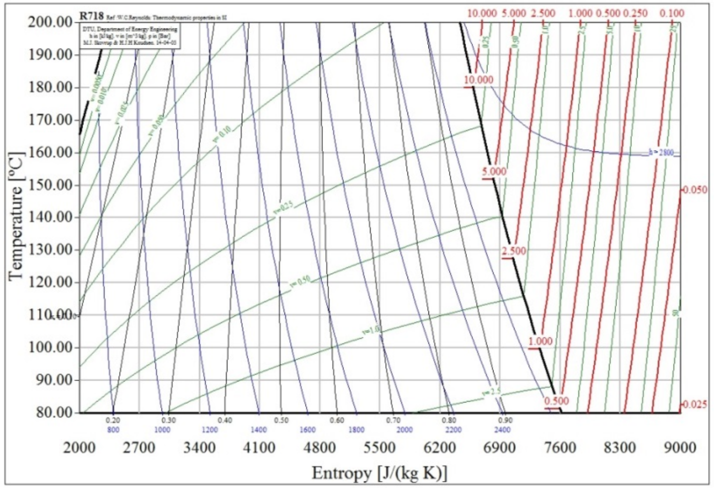
Food Security and Ethics from an energetic point of view

Ethics, sometimes known as **moral philosophy**, is a branch of philosophy that involves systematizing, defending and recommending concepts of right and wrong conduct, often addressing disputes of **moral diversity** *Internet Encyclopedia of Philosophy*: "Ethics"

Food Ethics? … it is all about the money Anonymous



SINTEF Energy Research, Department of Energy Efficiency

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2011 – 2012	Post-Doc at NTNU, *Energy efficiency in drying processes*
2007 – 2011	PhD at NTNU, *Study of high intensity, airborne ultrasound in atmospheric freeze drying.*
2002 – 2007	University of applied science, Konstanz Germany, Process and Environmental engineering, Diploma thesis: *Dimensioning of drying and conditioning unit for soybeans.*

SINTEF

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  - Close cooperation with Norwegian University of Science and Technology (NTNU)
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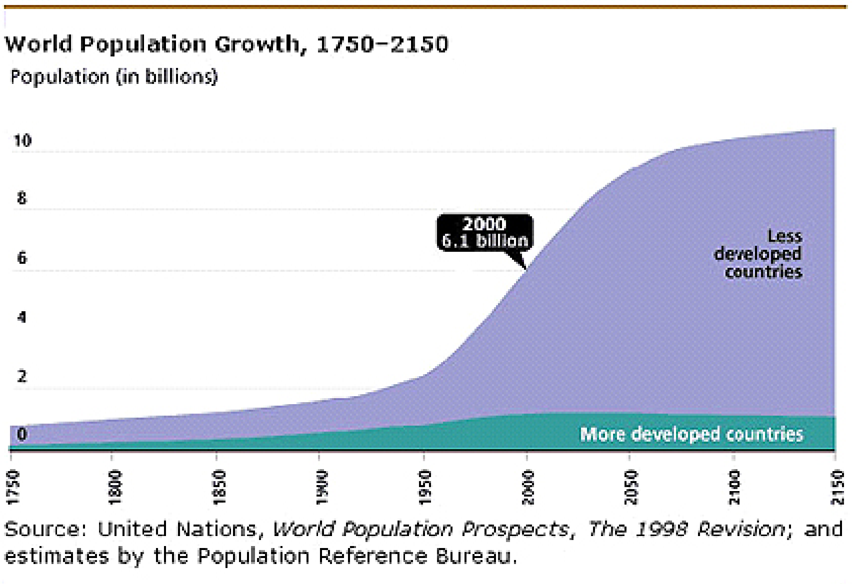
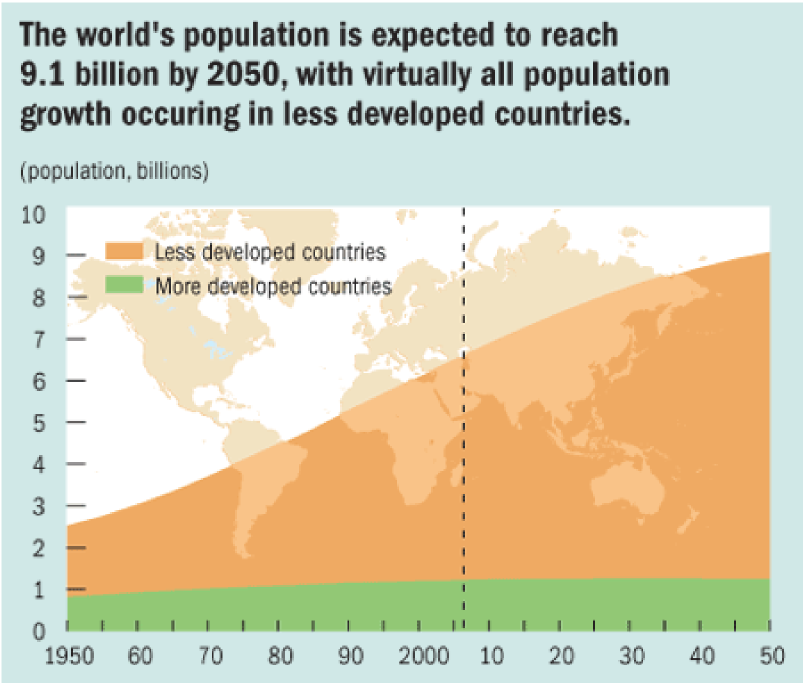
Agenda:

1. "Facts" about food and energy
2. Background for food and energy research
3. Some examples for higher food efficiency
    1. Concept of super-chilling
    2. Heat pump drying
    3. Superheated steam drying
4. Conclusion

1. Some "facts" about food and energy

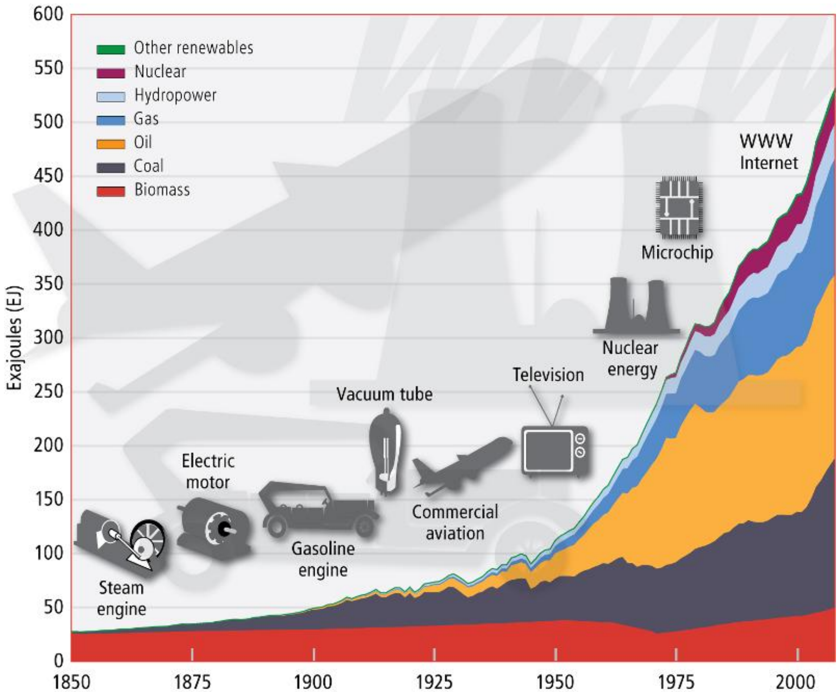
- World population of 13 billion by 2100
- Increase is the main "problem" for food security

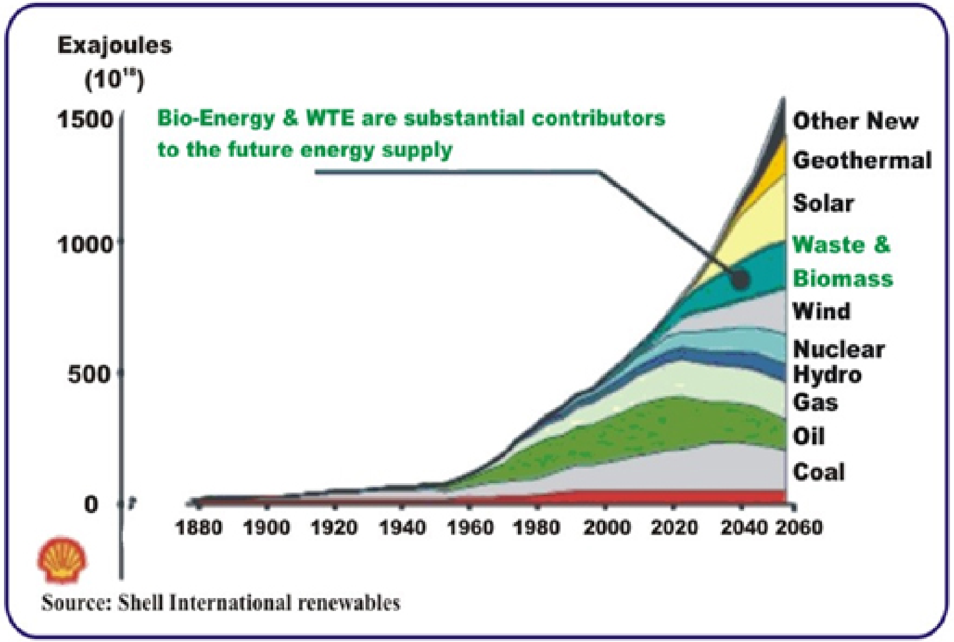




1. Some "facts" about food and energy

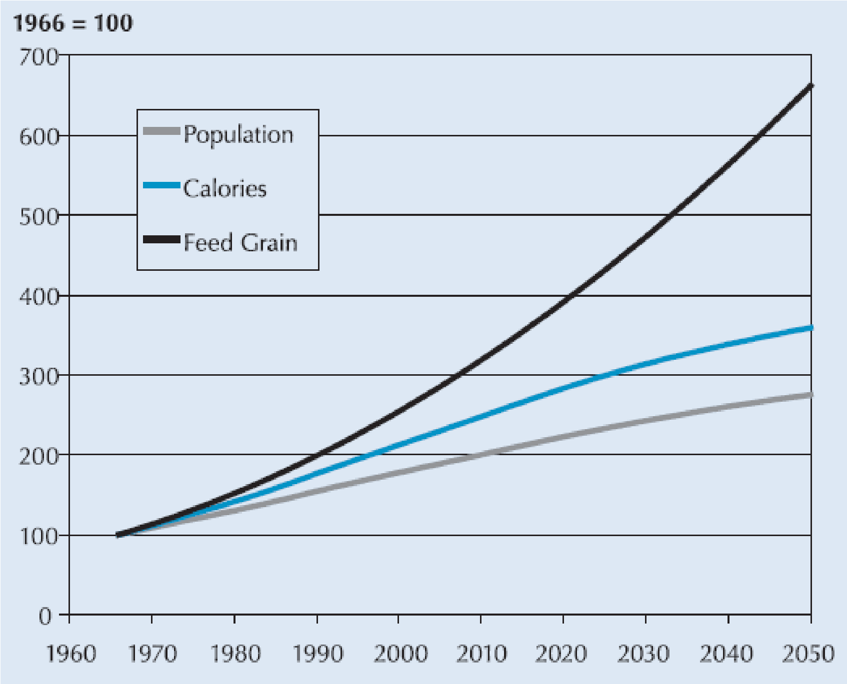
- Increased energy demand





1. Some "facts" about food and energy

- Food demand in the future
  - Increased demand for meat and dairy

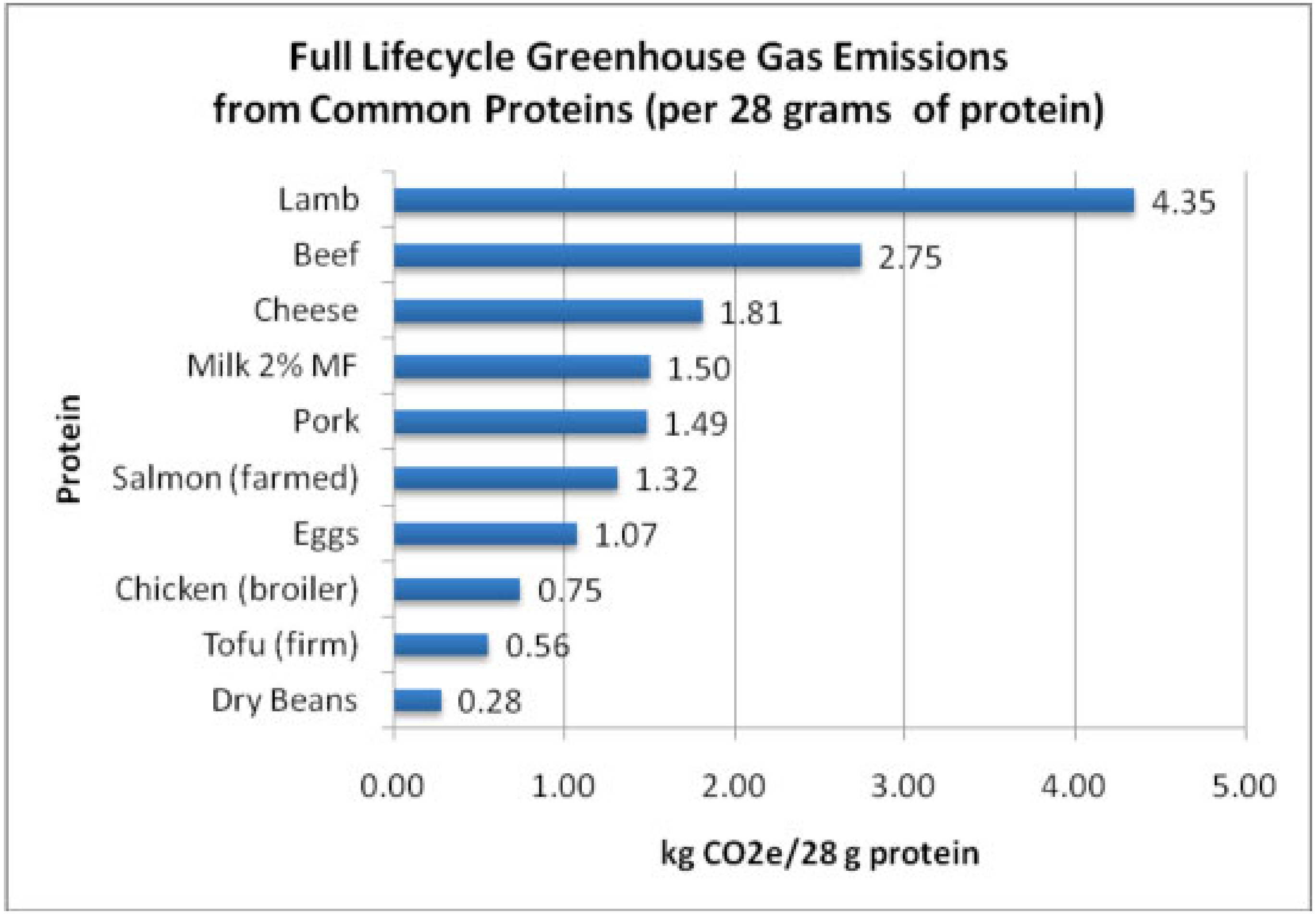


Three indicators of world food demand

Crop	1969	2009	Percent Increase
Sugar Cane	538	1,661	**209%**
Maize	270	819	**203%**
Wheat	309	686	**122%**
Rice, paddy	296	685	**131%**
Cow Milk	358	583	**63%**
Potatoes	278	330	**19%**
Vegetables	71	249	**251%**
Cassava	95	234	**146%**
Sugar Beets	217	227	**5%**
Soybeans	42	223	**431%**
Total	**2,474**	**5,697**	**130%**

Increase in World Production of Top Ten Major Commodities (1969 – 2009) (million metric tons)

1. Some "facts" about food and energy



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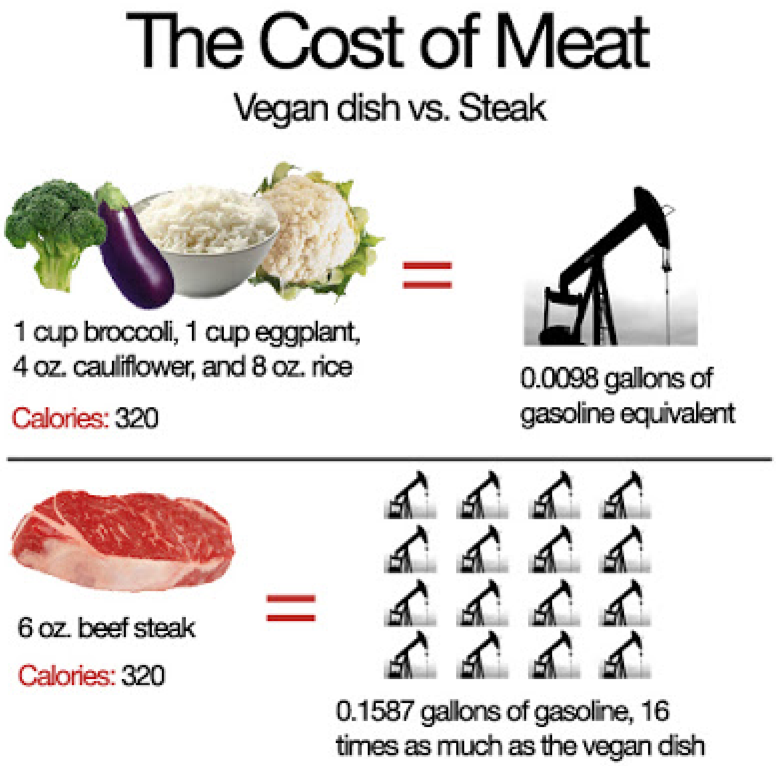


<u>Feed to food ratios:</u>

10 kg grain	→ 1 kg beef
4-5.5kg grain	→ 1 kg pork
2.1-3 kg grain	→ poultry meat
1.2 kg feed	→ 1 kg fish

1. Some facts about food and energy

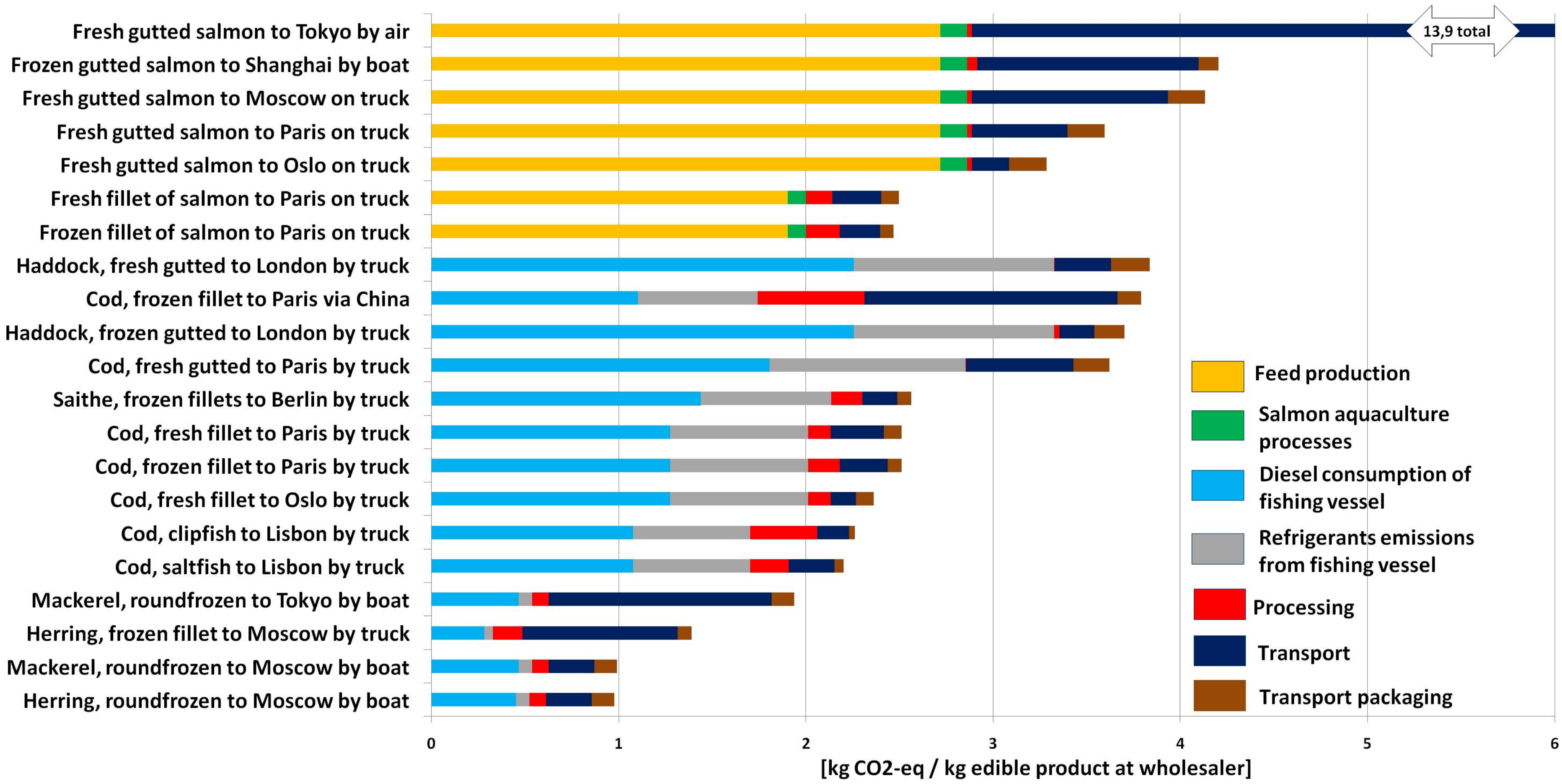
Table 1: List of Foods By Energy Required to Produce One Pound

Food	Energy (kWh) to Produce 1 Lb
Corn	0.43
Milk	0.75
Apples	1.67
Eggs	4
Chicken	4.4
Cheese	6.75
Pork	12.6
Beef	31.5

Table 2: Energy Efficiency of Various Foods (Measured as Food Calories / Energy Used in Production) [8]

Food	Calories / Lb	Energy Efficiency
Corn	390	102%
Milk	291	45%
Cheese	1824	31%
Eggs	650	19%
Apples	216	15%
Chicken	573	15%
Pork	480	8.5%
Beef	1176	4.3%

1. Some "facts" about food and energy

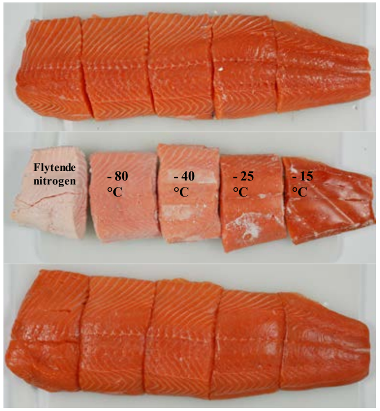


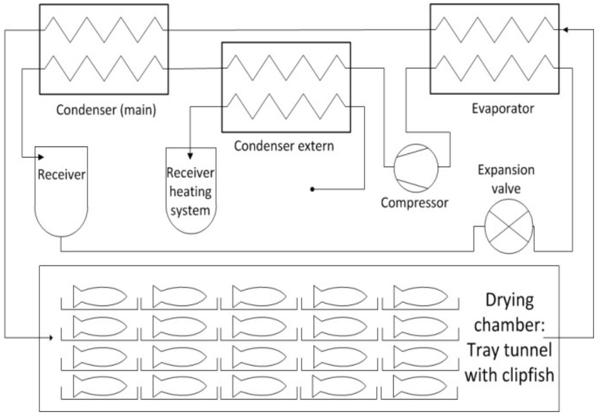
2. Background for food and energy research

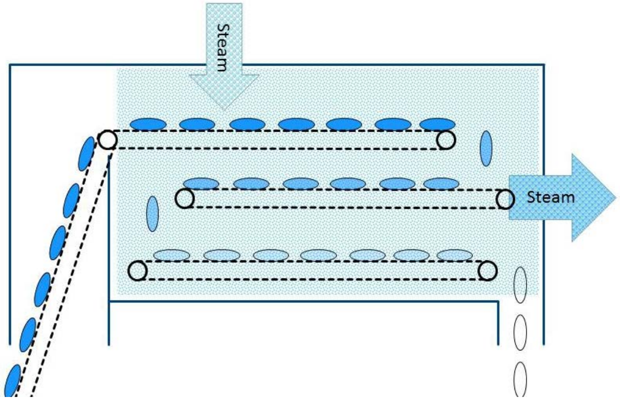
- Growing population → increasing demand and dependency for
  - Food (→ meat)
  - Energy (what is the future energy source?)
- Feed production stands for a large emission for green house gases
- Better usage of available food (and feed) sources
  - Food preservation will be a key element in this
    → drying vs. freezing
- Higher efficiencies, new technologies
- New food (and feed) sources
  - e.g. algae
- How to influence producers and consumers?
  → **Money (~ energy prices)**
  → **Legislative**

3. Some examples for higher food efficiency

1. Concept of super-chilling
2. Heat pump drying
3. Superheated steam drying

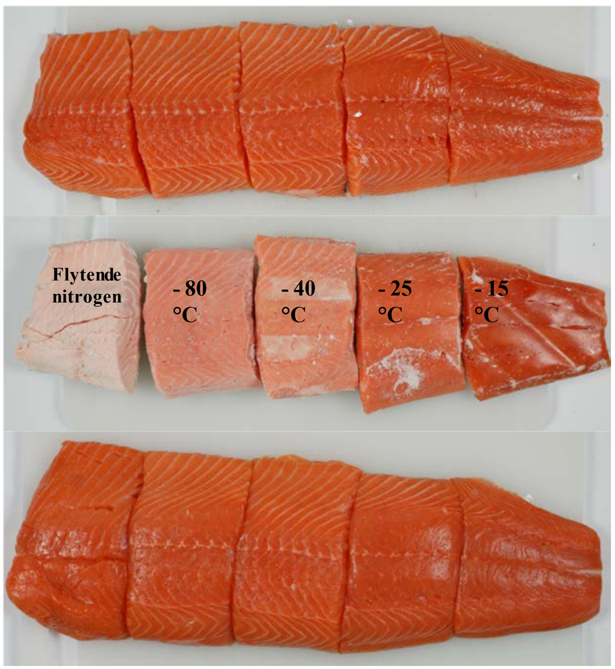


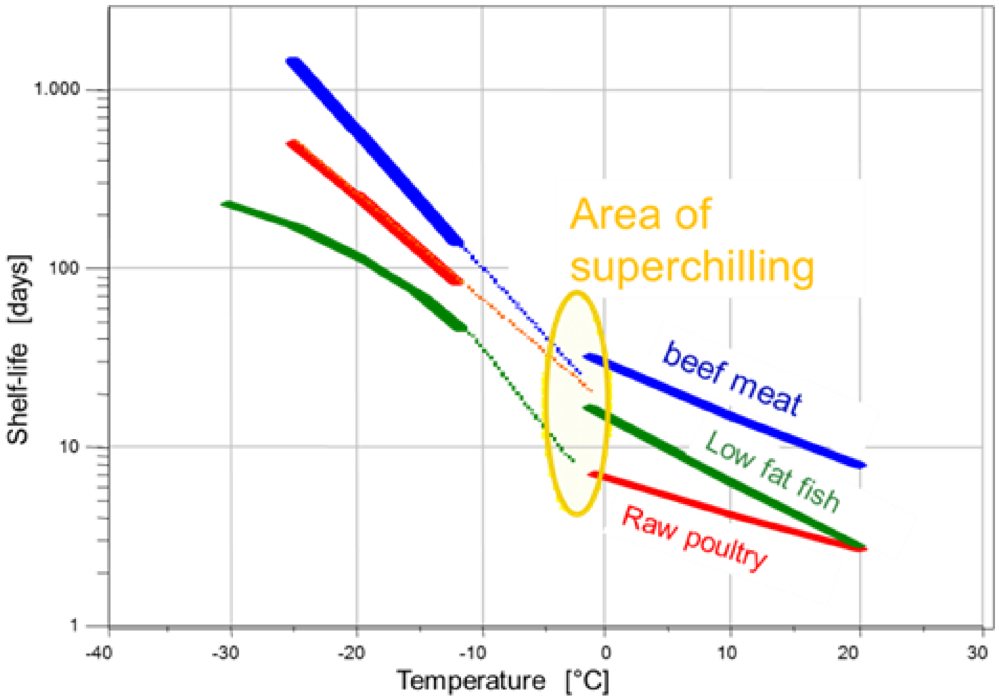




3.1 Super-chilling

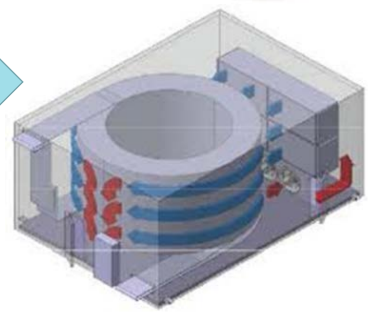
- Product temperature is lowered to just below initial freezing point, normally between -1 to -2 °C.
- Gives an ice content in product of 5-30 %.





3.1 Super-chilling: What is the process?

- Traditional chilling of fish, poultry and carcasses.
- Fast formation of ice. Shell-freezing and equilibrium in storage



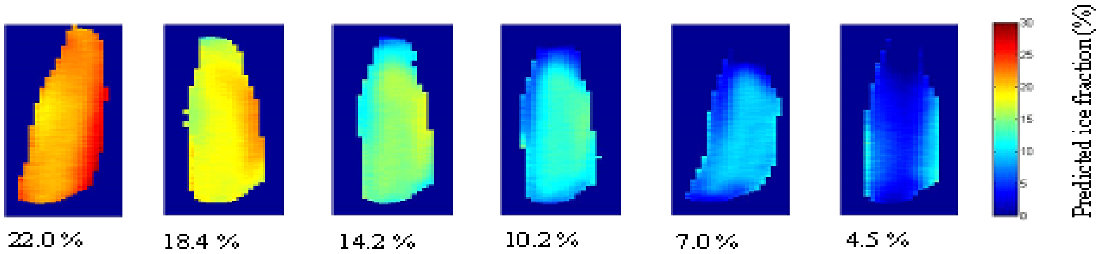
3.1 Super-chilling: advantages

- Prolong the shelf-life
- "fresh" quality
  - no significant difference in drip loss, color, pH, protein degradation and sensory
- Higher yield (+1.5% in fish fillet produciton)
- Less waste because of double shelf-life (today around 30% is lost in the food chain)
- Reduced demand of freezing
- No need of ice in fresh fish boxes during transport
  - around 20-30% of the transported weight is ice

Summer-
pork

3.1 Super-chilling: challenges and potenial

- More complex cold chain:
  - Shelf-life is a function of time and temperature
- Is it fresh or frozen? (consumer, regulation, …)
- Available technologies for shell-freezing
  - Calibration for each product
- Higher demand for temperature control during storage
- Short term: High potential for meat/poultry- and fish industry.
- Longer term: For consumers – cold chain
- **Industrial potential:**
  - Reduced demand for freezing, more sold as fresh
  - Stock-up before campaigns.
- **Consumer potential:**
  - Reduced waste
  - Longer shelf-life



3.1 Super-chilling: the FRISBEE project

http://www.frisbee-project.eu/

3.2 / 3.3 Drying: Why is it important for Food Ethics?

Estimates evaluate that air drying is responsible for **15-25% of the overall global industrial energy demand** in developed countries and efficiencies in food/feed drying can be as low as 10%, with 35-45% being the average.

Mujumdar, A., 2007. An overview of innovation in industrial drying: current status and R&D needs. Transport in porous media 66, 3-18.

3.2 Heat pump drying

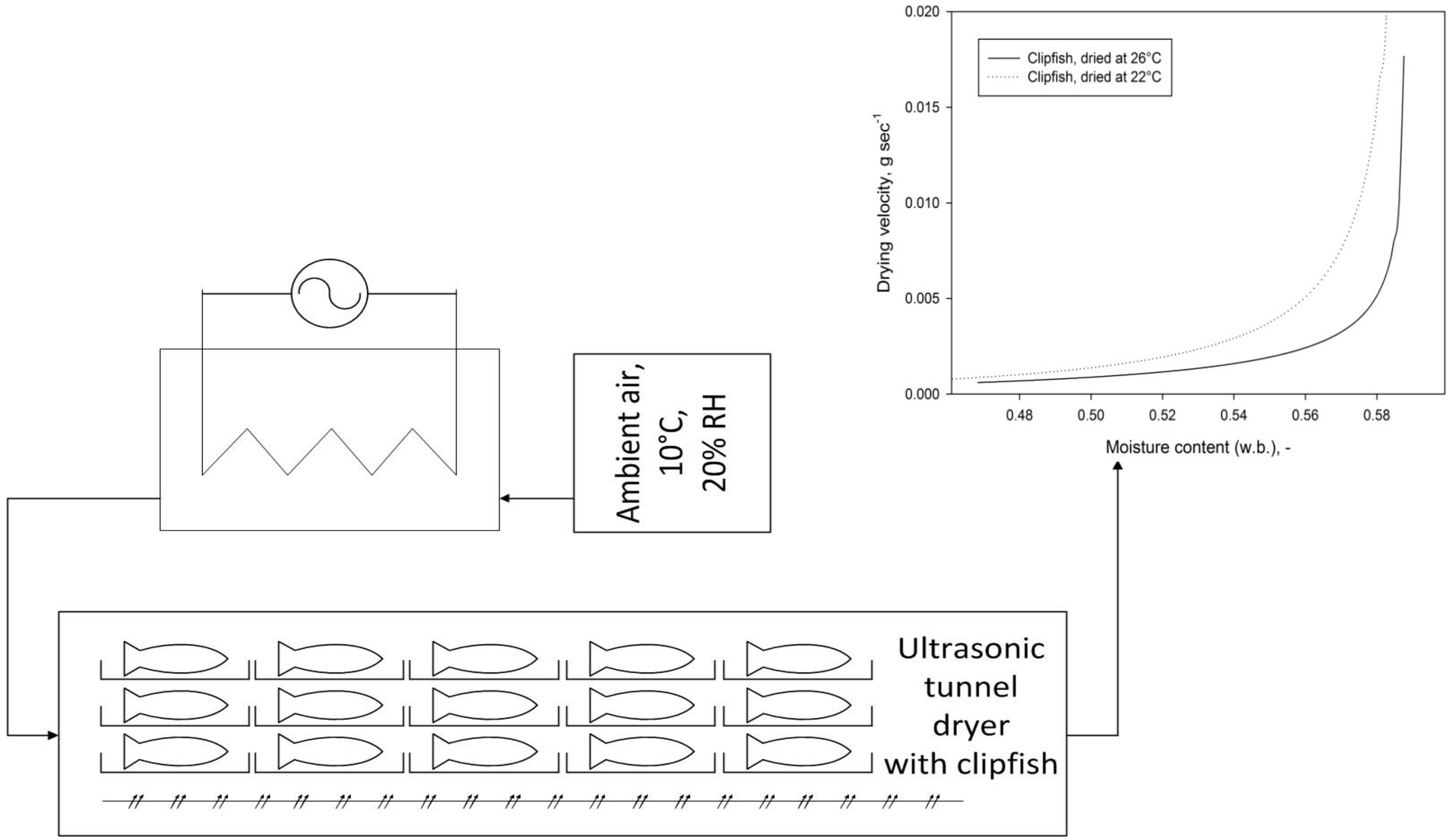
- Drying is the oldest and most important method for food preservation
- Convective drying is normally air drying
  - → delivers heat for evaporation
  - → removes water in the form of humidity
- Convective drying is mass transfer controlled
- Every product has different drying characteristics (quality vs. time, temperature,…)
- Latent heat of evaporation ≈ 2250 kJ/kg ≈ 0.63 kWh/kg (ideal)

  real: ≈ 2700 - 6000 kJ/kg ≈0.75 – 1.6 kWh/kg

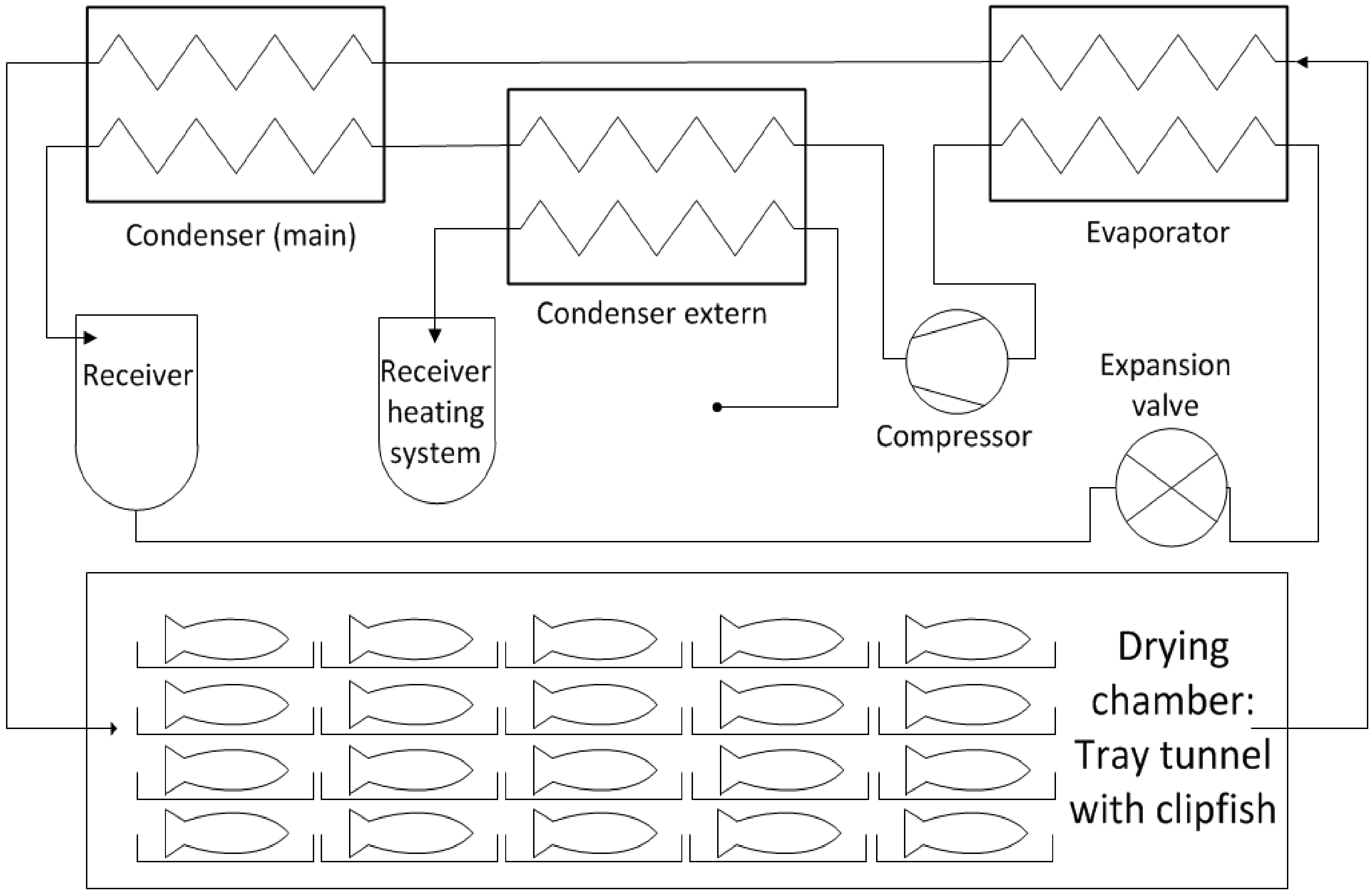
Table 1
General comparison of heat pump dryer with vacuum and hot air drying [15].

	Hot air drying	Vacuum drying	HPD drying
SMER (kg H_2O/kWh)	0.12–1.28	0.72–1.2	1.0–4.0
Drying efficiency (%)	35–40	⩽70	95
Capital cost	Low	High	Moderate
Running cost	High	Very high	Low

3.2 Heat pump drying: "conventional" drying



3.2 Heat pump drying



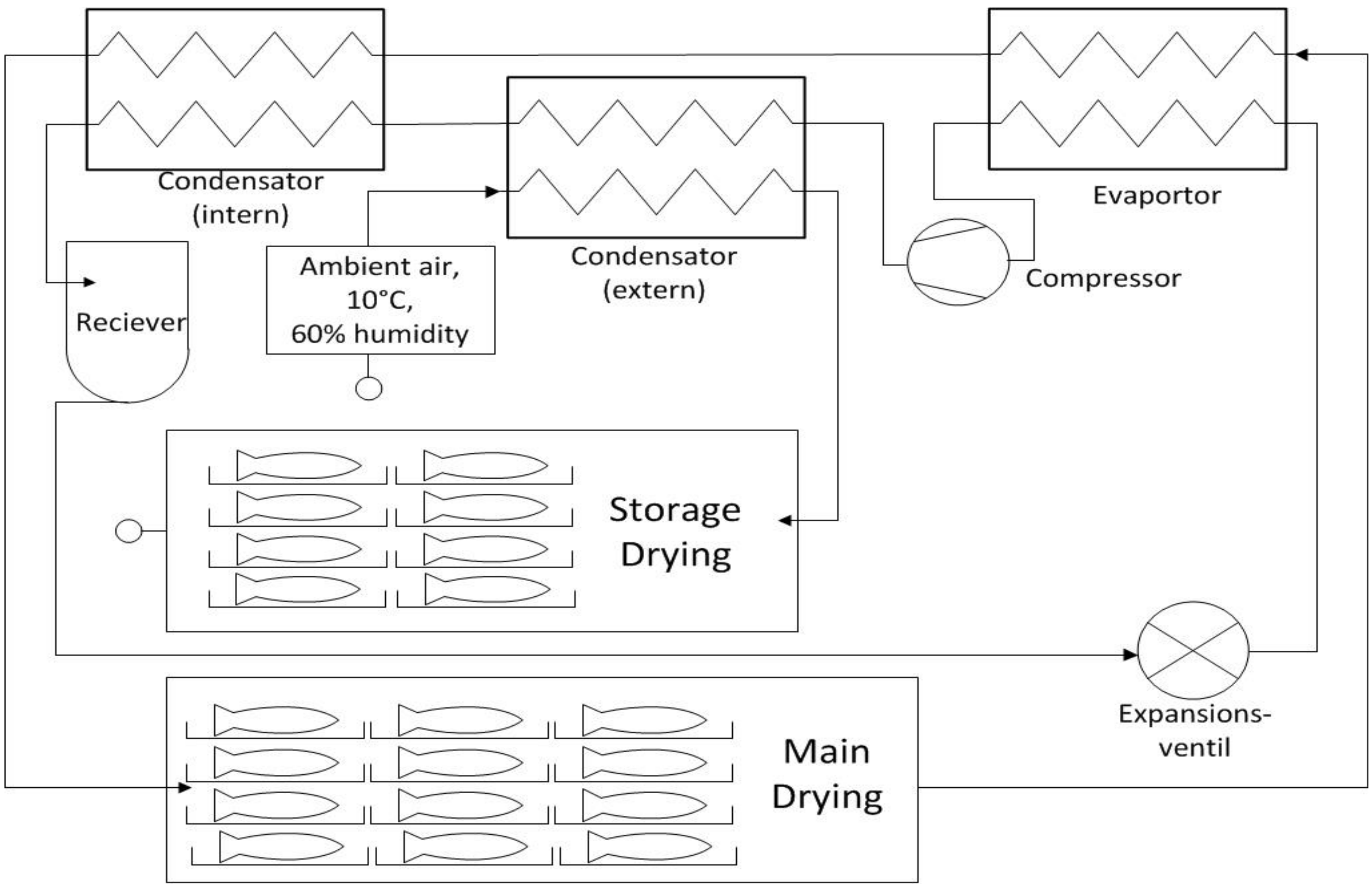
3.2 Heat pump drying

- 75% of the drying energy can be recovered in HPD (compare to HAAD)
  - Production costs
  - Energy consumption
- Falling SMER as a result of the reduced latent heat towards end of drying is reducing the energy efficiency

	Production costs
HPD	222.8 kWh per ton
HAAD	973.8 kWh per ton

- Energy prices are not taken into account
  - 1:4 ratio between fossil fuel and electric

3.2 Heat pump drying: with storage drying



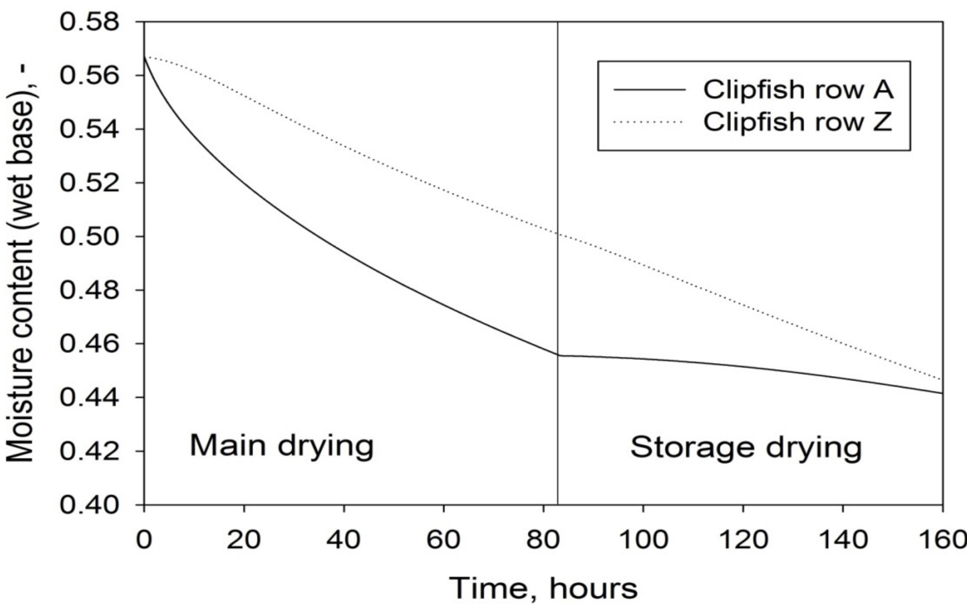
3.2 Heat pump drying: with storage drying

	Production costs
Main + Storage Drying	133.6 kWh
HPD	222.8 kWh per ton
HAAD	973.8 kWh per ton

→ Efficient enough energy supply at for the final drying stage

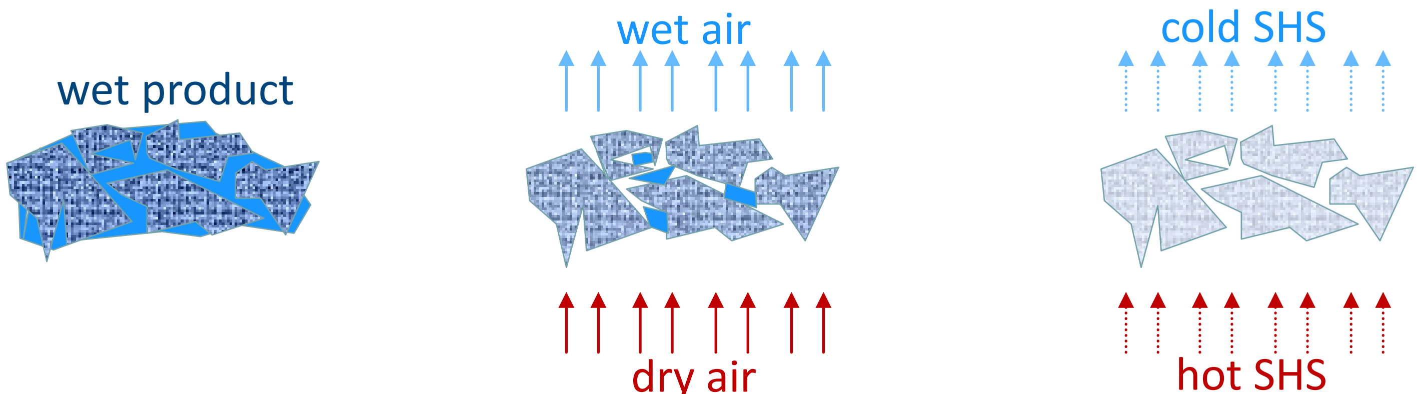
→ Control the drying process according to drying velocity

- Increase of productivity by 40%
- Increase of drying time from 6 to 7 days
- 40% more energy efficient

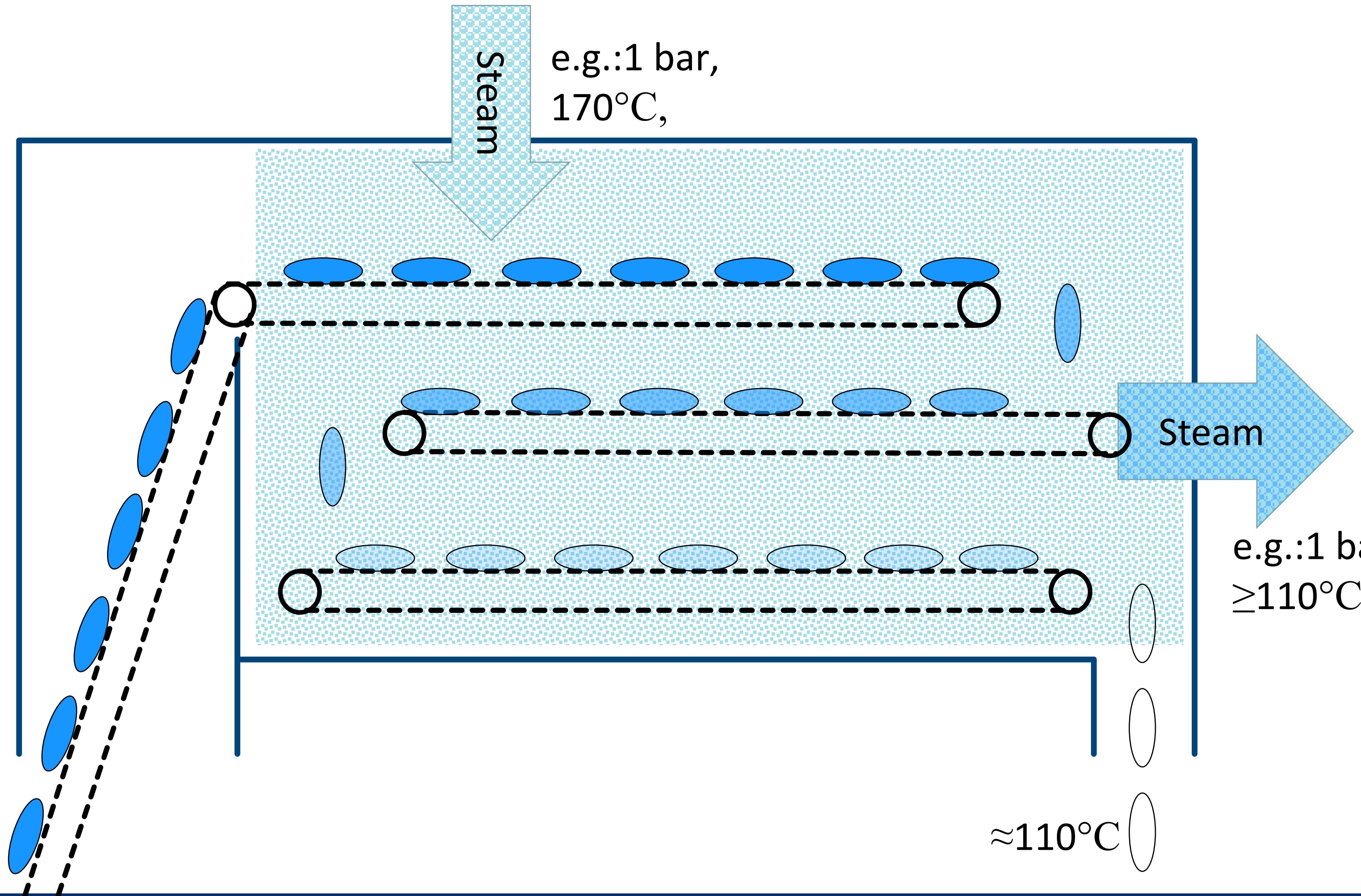


3.3 What is Superheated Steam Drying (SHSD)

- Convective drying, using superheated steam as drying agent
  - Heat for evaporation is supplied from the steam
  - Evaporated water (= steam) is removed from the product and added to the drying agent
- Steam is a good heat carrier (heat/mass transfer coefficient almost double compare to air)
- Low viscosity than air (→ penetrates the products better)
- Steam is condensable (air not) → treatment of exhaust gas
- Steam has a low density 0.6 kg/m^3 t (lower than air, important for design)
- Superheated steam contain no oxygen (air) → inert gas (no risk for fire/explosion, low oxidation)
- Important to avoid condensation



3.3 Design of a SHSD at atmospheric pressure



3.3 Components air vs. superheated steam drier

Component	**Air Drying**	**Superheated Steam Drying**
Drying chamber at ambient pressure	Yes	Yes (smaller → footprint)
Product transport	Air-conveying	Elevator/Conveying
Drying agent	Ambient air	Superheated steam → generator + water
Energy	Oil/gas/electric	Oil/gas/electric
Pre-treatment of product	-	Pre-heating (recommended), via extruder
Transport of drying agent	Fans	Special fans (compact)
After-treatment of drying agent (open system)	Air filter + fans (biofilter)	Condenser → small volumes

3.3 Advantages of Superheated Steam Drying

- Around 20% more energy efficient than air drying
- SHS above 100°C is a non-visible, condensable, light gas which is capable to evaporate water very efficient
- Pasteurization and sterilisation is possible within the drying process
- SHS at atmospheric pressure has no risk for explosion (etc.)
- SHS is inert drying (comparable to vacuum drying, no oxidation)
- SHS can also be used for conveying without risk of condensation and e.g. salmonella growth
- Flash-Off from extruding can be used for drying → conveying (IP)
- SHS can be condensed out of the system (no air filtration with forced ventilation etc.)
    - Accumulation of volatiles
- Shorter or smaller drying chambers (footprint)
- Drying energy (Excess superheated steam) can be used as energy source in other process steps (e.g. conveying,…)
- Independent on ambient air conditions

3.3 Superheated Steam Drying: Possibilities for vapor re-compression

System:

→ **evaporation of 2.5 tons/hour (90°C) per extruder (≈1.6 MW)**

EXAMPLE:

→ **1600 kW drying system** produces at least 1600 kW excess heat at low temperature
  - → How to use this energy? → energy demand for this excess energy in other processes is normally not fitting (PINCH analyse)
  - → Possible to sell energy?
  - → But even if the excess energy is used/sold the drying process still needs 1600kW

→ with **re-compression** of the excess superheated steam it is possible to recover this energy back into the drying process
  - → 1600 kW drying systems **would need around 500 kW** compression energy (estimated)
  - → Excess energy would be 500 kW at higher temperature levels
  - → Efficiency of the drying system is significant increased

3.3 Conclusion and Potential of SHS Drying

- **Fast and energy efficient drying process**
  - for products that can handle/require drying temperature above 100°C
  - Specific energy consumption around 2500 kJ/kg ≈ 0.7 kWh/kg

  → Less drying related CO_2 emission
- Suitable for pet-food (other products: wood, sludge, coal, beet pulp, lumber, peat, paper and tissues, snack products, products dried close to 100°C)
- Possibility for pasteurization / **sterilisation**
- SHS creates an sterile/aseptic system
- Inert drying → no oxidation → **high product quality**
- Exhaust gas is easy to handle (condensation)
- **Possibility for energy recovery with turbo-charger-compression approach**

  → Vapour re-compression **<1000 kg/kg ≈ 0.25 kWh/kg**
- No risk for fire or explosion
- Focus on systems from **100 kW to 1000 kW**
- Focus on atmospheric pressure systems → cheaper → conveying possible

4. Conclusions and future challenges:

- Increasing demand for:
  - High-quality food and feed
  - Reliable, "green" energy

  → Increased prices (?)
- Meat/Fish industry is associated with high amount greenhouse gases (~energy)
  - New food (and feed) sources
- Better usage of available food (and feed) sources

  → Food preservation will be a key element
- Use of "new" technology which is more energy efficient
  - Food/feed industry is quite conservative towards innovations
  - Payback time should be short (→ problematic)
- Food processing demands thermal energy

  → Heat pumps (European directive on use of renewable energy) for upgrade to premium energy

Thank you for your attention!

→ Questions? No?

→ Let's do it !!!