A novel concept to study sauna stoves

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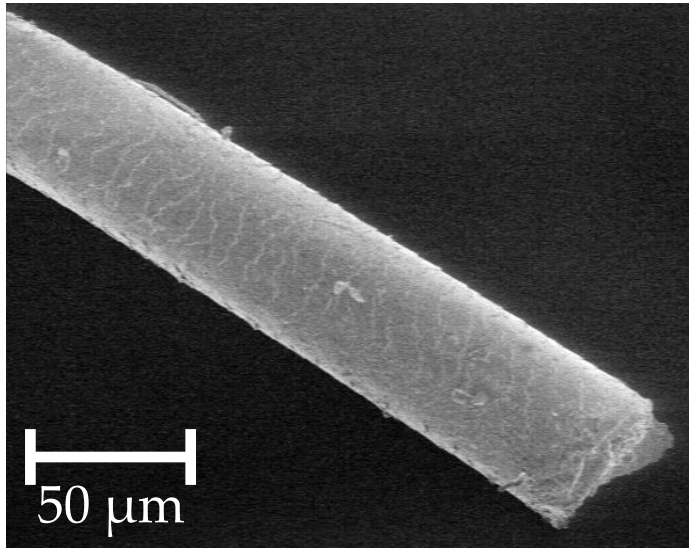
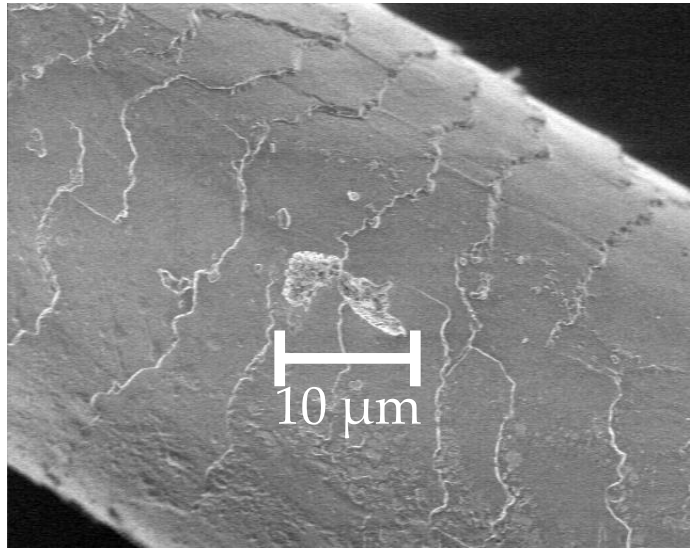
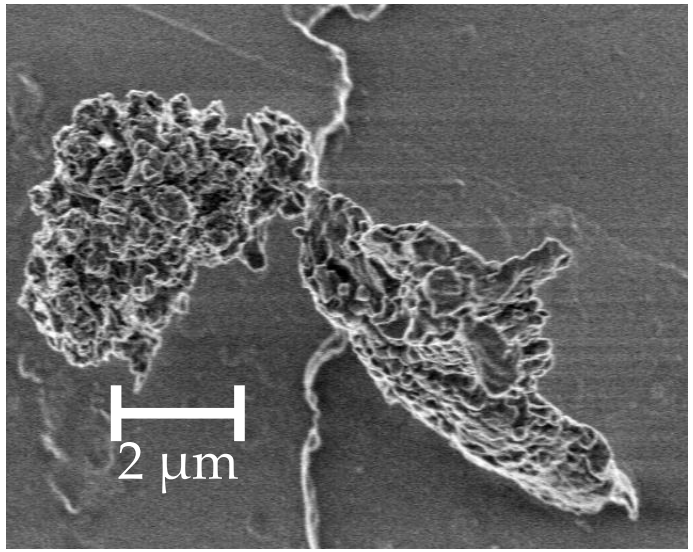
RWC emissions

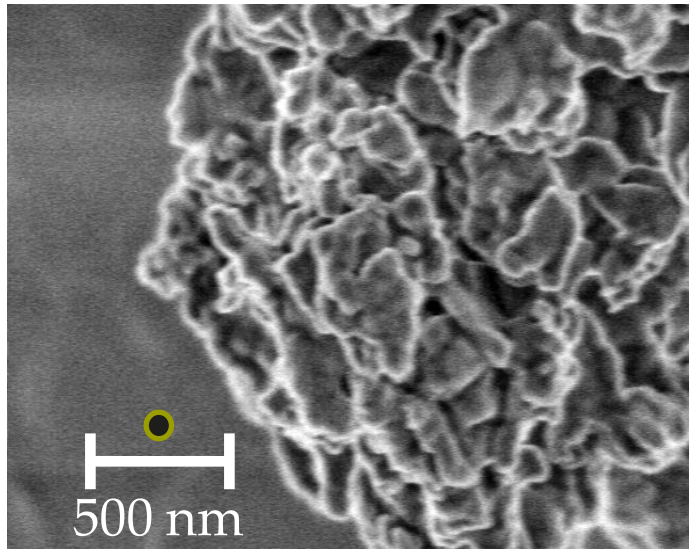
- Residential wood combustion causes a lot of emissions, mainly due to poor combustion conditions
  - Insufficient amount of combustion air
  - Insufficient mixing of gases
  - Too low combustion temperature
- Emissions:
  - Large amounts of carbon monoxide (CO)
  - Organic gaseous carbon (OGC)
  - Fine particulate matter (PM2,5)
  - Polycyclic aromatic hydrocarbons (PAHs) (IARC; Class 1 carcinogen)

RWC emissions









Combustion particles 100 nm

To 1 mm segment, 10 000 # in a row.

Lump = 1 cm^3

10 µm particles
1000 × 1000 × 1000
= 1 billion #

In flue gas, number concentration is typically 10-100 million /cm3

If conc is higher -> collisions (= coagulation) -> size increase, number decrease

RWC is a challenging emission source

- There are many different uncontrolled factors that also affect the combustion conditions and emissions. E.g.
  - types and models of appliances;
    - masonry heaters, sauna stoves, pellet boilers, log boilers, stoves...
  - tree species and fuel quality;
    - heating value, fuel chemical composition ...
  - operational practices;
    - fuel seasoning/storing (-> fuel quality, moisture content)
    - combustion patterns (batch size, log size, number of batches...)
    - combustion rates (draught conditions, air and damper settings...)
    - kindling approaches
  - weather conditions, atmospheric aging of aerosols etc.

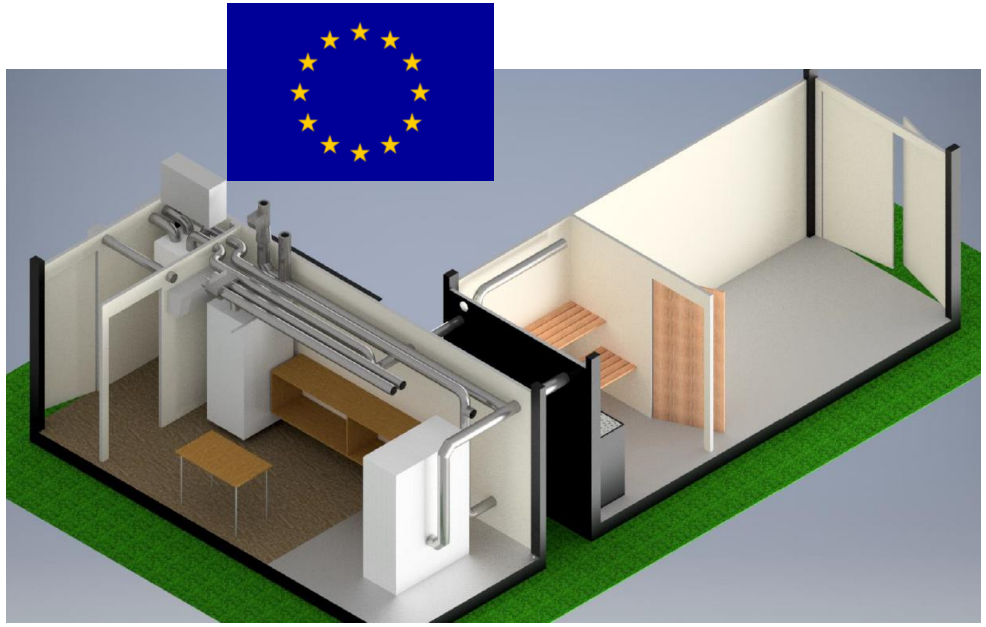
Effects of fine particles

- EU Clean Air For Europe-programme (COM(2013) 918):
  - the most important pollutant in outdoor air.
    - 400 000 premature death
    - Respiratory and heart illnesses
    - 10-fold more death than road accidents
- Atmospheric aerosols influence climate locally and globally
  - Cooling and warming effects
- Residential wood combustion (RWC) has been assessed to be a major source of fine particle emissions throughout Europe.
  - Half of Finland's particulate matter emissions come from wood combustion

Source: Air Quality in Europe -2015 report

Wood combustion simulator

- SIMO- and KIUAS projects



Novel concept to study sauna stoves - goals

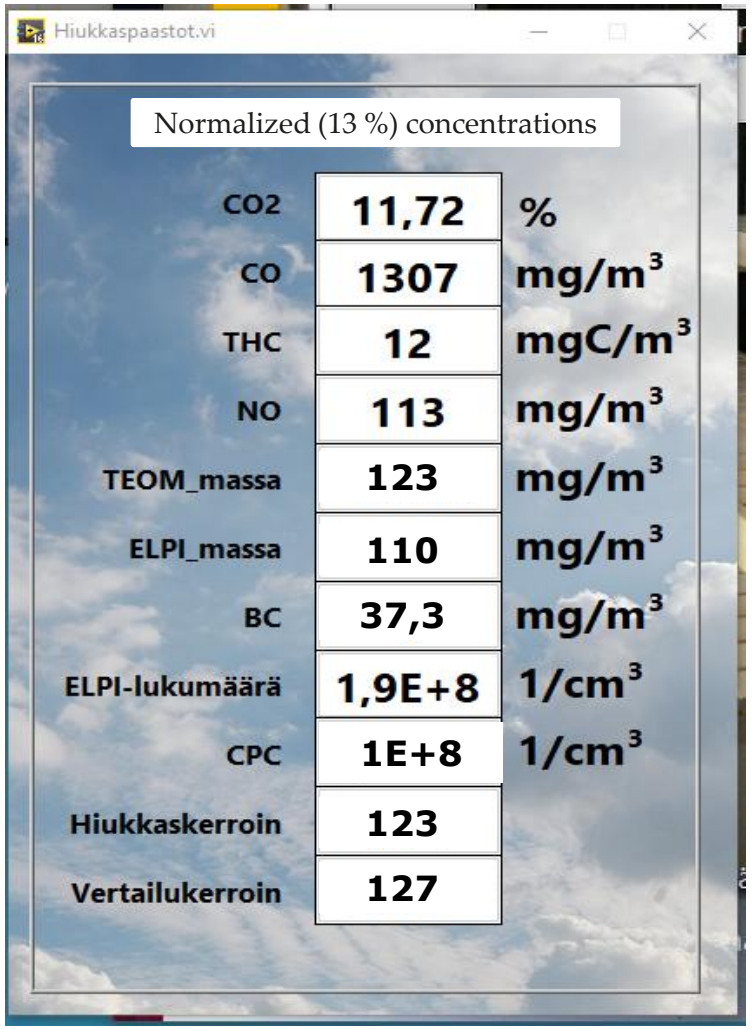
- To produce a simple, affordable and repeatable way to measure sauna stove emissions in real life conditions
  - mimics the real life end user way of operating the stove
  - measures the emissions of the sauna stoves as well as the conditions affecting sauna bathing
- Aim to produce comparable information between the different sauna stoves
  - Total efficiency
  - Real life emissions

Novel concept to study sauna stoves

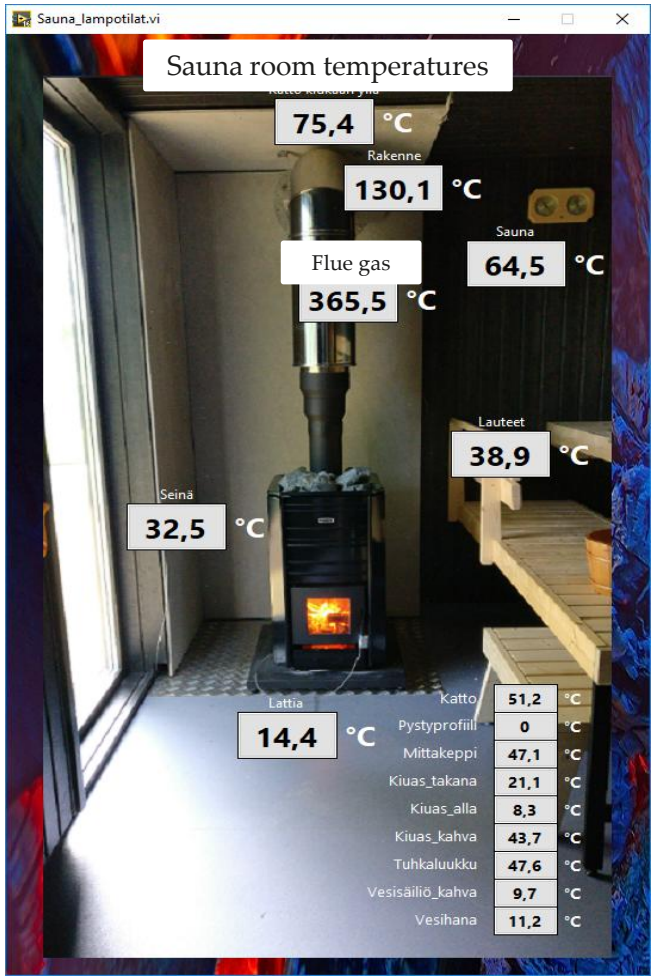
- Measuring concept:
  - Sauna room 16 m^3
  - Batches: 3+3+1 kg of birch (moisture content 16 %)
  - Ignition from the top, the firing batch always the same (largest logs on the bottom, tinder on top)
  - Addition of firewood at 25 % of batch's maximum CO2 level
  - Ventilation factor 3 measured from the outgoing air
  - Flue draught 6 Pa at the ignition, let it develop freely afterwards
  - Three repetitions of the measurement

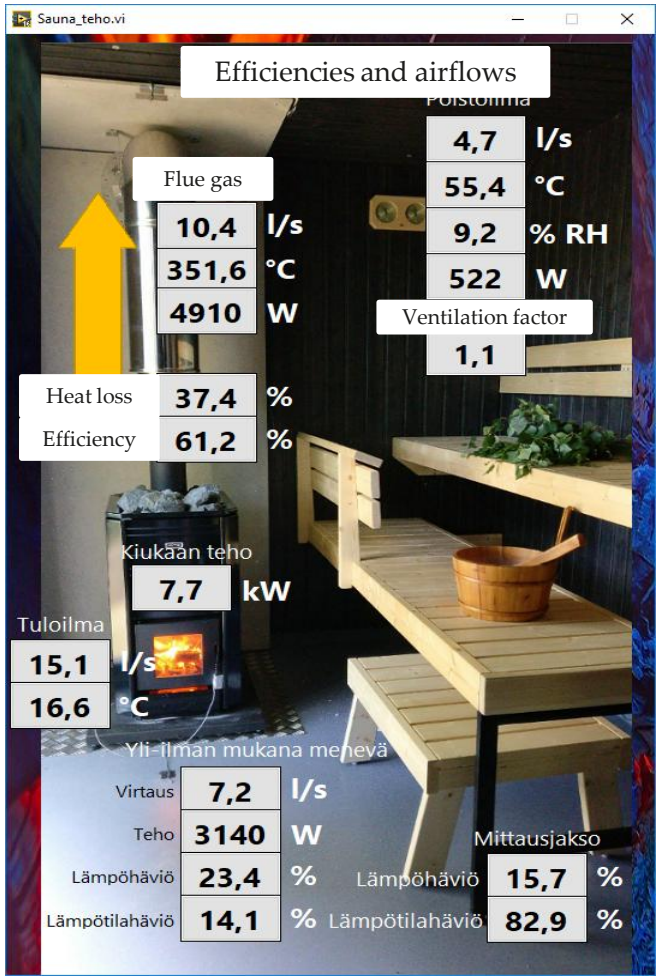
Measurement methods

- Measures:
  - Particle mass (ELPI)
  - Particle number (ELPI + CPC)
  - Gaseous emissions (Gas analyzer rack; Siemens Fidamat 6, Siemens Ultramat 23)
  - Black carbon (Aethalometer)
  - OC/EC filter gathering
  - PM1 filter gathering

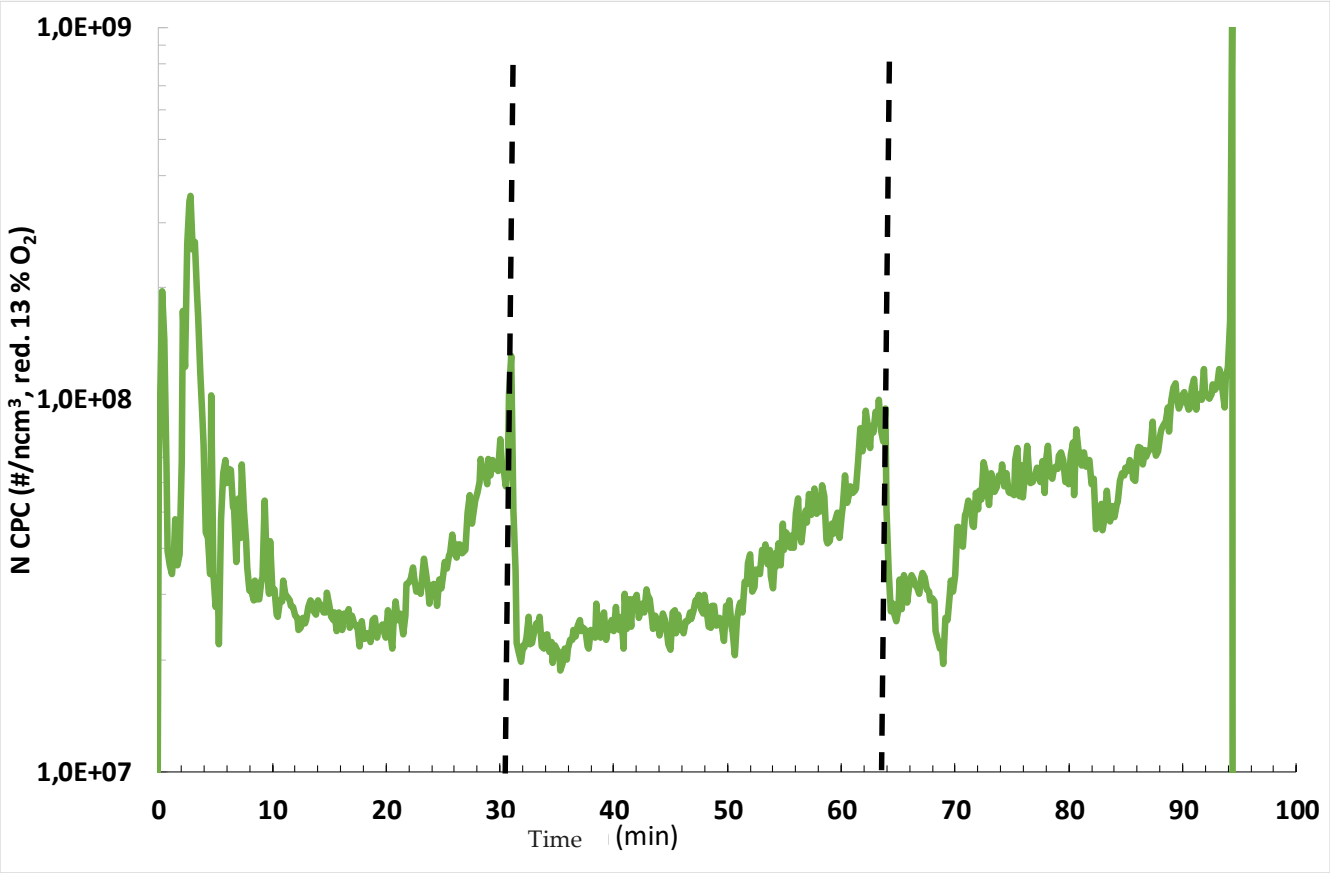


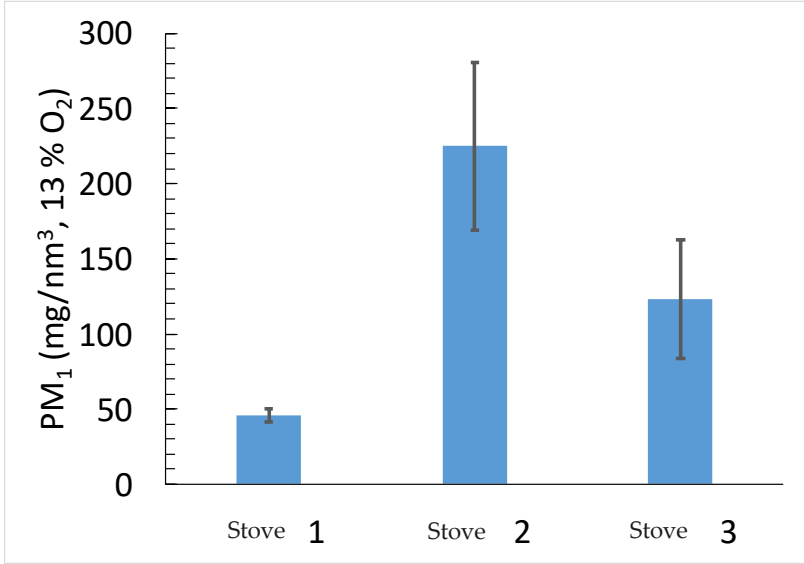
Example of data from the sauna room

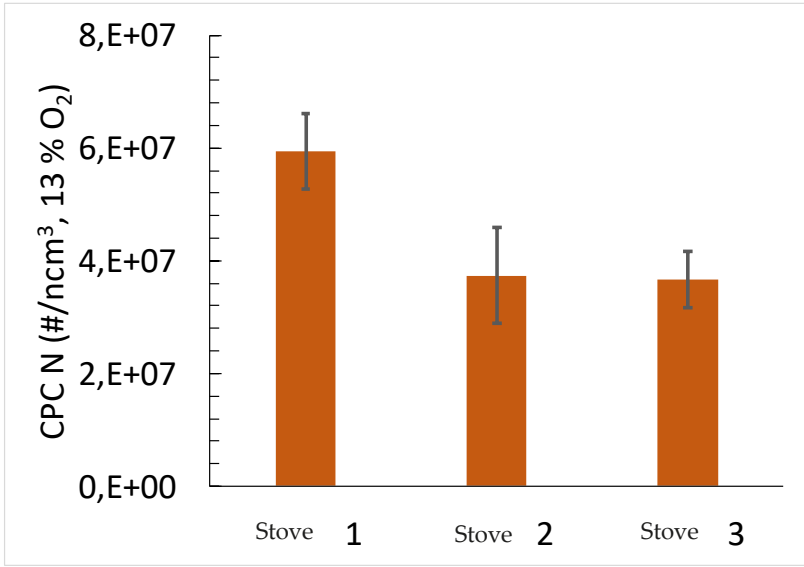


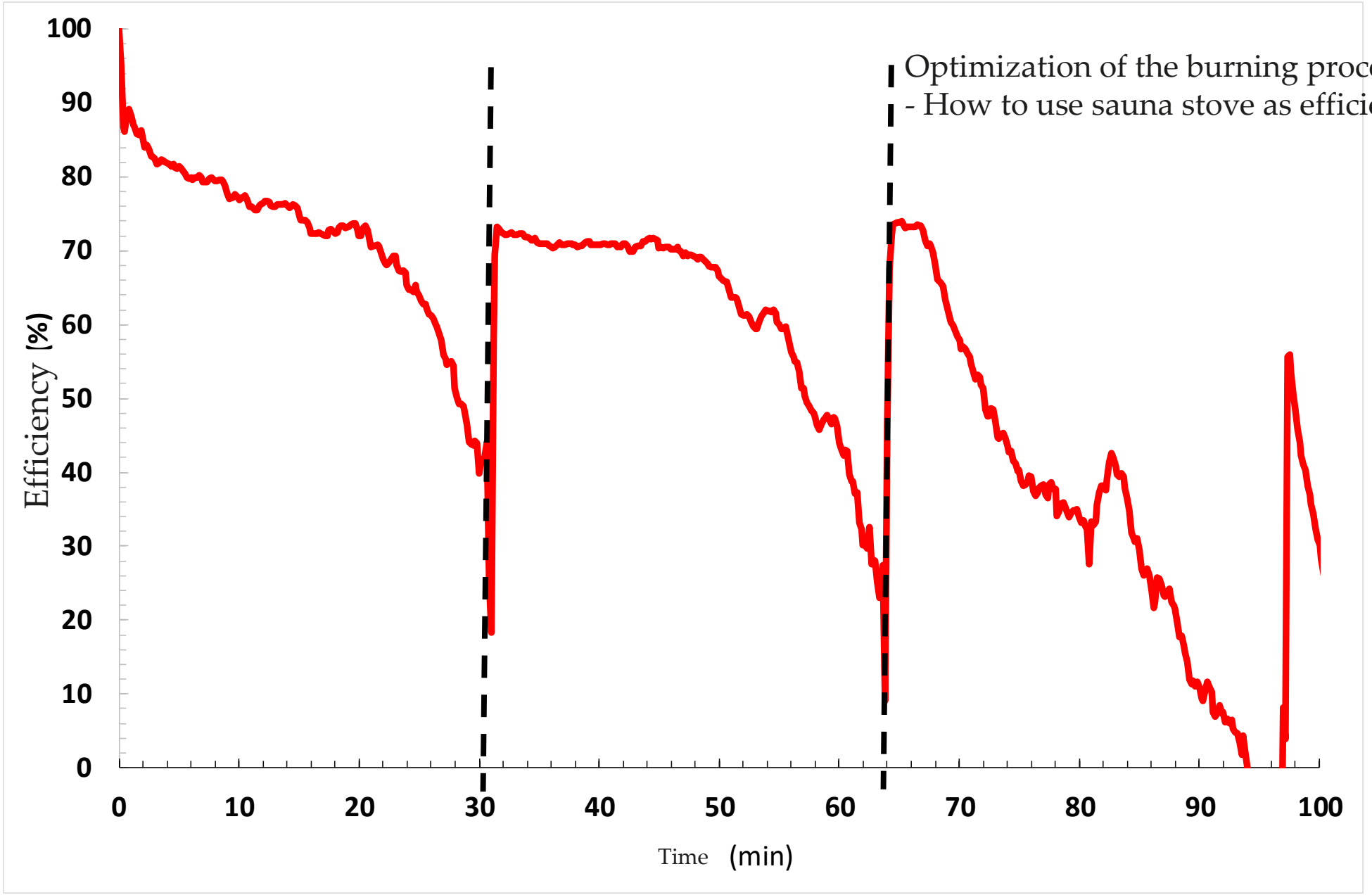


Some examples of results so far…








Optimization of the burning process
- How to use sauna stove as efficiently as possible
Efficiency (%)
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Time (min)

Thank you!