Greenhouse gas emissions from direct combustion of various fuels (e.g. grain dryer)

- The most significant greenhouse gas from direct combustion is carbon dioxide (CO_2)
- Large number of other compounds are also formed
- Their effect on global warming is described with the carbon dioxide equivalent (CO_2eq, CO_2e, CDE)
  - CO_2eq describes the amount of CO_2 units that has similar global warming potential (GWP) than one unit of the substance concerned
  - Methane (CH_4) 24,5 CO_2eq
  - Nitrous oxide (N_2O) 320 CO_2eq

Direct CO_2 emissions

- CO_2 is formed always when burning fuel that contains carbon
- The carbon in the fuel combines with the oxygen from the air:

$$C + O_2 \Rightarrow CO_2$$

- The amount of CO_2 can be calculated by the atomic masses of carbon and oxygen and the carbon content of the fuel

Direct CO_2 emissions

- Atomic mass of carbon is 12u and oxygen 16u

$$CO_2 = 12u + 2 \times 16u = 44u$$

- Burning 1 kg of carbon produces 44/12 ≈ 3,67 kg of CO_2 in complete combustion
- **The CO_2 emission of combustion is 3,67 x c_C x m_{fuel}**

  c_C = fuel carbon content (mass basis)

Direct CO_2 emissions

Example: carbon content of diesel fuel is 85,7 %. CO_2 emission from burning 1 kg of diesel fuel is:

$$m_{CO2} = 3{,}67 \times c_C \times m_{fuel}$$

$$m_{CO2} = 3{,}67 \times 0{,}857 \times 1\ kg = 3{,}15\ kg\ /\ 1\ kg\ fuel$$

Density of diesel fuel is 0,84 kg/l

$$m_{CO2} = 3{,}15\ kg \times 0{,}84 = 2{,}64\ kg\ /\ 1\ l\ fuel$$

Direct CO_2 emissions

- CO_2 emission is usually expressed in g/MJ or t/TJ
- CO_2 emission g/MJ of fuel = 3,67 x c_C / H_a

  c_C = fuel carbon content (mass basis)
  H_a = lower heating value of the fuel

Example: carbon content of diesel fuel is 85,7 % and lower heating value H_a = 42,7 MJ/kg. CO_2 emission is:

3,67 x c_C / H_a

3,67 x 0,857 / 42,7 MJ/kg = 0,0736 kg/MJ = 73,6 g/MJ

Calculated CO_2 emissions from different fuels

Fuel	Carbon content [%]	H_a [MJ/kg]	CO_2 emission [g/MJ]
Diesel fuel	85,7	42,7	73,6
Natural gas*	75	50	55,0
Rapeseed oil	78,2	37,3	76,9
Wood (chips)	50 (48-52)	19 (dry matter)	96,5

* Natural gas imported to Finland is 98% methane. It has carbon content of 75% (C=12u, H=4x1u, CH_4=16u, 12/16=75%)

http://www.maakaasu.fi/kirjat/maakaasukasikirja/maakaasun-koostumus-ja-ominaisuudet

Official Finnish figures

Fuel	H_a [MJ/kg]	CO_2 emission [g/MJ]
Diesel fuel	42,8	73,0
Light fuel oil	42,4	74,1
Natural gas	36,0 [MJ/m^3]	56,1
Liquid biofuels	40	77,4
Wood (chips)*	10,4	109,6

* Heating value of wood is expressed in wet basis, moisture ~ 40%

http://www.stat.fi/til/khki/2003/khki_2003_2005-09-12_luo_002.html

CO_2 emission per litre of liquid fuel

- Liquid fuels are sold in litres

Example: diesel fuel

Density = 0,84 kg/l
Ha = 42,7 MJ/kg
= 0,84 kg/l x 42,7 MJ/kg = 35,868 MJ/l

Volume of 1 MJ = 1 / 35,868 MJ/l = 0,02788 l/MJ

CO_2 emission = 73 g/MJ / 0,02788 l/MJ = 2640 g/l = 2,64 kg/l

CO_2 emission per m^3 (of wood chips)

- Wood chips are sold in cubic meters

Example: wood chips

Density = 300 kg/m^3 (250-350 kg/$m^{3)}$
Ha = 10,4 MJ/kg
= 300 kg/m^3 x 10,4 MJ/kg = 3120 MJ/m^3

Volume of 1 MJ = 1 / 3120 MJ/l = 0,000321 m^3/MJ

CO_2 emission = 109,6 g/MJ / 0,000321 m^3/MJ = 324 kg/m^3

Other GHG from combustion

- In internal combustion engines also methane and nitrous oxide are formed
  - Figures of 0,004 g NH_4 /MJ_{fuel} and 0,031 g N_2O /MJ_{fuel} are suggested (Mäkinen et al 2006)
  - Concentrations in exhaust gases for NH_4 ~ 5 – 15 ppm and N_2O ~ 1 – 3 ppm
- Other GHG from combustion in furnaces?
  - Controlling the combustion is much easier than in engines
  - Continuous combustion
  - Steady conditions

This material has been produced in ENPOS project. ENPOS is acronym for ***Energy Positive Farm***.

The project partners are
• University of Helsinki, department of Agricultural Sciences – Agrotechnology
• MTT Agrifood Research Finland - Agricultural Engineering
• Estonian University of Life Sciences

Project home page is at http://enpos.weebly.com/

The project is financed by the EU Central Baltic IV A Programme 2007-2013

ENPOS Energy Positive Farm

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND
INVESTING IN YOUR FUTURE

CENTRAL BALTIC
INTERREG IV A
PROGRAMME
2007–2013