓								✓					✓														
36	✓					✓	✓	✓		✓	✓		✓			✓		✓	✓			✓															
37																		✓				✓															
39	✓																	✓	✓																		
40																		✓				✓															

Question 6 to 10

ID	6. fuel	7: transport of biomass							10: language					
		a	b	c	d	e	f	g	a	b	c	d	e	f
1	wood	✓	☐	☐	☐	☐	☐	☐	☐	✓	☐	☐	☐	☐
4	wood, but other biomass can also be modeled	☐	✓	☐	☐	☐	☐	☐	☐	☐	☐	☐	✓	☐
5	wood	☐	✓	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	✓
7	general	☐	☐	✓	☐	☐	☐	☐	☐	✓	☐	☐	✓	☐
10	wood, but other biomass can also be modeled	☐	☐	✓	☐	✓	☐	☐	✓	☐	☐	☐	☐	☐
14	straw	☐	✓	☐	☐	☐	☐	☐	☐	✓	☐	☐	☐	☐
22	wood	☐	☐	✓	✓	☐	☐	☐	☐	✓	☐	☐	☐	☐
24		✓	☐	☐	☐	☐	☐	☐	☐	✓	☐	☐	☐	☐
35	wood	☐	✓	✓	✓	☐	☐	☐	☐	✓	☐	☐	☐	☐
36	wood, bark	☐	✓	☐	☐	☐	☐	✓	☐	✓	☐	☐	☐	☐
37	general	✓	☐	☐	☐	☐	☐	☐	☐	✓	☐	☐	✓	☐
39	wood, but other biomass can also be modeled	☐	✓	☐	☐	☐	☐	☐	☐	✓	☐	☐	☐	☐
40	wood	✓	☐	☐	☐	☐	☐	☐	☐	✓	☐	☐	☐	☐

Questions 11 to 16

ID	11: commercial package									12: operating system								13: user interface				14: availability					16: co-op?
	a	b	c	d	e	f	g	h	i	a	b	c	d	e	f	g	h	a	b	c	d	a	b	c	d	e	
1	☐	✓	☐	☐	☐	☐	☐	☐	☐	☐	☐	✓	✓	✓	☐	☐	☐	✓	✓	✓	☐	✓	✓	☐	☐	☐	✓
4	✓	☐	☐	☐	☐	☐	☐	☐	✓	✓	☐	☐	☐	☐	☐	☐	☐	✓	☐	☐	☐	☐	☐	☐	☐	✓	✓
5	☐	✓	☐	☐	☐	☐	☐	☐	✓	☐	☐	☐	☐	✓	☐	☐	☐	✓	✓	✓	☐	☐	☐	✓	✓	☐	✓
7	☐	☐	☐	☐	☐	☐	☐	☐	✓	✓	✓	✓	✓	✓	☐	☐	☐	☐	✓	✓	☐	☐	☐	☐	✓	☐	✓
10	☐	☐	☐	☐	☐	✓	☐	☐	☐	☐	☐	☐	✓	☐	☐	☐	☐	☐	☐	✓	☐	☐	☐	✓	☐	☐	✓
14	✓	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	✓	✓	✓	☐	☐	☐	✓	☐	☐	☐	☐	☐	☐	☐	✓	✓
22	✓	☐	☐	☐	☐	☐	☐	☐	☐	✓	☐	☐	☐	☐	☐	☐	☐	✓	☐	☐	☐	☐	☐	☐	☐	✓	✓
24	☐	☐	☐	☐	☐	☐	☐	☐	✓	✓	☐	☐	☐	☐	☐	✓	☐	✓	☐	☐	☐	☐	☐	✓	✓	☐	✓
35	✓	☐	☐	☐	☐	☐	☐	☐	☐	✓	✓	☐	☐	✓	☐	☐	☐	✓	✓	☐	☐	✓	☐	☐	☐	☐	✓
36	☐	☐	☐	☐	☐	☐	☐	☐	✓	✓	☐	☐	☐	☐	☐	☐	☐	✓	☐	✓	☐	☐	☐	☐	✓	☐	✓
37	✓	☐	☐	☐	☐	☐	☐	☐	☐	✓	☐	☐	☐	✓	☐	☐	☐	☐	✓	☐	✓	☐	✓	☐	☐	✓	☐
39	☐	☐	☐	☐	☐	☐	☐	☐	✓	✓	☐	☐	☐	☐	☐	☐	☐	✓	☐	☐	☐	☐	☐	✓	✓	☐	✓
40	✓	☐	☐	☐	☐	☐	☐	☐	✓	✓	☐	☐	☐	☐	☐	☐	☐	✓	☐	☐	☐	☐	☐	✓	☐	☐	✓