

State-of-the-art of small-scale biomass combustion with respect to fine particle emissions

Country report from Finland

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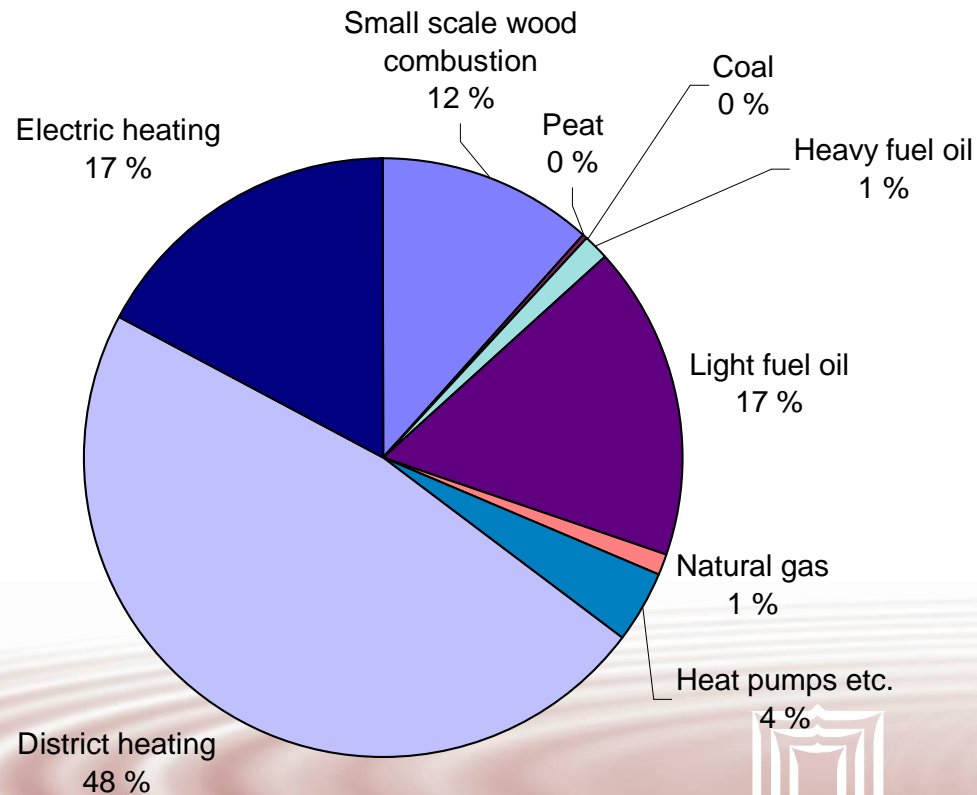
University of Kuopio

Central European Biomass Conference 2008 in Graz, 18.1.2008



Energy Sources for Heating Residential, Commercial and Public Buildings in Finland

§ Total energy used for heating is 234,170 TJ



§ 21% of energy consumption in Finland is used for space heating

§ 12% of the energy for space heating is produced with wood (18% with oil)

§ wood is used as a fuel in one-family houses for 12.1 TWh

(Alakangas, 2005)

General information

- § over 1000 new households per year choose to heat primarily with wood
- § there are about 200 000 central-heating installations which use wood as fuel
- § most of the wood used as split logs
- § wood chips are used in farms and public buildings
- § pellet heating is increasing
 - § now used in 3000 houses and in several hundred public buildings
 - § 40 000 t, which means 188 GWh per year

Alakangas, 2005



Wood consumption

§ consumption of fuel wood in detached houses has been studied

§ by Finnish Forest Research Institute (METLA) in 2000/2001:
6.1 million m³ (Sevola et al., 2003)

§ METLA and Work Efficiency Institute (TTS) in 1992/1993:
5.6 million m³ (Peltola & Tuomi, 1996)

| Small-scale use, TJ (nett energy) | | | |
|-----------------------------------|--------------|----------------------------|------------------|
| | Forest chips | Logs, pellets & briquettes | Pellets (<25 kW) |
| 1999 | 1296 | 45254 | |
| 2000 | 1022 | 44278 | |
| 2001 | 2747 | 45053 | |
| 2002 | 2786 | 45914 | |
| 2003 | 2786 | 45914 | 253 |
| 2004 | 2786 | 45694 | 355 |

| Use of fuel wood, million m ³ 2000/2001 | | | |
|--|-----|------------------------------------|-----|
| <i>According to house type</i> | | <i>According to purpose of use</i> | |
| detached houses | 3,1 | heating of residential houses | 4,4 |
| farms | 2,2 | heating of saunas | 1,2 |
| recreational buildings | 0,7 | heating of outbuildings | 0,5 |
| Total 6,1 (~46 PJ) | | | |

Energy Statistics 2004,
Finland Statistics



Tuomi & Peltola, 2002

Small-scale biomass combustion technologies

Manually fed systems

| Appliance | Capacity range | Fuel | Efficiency |
|--|--|---|------------|
| Heat-storing: masonry heater baking ovens | 20-40 kW during combustion (1-4 h) 1-3 kW heat output/h 40-100 kWh heat output | wood logs, mostly birch , also spruce, pine, alder, aspen etc | 75-85% |
| Sauna stoves -continuous heating | 20-40 kW during combustion (1-2 h) | construction wood | 50 -70% |
| Others: kitchen ranges iron stoves open fireplaces etc. | 5-15 kW nominal during combustion <40 kWh (soap stone stove: semi-heat storing) | | ? |
| boilers | 20-40 kW | same as above, wood briquettes | >80% ? |

Sauna stove has the greatest need for further development -
better efficiency

Automated systems

| Appliance | Burner | Capacity range | Fuel | Efficiency |
|-------------------|---------------|----------------|---|------------|
| Up draught boiler | stoker burner | 0-1000 kW | wood pellet, wood chip, other combustible fuels which can be fed by spiral, like peat, grain etc. | 80-95% |
| | pellet burner | 0-50 kW | wood pellet | 80-95% |



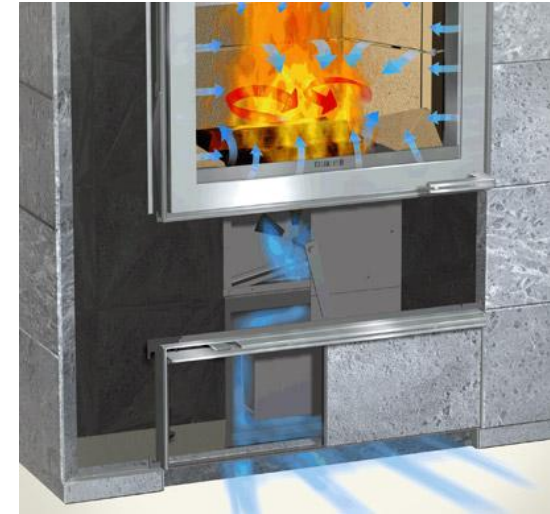
Typical features of Finnish batch burning

- § in Finland batch burning appliances are typically massive
 - § 1000-4000 kg
- § made of brick, soap stone or ceramic material
- § appliances are used with high burn rate, for example 10 kg wood/h, for some hours
- § appliances store heat and release it slowly during a long period of time
- § in sophisticated appliances **secondary combustion air** is introduced in the firebox



Example of Finnish heat-storing batch burning appliance: whirlbox by Tulikivi

- § air is led to different parts of firebox to gain more efficient burning
 - § 20% of air is led through the grate (primary air)
 - § over 45% is led through wall panels of firebox (secondary air)
 - § 35% flushes the glass door
- § efficiency 85%
- § emissions for example CO ~ 700 mg/MJ, OGC~60 mg/MJ, NO_x~70 mg/MJ, dust~30 mg/MJ



Source: Tulikivi



Distribution of different types of wood furnaces

- § important aim of research in near future
 - § no up-to-date statistics or register
 - § one estimation is 2.2 million fireplaces and 1.5 million sauna stoves and cauldrons for heating of water in sauna -reliability??
 - § probably heat-storing masonry heaters and sauna stoves are the most common appliances
 - § Latest results concerning distribution of types of biomass furnaces from 1988 (Tuomi, 1990)



Case Kurkimäki

Kurkimäki: a rural small-house area near Kuopio, both old and new houses

local chimney sweeper:

§ 154 houses with fireplace, 6% had none

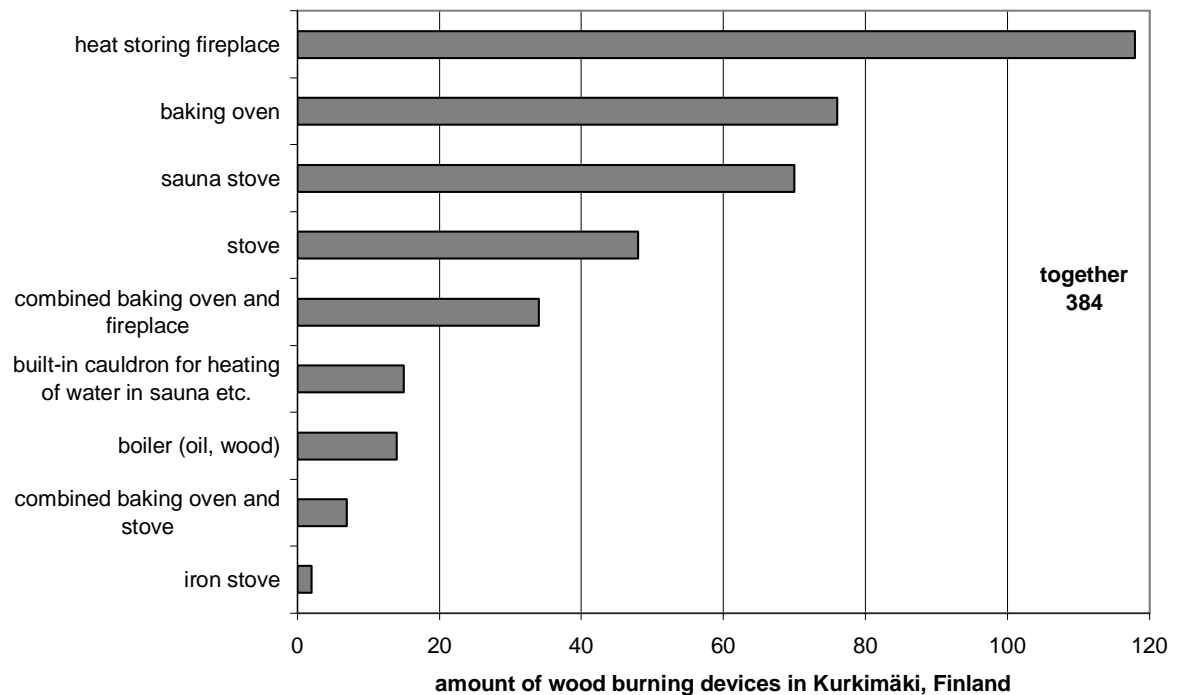
§ distribution of devices

questioning:

§ 2005: 650 m³ (solid) of wood burned

§ congruent with the nationwide results

§ information about operation: batch weight, heating activity, typical days for heating, heating time etc.



Source: Tuomi, 2007

Current situation concerning emission legislation

§ legislation

- § limit values for CO and OGC concentration in emission from RWC appliances will come into force in 2008
- § Testing according to EN standards
- § No limit values for PM emissions from RWC in Finland



SOLID FUEL BOILERS (emission limits in Finland 1.1.2008)

| | Proposed limits | | |
|--------------------|---|--|-----------------|
| Power kW | CO 10 % O ₂ dry mg/m ³ _n | OGC 10 % O ₂ dry mg/m ³ _n | Efficiency % |
| P ≤ 50 kW | 3 000 | 100 | 67 + 6logP |
| 50 kW < P ≤ 150 kW | 2 500 | 80 | 67 + 6logP |
| 150 kW < P | 1 200 | 80 | 67 + 6logP |

**Same as in
EN 303-5**

NEW BATCH BURNING APPLIANCES (emission limits in Finland 1.1.2008)

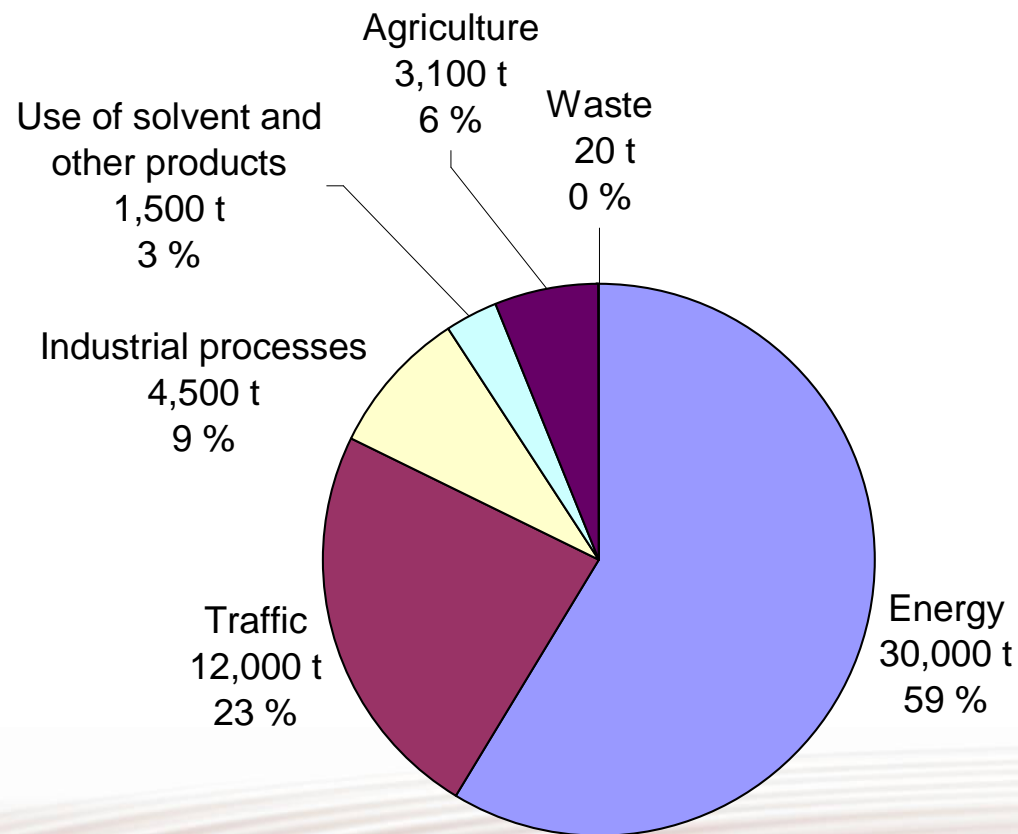
| | CO 13 % O ₂ dry % |
|--------------------------|------------------------------------|
| primary heating system | 0.17 |
| secondary heating system | 0.3 |
| sauna stoves | 0.5 |

prEN 15250
0.3% (13% O₂)



Particulate emissions from small-scale combustion

Origin of PM10 emissions in Finland in 2005



In 2000, residential wood combustion accounted for 25% of PM_{2,5} emission in Finland to which batch burning has significant contribution (Karvosenoja et al., 2007)

Estimates are based on best available data

-on wood consumption

-on distribution of burning appliances (1988)

-emission data (provided also by UKU)

Source: Finnish Environment Institute



Emission factors

| | TSP | PM1 | N (ELPI) | CO | OGC | NOx | CH ₄ | Appliances | Ref. |
|--|---------|---------|-------------------------|-----------|---------|--------|-----------------|------------|------|
| | mg/MJ | mg/MJ | × 10 ¹³ #/MJ | mg/MJ | mg/MJ | mg/MJ | mgC/MJ | n | |
| Sauna stoves | 130-260 | 130-160 | 5.2-9.4 | 3100-7900 | 590-720 | 120* | 230-630 | 7 | a/b |
| Masonry heaters, baking oven, stove, fireplace inserts | 100-150 | 30-100 | 4-21 | 1200-3500 | 100-310 | 55* | 30-50* | 17 | a/b |
| Pellet stove | | 65 | 3.2 | 170 | 10 | 40 | | 1 | a |
| Boilers (+burners), below 500 kW, wood pellet/chips | 13-90 | 8-25 | 0.69-3 | 85-1400 | 1-35 | 55-145 | 15-20* | 9 | a/b |
| Regional boiler, 10 MW** | 11 | 3 | 0.043 | 20 | | 70 | | 2 | a |
| Oil burner, light fuel oil | 2 | 2 | 0.011 | 35 | | 40 | | 2 | a |

*Number of appliances lower than n

a PIPO-project: Tissari et al., 2005

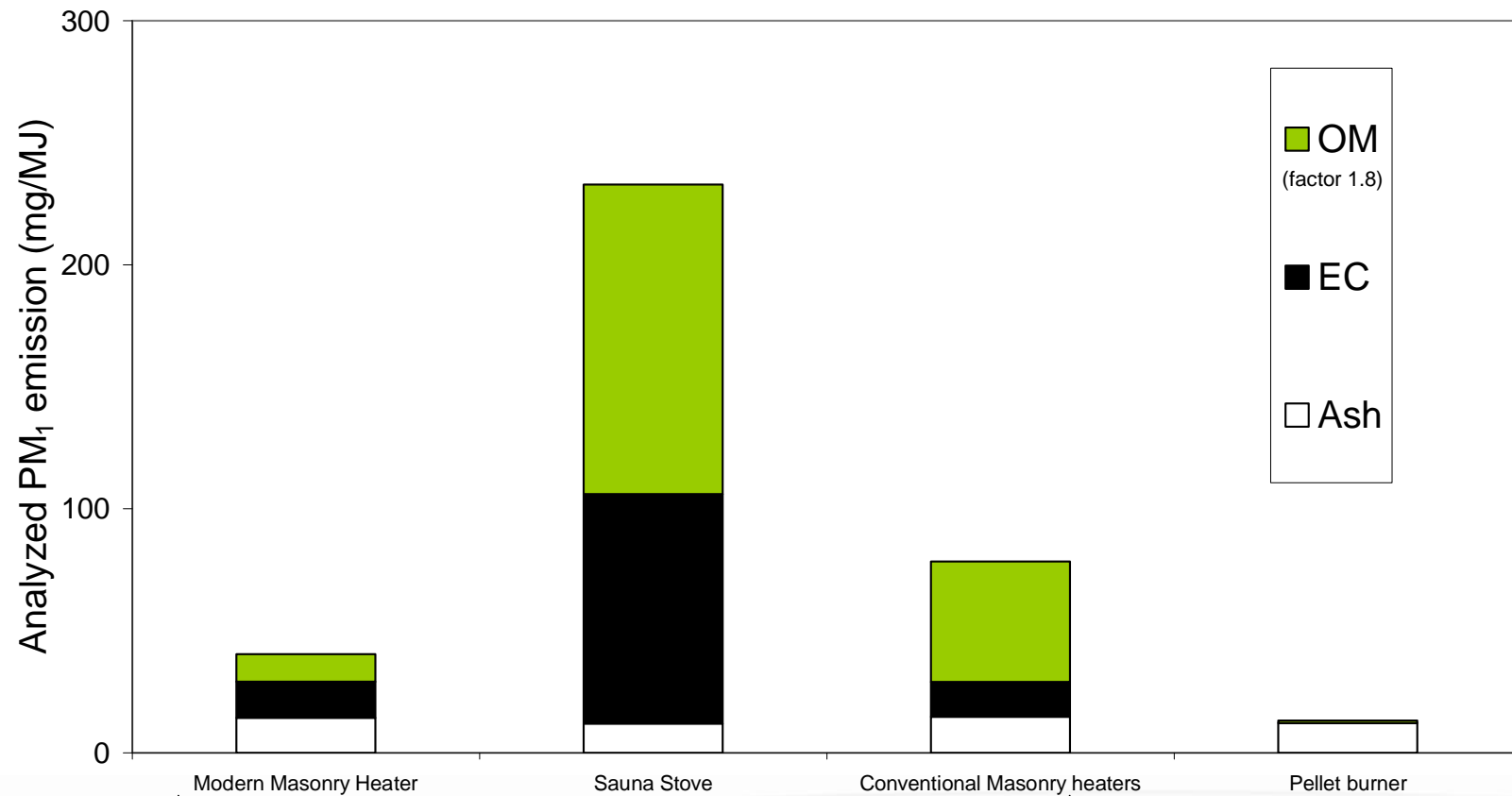
**Multicyclone and ESP

b PUPO-project: Tissari et al., 2007b

Includes results measured both in field and in lab, little differences



Chemical composition of particles

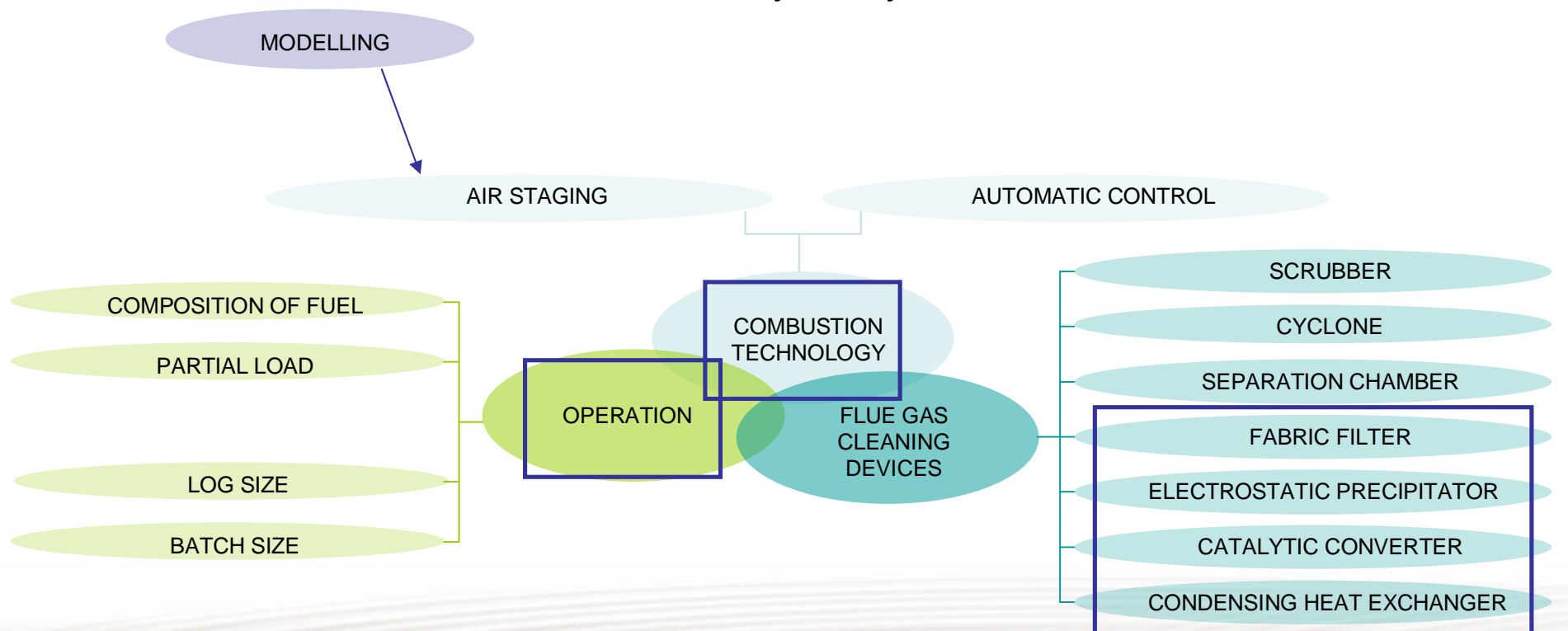


Tissari et al., 2007
(Field measurements, *Atm. Env.*)



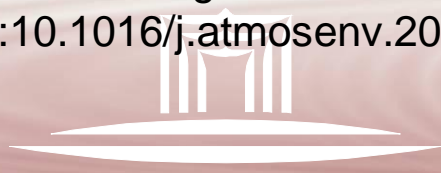
Primary and secondary measures for PM-emission reduction

Reduction of fine particle emissions from residential wood combustion
 UKU & VTT Jyväskylä, 2006



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