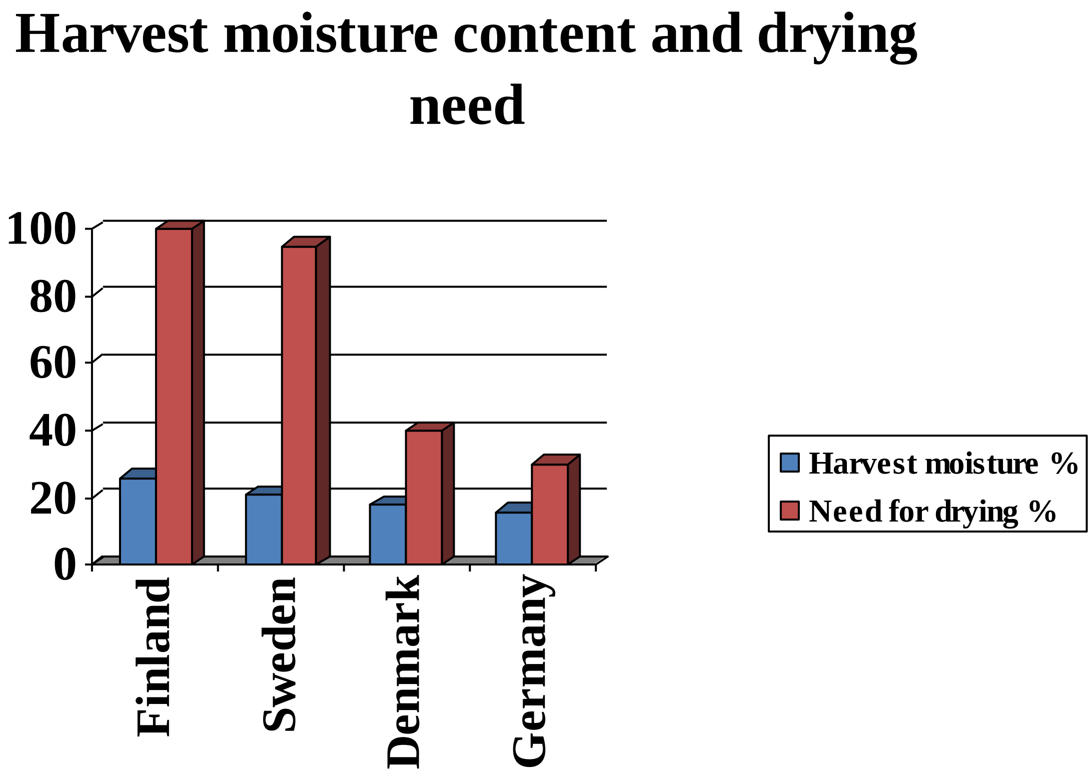
Energy consumption in grain drying

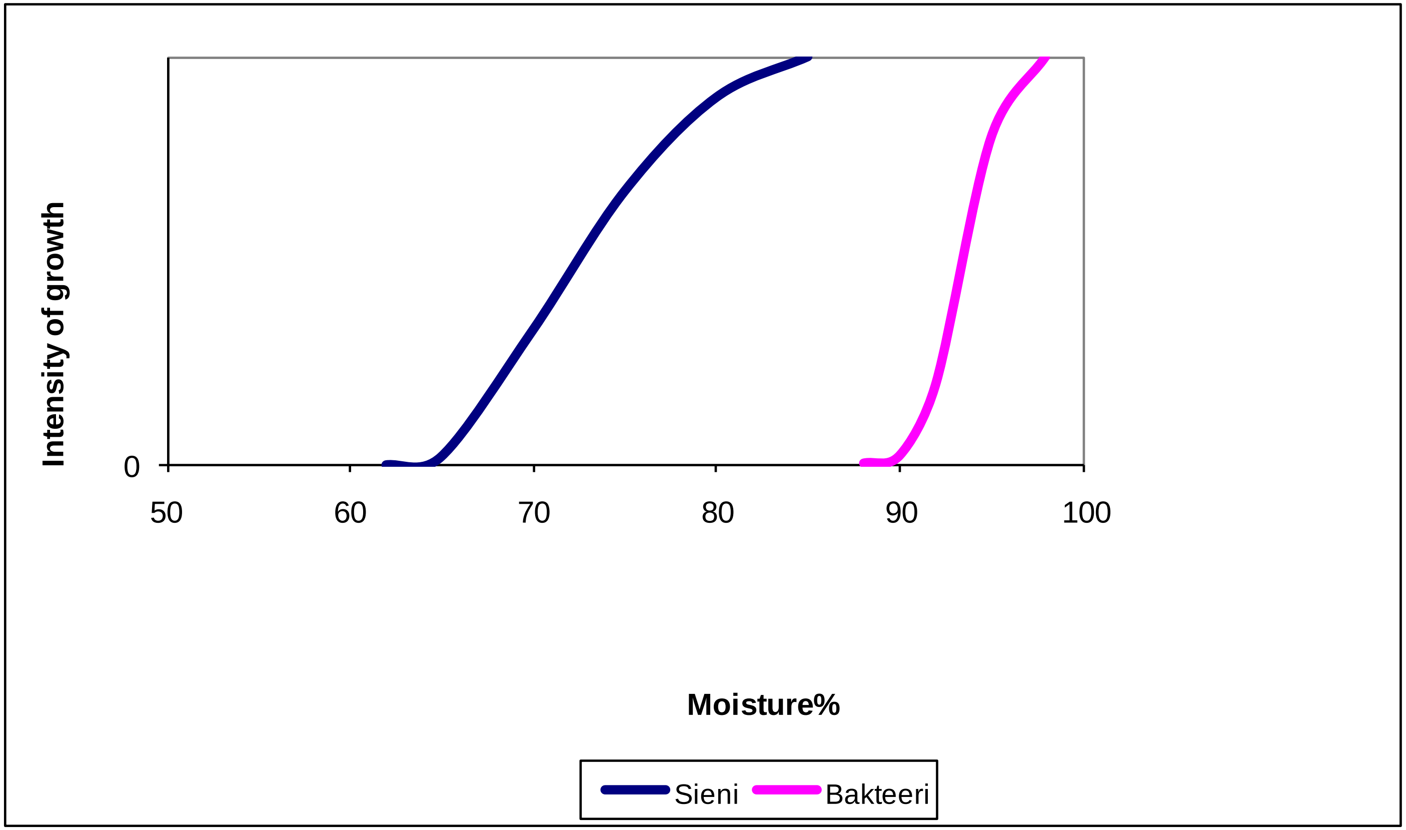
Why do we dry grain?

- The grain moisture content after harveting is in most cases so high that spoiling of grain starts if the grain is not dryed
- High moisture content makes possible for the microbes to start their work
- Moisture content is the key factor in microbe growth
  - Low moisture content of material prevents vital functions of microbes
  - When air moisture content is higher than 62% molds start to grow
  - When air moisture content is higher than 90% bacterias start to grow

Drying demand in European countries

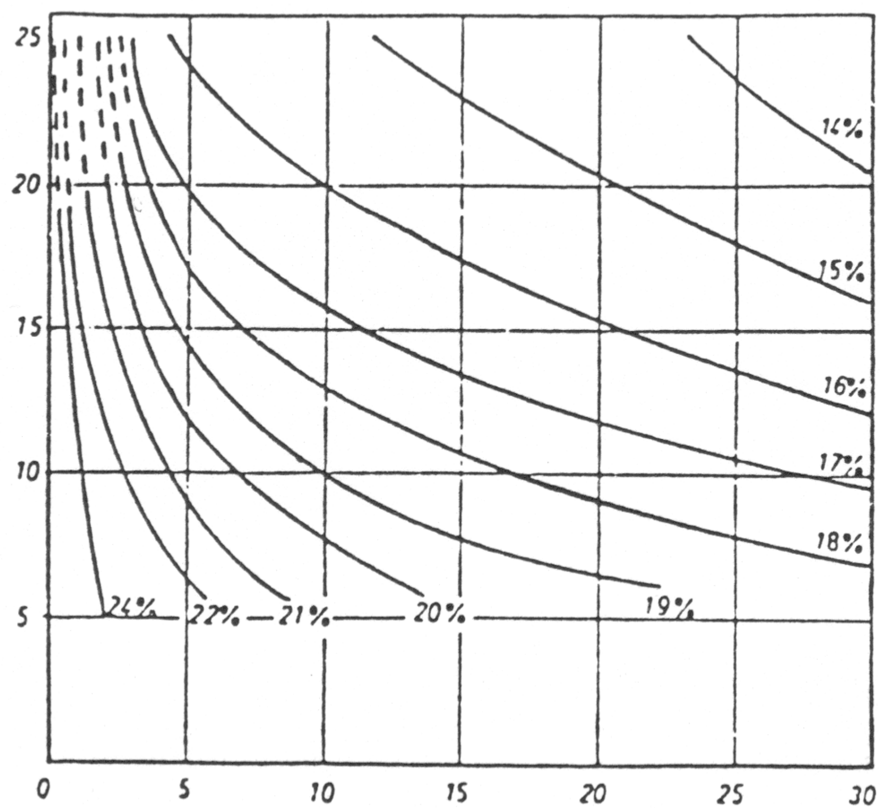


Microbes and water



Crop storage

Crop temperarture

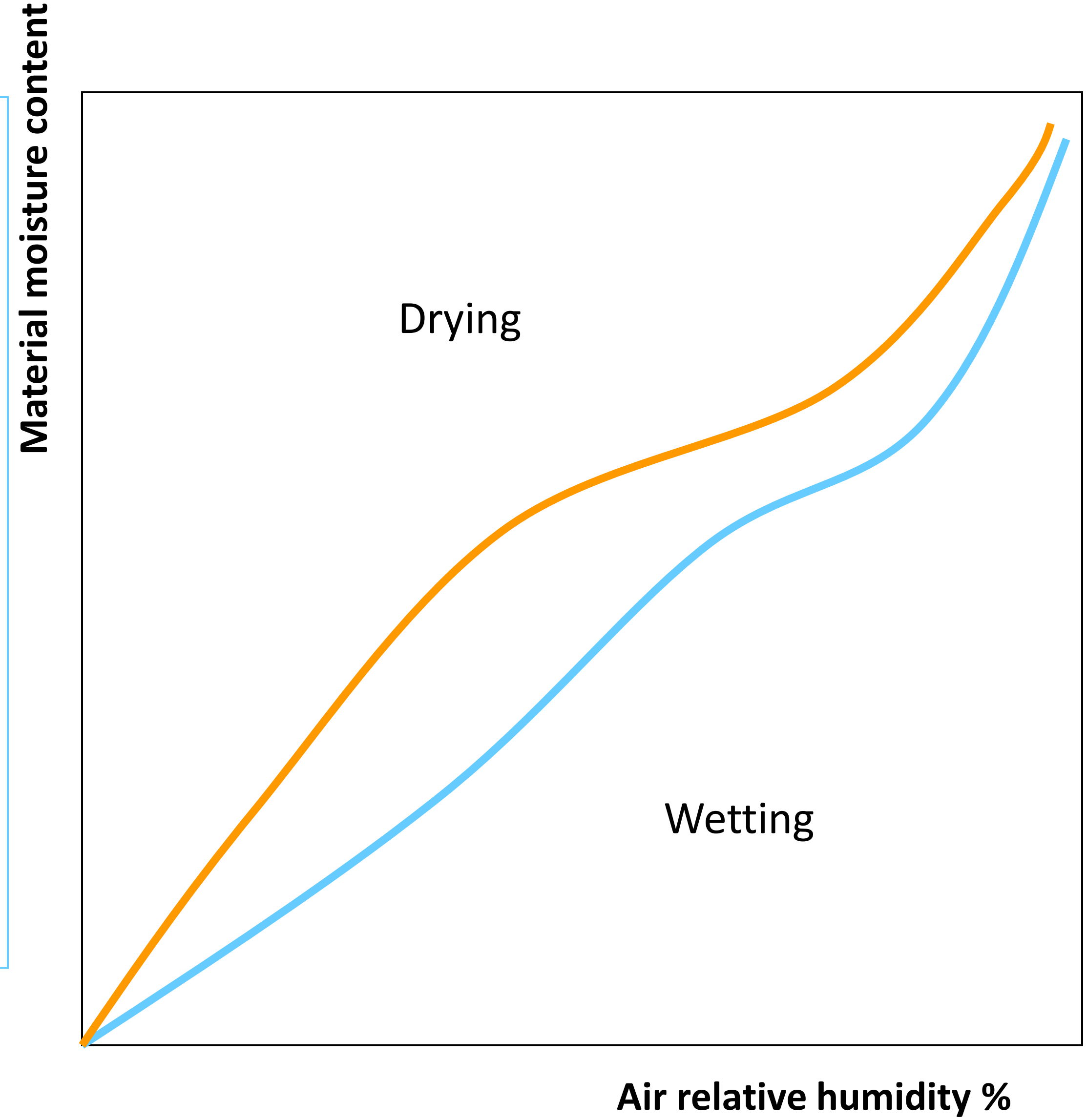


crop moisture content

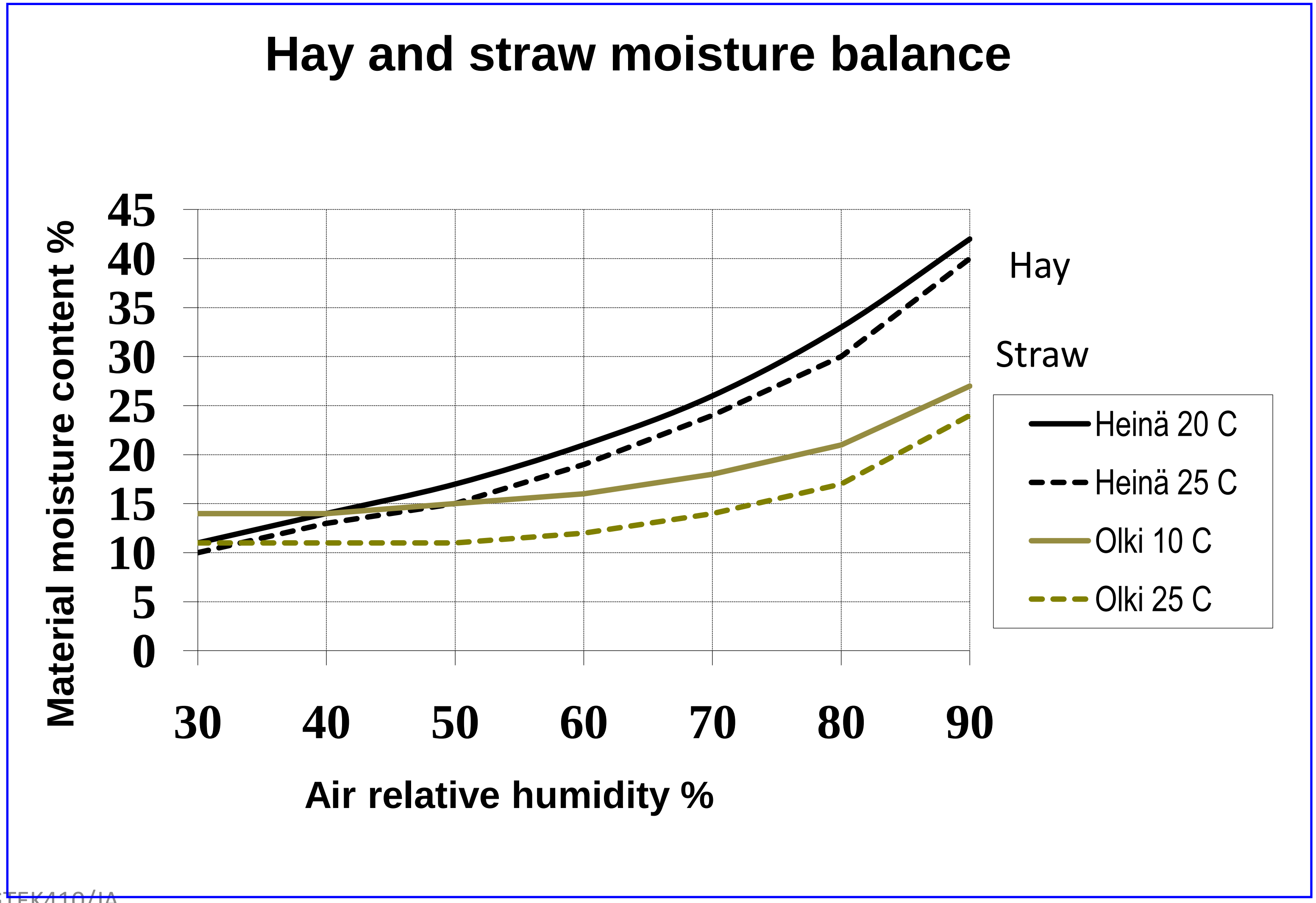
Storage time, weeks

Moisture balance

- When biomas is kept in a constant air moisture content after some moisture movement between the material and the air there is a balance between the material and air
- Hysteresis makes the moisture balance figures different depending on if the material is drying or wetting
- Temperature has an effect on balance, the curves are called moisture isotherms

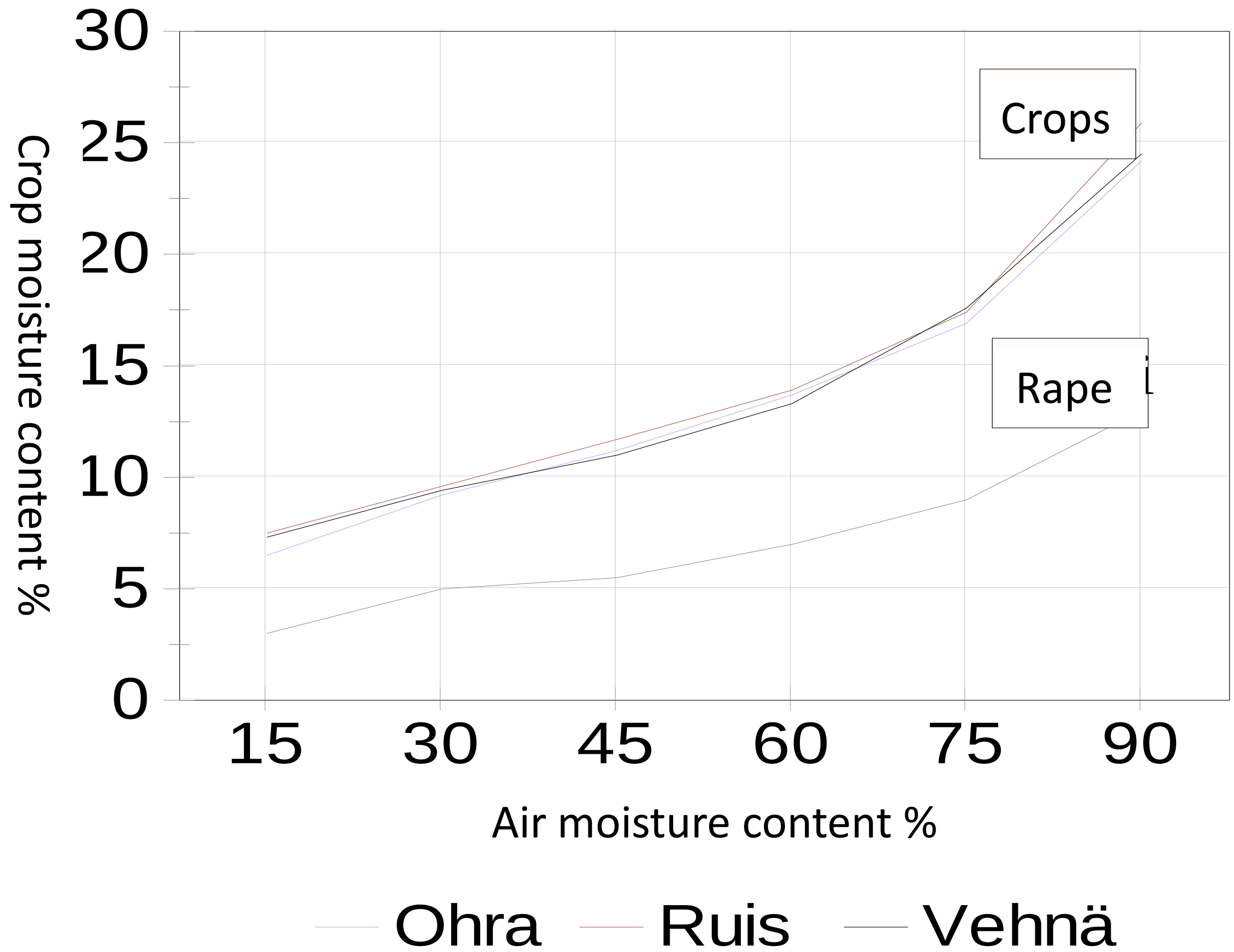


Moisture balance



Crop moisture balance

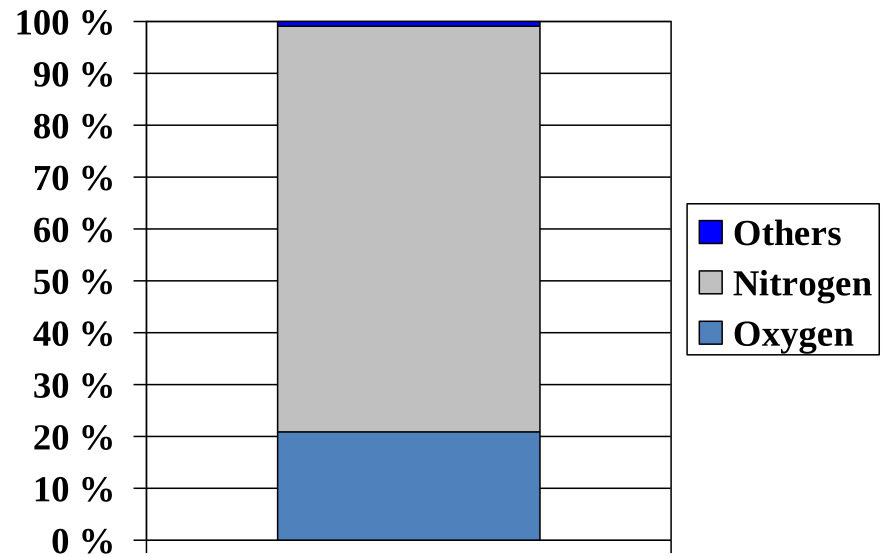
Barley, rye, wheat



Air

- Air is a gas mixture
- Besides gases air embodies water vapour (moisture)
- Air density in normal conditions (1 atm, 0C) is 1.29 kg/m^3

Alkuaine	Tilavuus %	Paino %
Happi O_2	20,95	23,14
Typpi N	78,09	75,53
Argon Ar	0,93	1,28
Hiilidioksidi CO	0,03	0,05
Neon Ne	0,002	0,001



Air moisture contents

Relative humidity expresses how near air is to saturation, 100 % = saturation

$$s = \frac{p_h}{p'_h}$$

s = relative humidity
p_h = water vapour partial pressue
p'_h = water vapour partial pressue at saturation

Humidity ratio (absolut humidity) expresses how much the air has water in

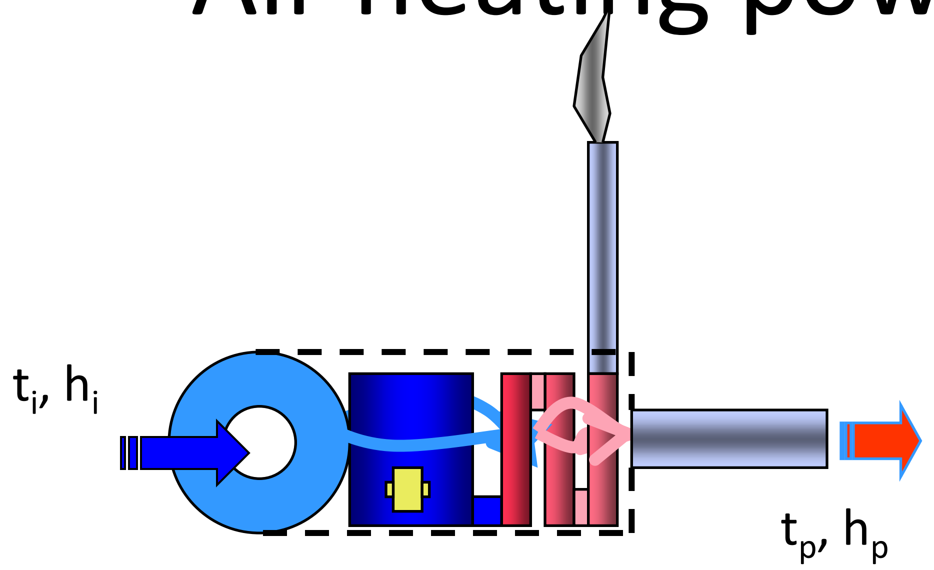
$$x = \frac{m_h}{m_i}$$

x = humidity ratio

m_h = mass of water

m_i = mass of dry air

Air heating power



$$P_k = \dot{V}_i \rho c_i \Delta T$$

c_i air heat capacity, n 1,006 kJ/kgK
ΔT temperature change

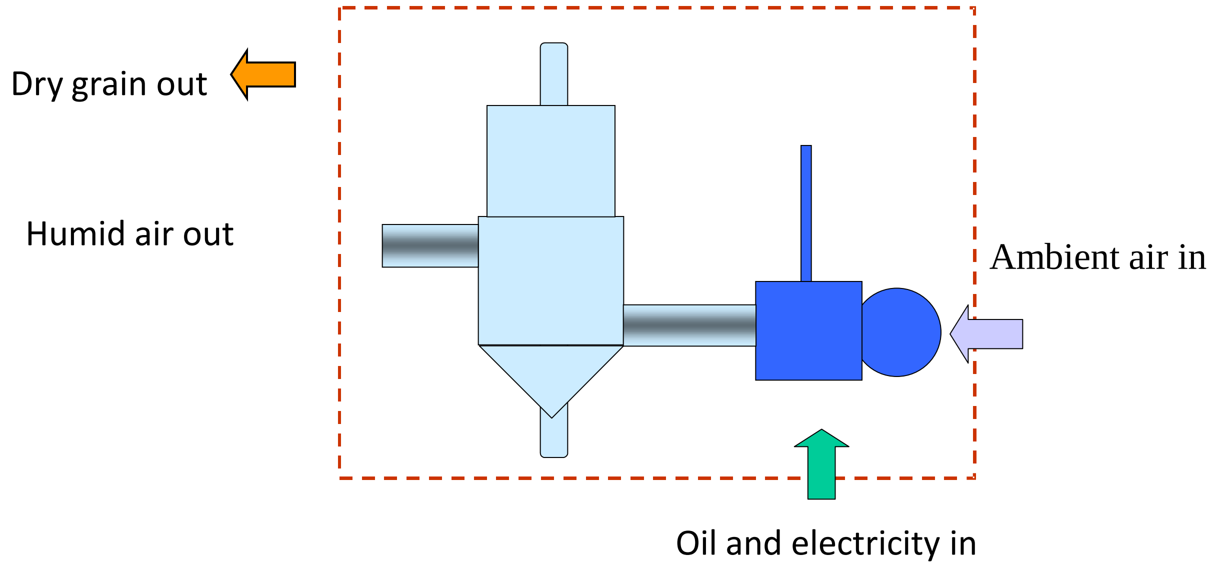
This is an approximate way to calculate air heating power

Example

Grain dryer furnace air flow value is 21 000 m3/h and the temperature change is 60 C. What is the heating power of the furnace?

Grain drying

In boreal conditions crops must be dryed. Drying consumes enerfgy!



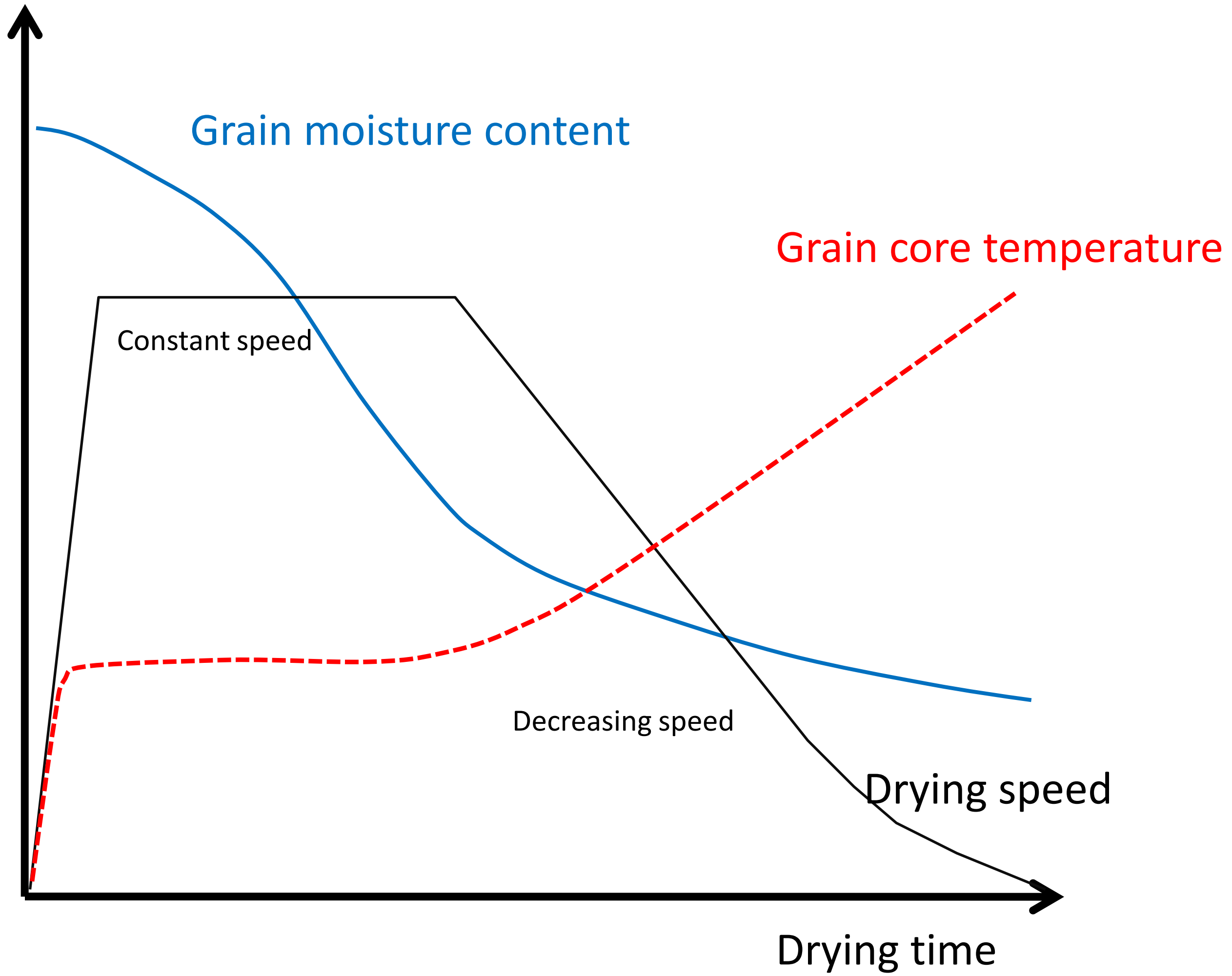
In grain drying the moisture in the grain moves to the air, which is blown through the grains

Drying

During drying different phases can be seen

- Drying starts with rapid moisture removal, the free water on the grain surface is removed
- When the free water has been removed water inside the grain must move to the surface, the moisture removal speed is decreased
- Temperature has an effect of water moving speed, high temperatures give higher moving speeds

Drying



Grain moisture content
Grain core temperature
Constant speed
Decreasing speed
Drying speed
Drying time

Drying

Removed water amount:

$$M_{RW} = M\frac{w_h - w_d}{1 - w_h}$$

M_{RW}	=	mass of evaporated water
M	=	mass of the dryed grain
w_h	=	moisture content of harvested grain (wb)
W_d	=	moisture content of dryed grain (wb)

Example

- Barley yield of Finland is 1 700 milj. kg. What is the evaporated water amount when harest moisture content is 25, 20 or 18%.

Drying energy need

- The minimum energy need is got from the water evaporation energy and vapour heat content

$$E = h_{vh} + c_v T_v$$

h_{vh} = water evaporation energy at 0 C, 2502 kJ/kg

c_v = water vapour heat content, 1,87 kJ/kg C

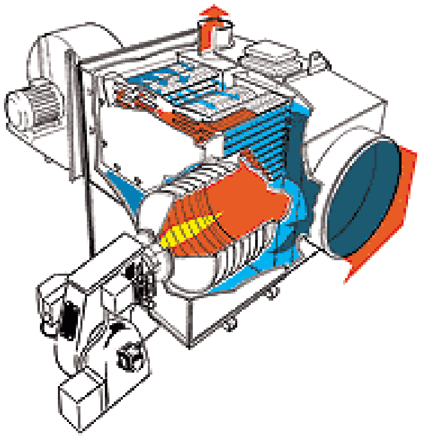
Example

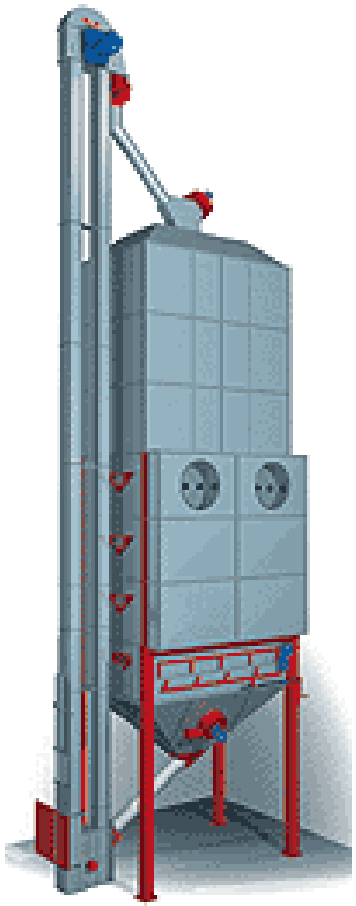
- What is the minimum energy needed to remove 1 kg of water at 50 C?

Drying

In grain drying

- 120 g of burning oil is needed per evaporated water kg
- This corresponds to 5,1 MJ/kg H_2O
- Besides this energy (electricity) is needed to run the fan, elevator and other dryer equipments





Example

- A farm has 210 ha of grain with average yield of 3,5 t. What is the average oil consumption in grain drying?

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

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• MTT Agrifood Research Finland - Agricultural Engineering
• Estonian University of Life Sciences

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