Institute of Biological Engineering

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Recent Developments in Biomass Densification Technology

Recent Developments in Biomass Densification Technology

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Introduction

- Densification of biomass is a process of reducing the bulk volume of the material by mechanical means for easy handling, transportation and storage.
  - Mechanical press- **Pellets**, tablets, cubes

Densification Process

5 lbs/ft^3

40 lbs/ft^3

Advantages of Pelletization

Uniform in size, density and moisture content

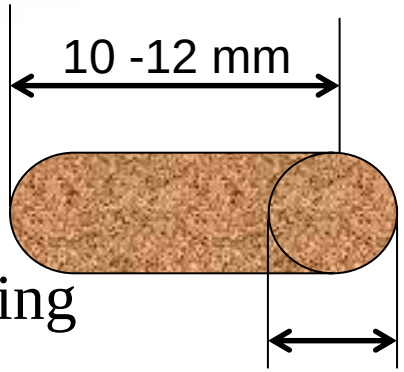
Moisture content: 6 to 8% (wb)

Easy to transport, convey and feed using the existing systems

High heating value: 18.5 GJ/t

Export commodity - >70% pellets produced are exported to Sweden, Denmark, Netherlands, USA

Domestic heating, animal bedding, power generation, biofuels production



Export demand = 3-5 million t/y

Samson et al., (2005); Melin, (2006)

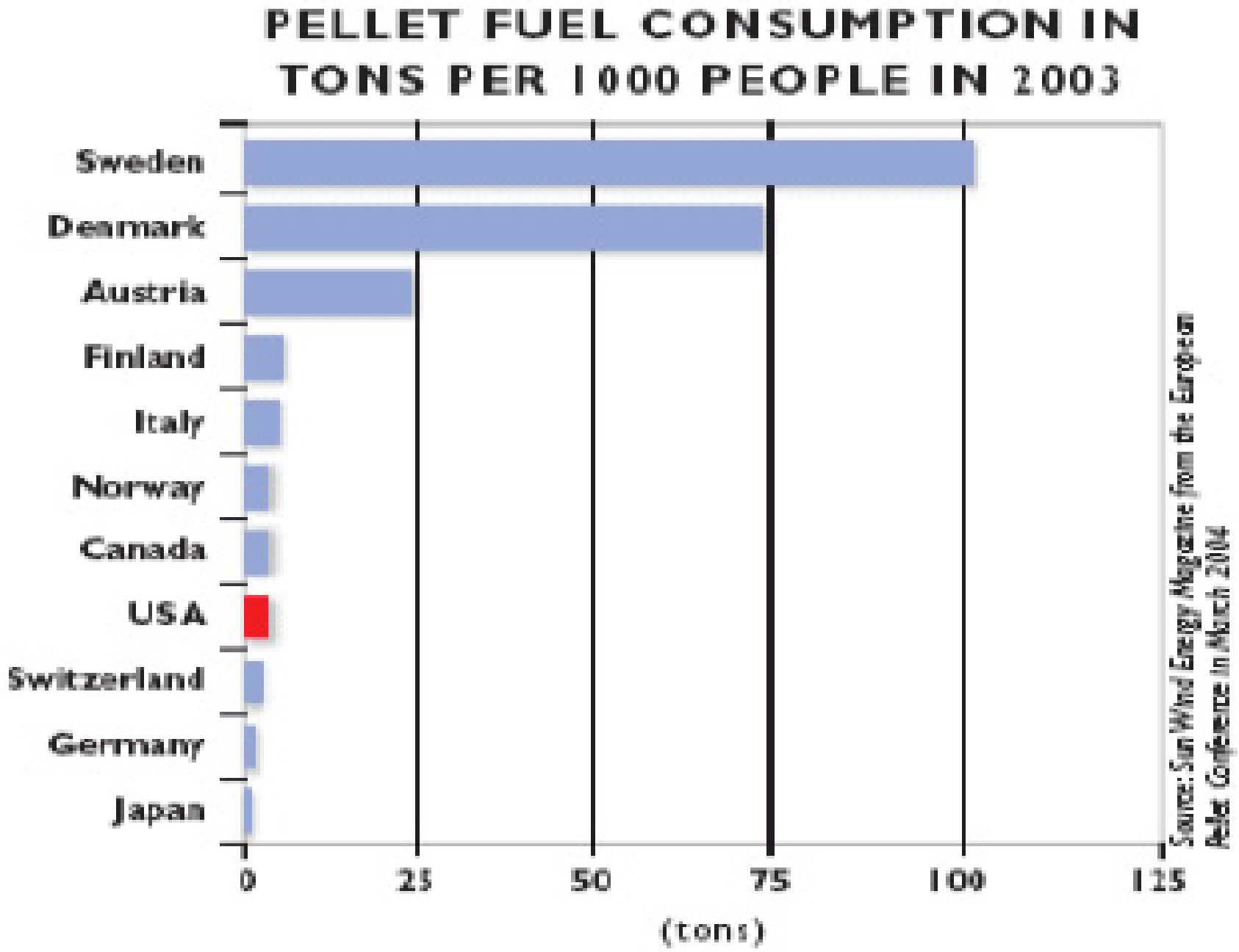
TRANSPORTATION AND STORAGE

Bulk density of biomass and its effect on transportation and storage requirements*

Form of biomass	kg/m^3	Weight per load (t)	No. of loads	Area (ha)
Loose	45	2.0	2469	2.22
Chopped	75	3.4	1481	1.33
Ground	100	4.5	1111	1.00
Baled	200	9.0	556	0.50
Cubed	400	18.0	278	0.25
Pelleted	600	27.0	185	0.17

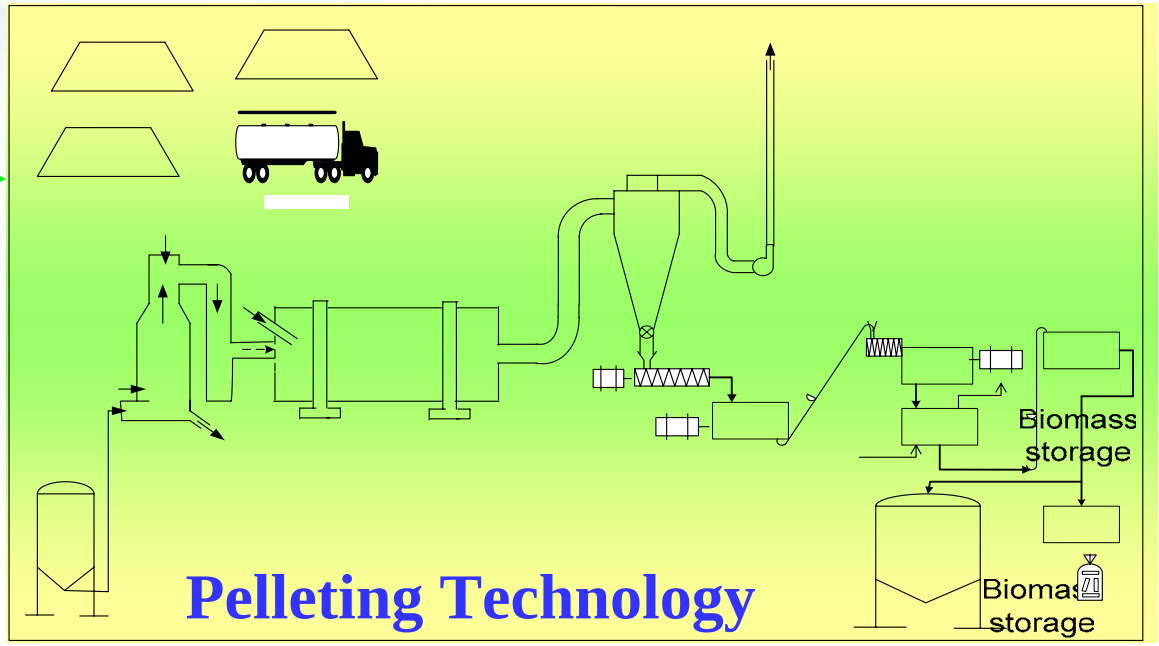
*Biomass quantity 5000 t. Each load size 45 m^3 · Storage height 5 m

Sokhansanj et al. 2005


PELLET FUEL CONSUMPTION IN TONS PER 1000 PEOPLE IN 2003
Sweden
Denmark
Austria
Finland
Italy
Norway
Canada
USA
Switzerland
Germany
Japan
0
25
50
75
100
125
(tons)
Source: Sun Wind Energy Magazine from the European Pellet Conference in March 2004

Biomass Densification Process

- Loose material (~5 lb/ft³)
- high moisture biomass,
- non-uniform particle sizes,
- susceptible to spoilage,
- low energy content



High energy density
No off gas emissions during storage
Hydrophobic in nature, low grinding energy
No fines in the final product

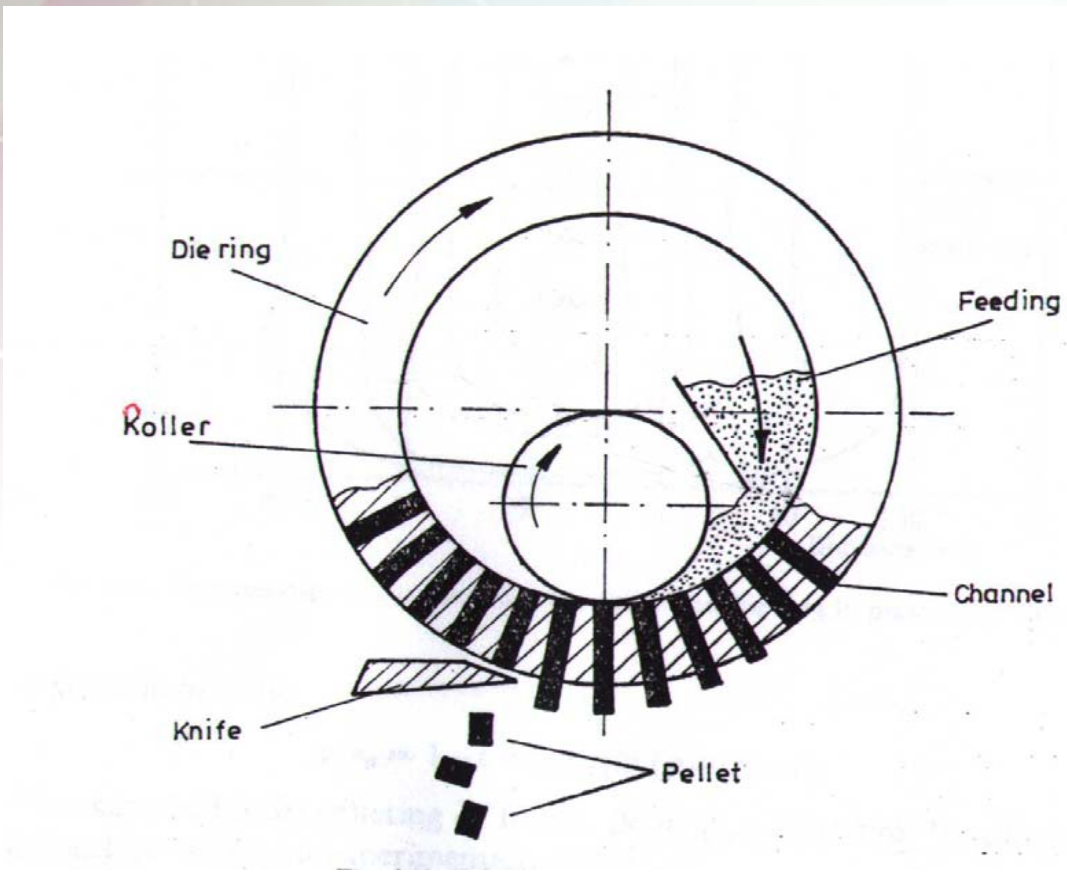
- High density pellets (~40 lb/ft³) ,
- Low moisture content, uniform size
- Easy to store and
- transport to long distances

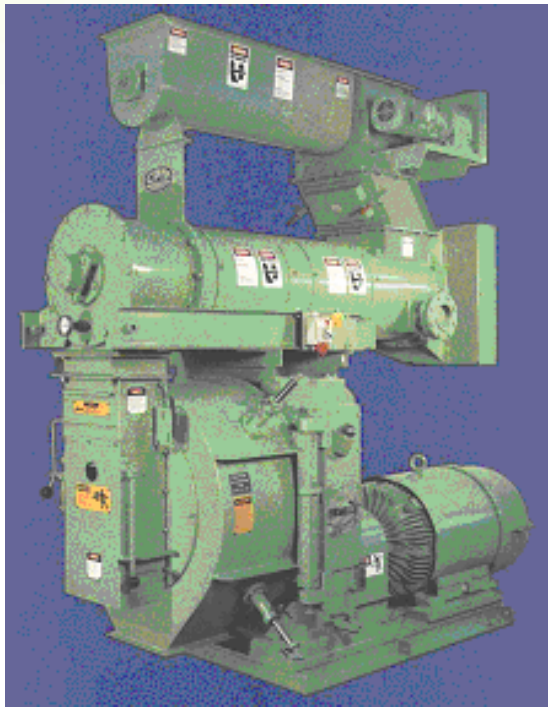
Bio-pellets

Proposed developments in the biomass densification area

1. Modification of pellet mill design
2. Pretreatment of biomass – steam treatment/ steam explosion of biomass
3. Thermal pretreatment of biomass – torrefaction process
4. Mixing of feedstocks – Low lignin and high lignin materials
5. Additional of binders – starch-based binders, plastic wastes, bio-oil, black liquor and lignin
6. Granulation/agglomeration of biomass using liquid binders

Existing pelleting process

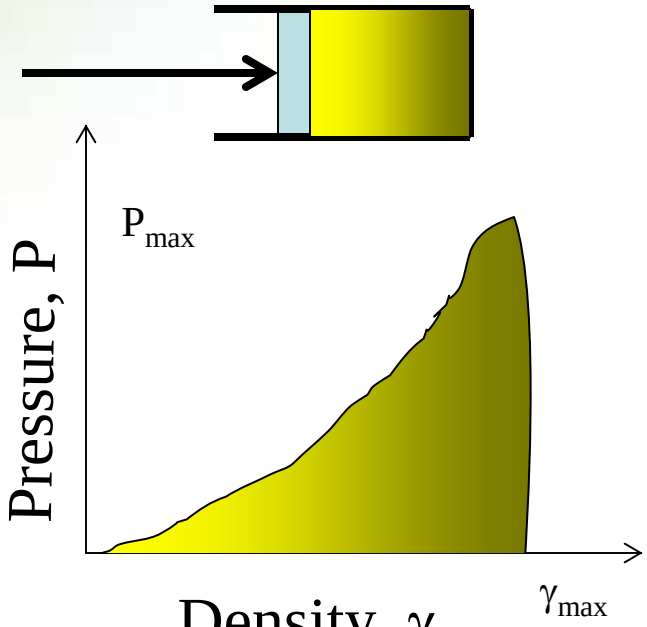




80-100 kW/tonne power requirement

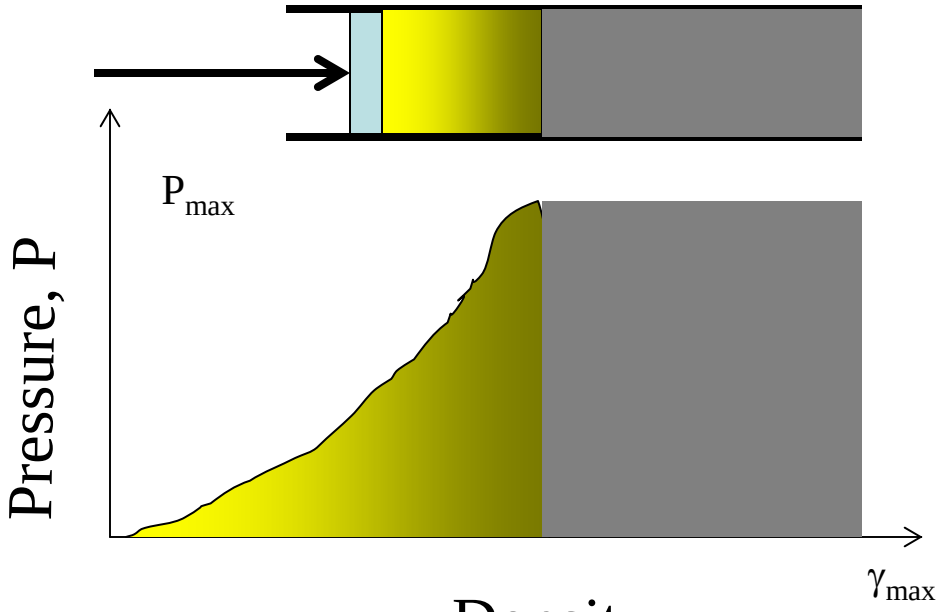
Energy (work) to compact biomass in open-end and closed-end die pellet mills

Closed-end die



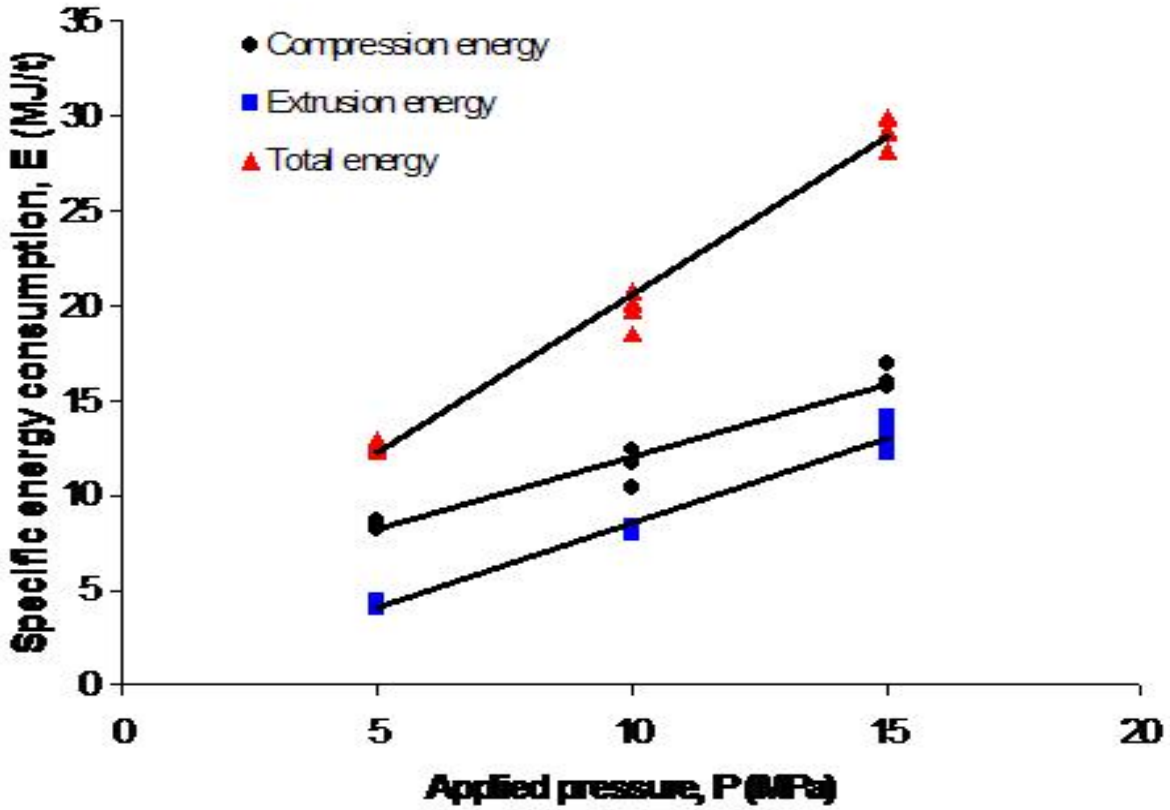
$$W = \int_{\gamma_0}^{\gamma_{max}} P d\left(\frac{1}{\gamma}\right)$$

Open-end die



$$W = \int_{\gamma_0}^{\gamma_{max}} P d\left(\frac{1}{\gamma}\right) + \frac{P_{max}}{\gamma_{max}}$$

Pellet Energy Model



More than 60% of the total energy is spent to extrude the pellet.

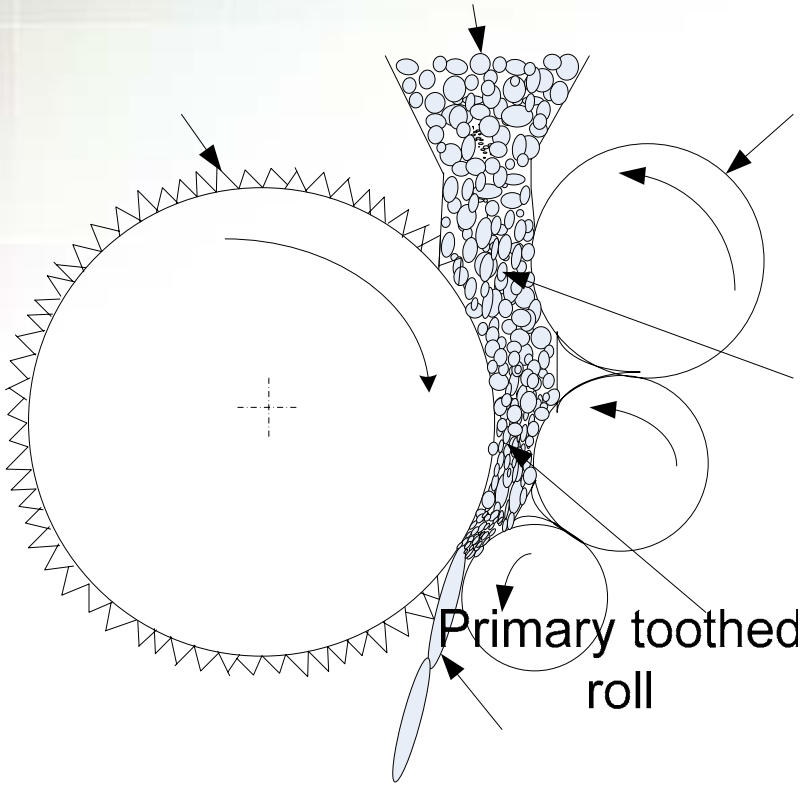
Pellet mill should be modified to reduce the extrusion energy

Specific energy (kWh/t)

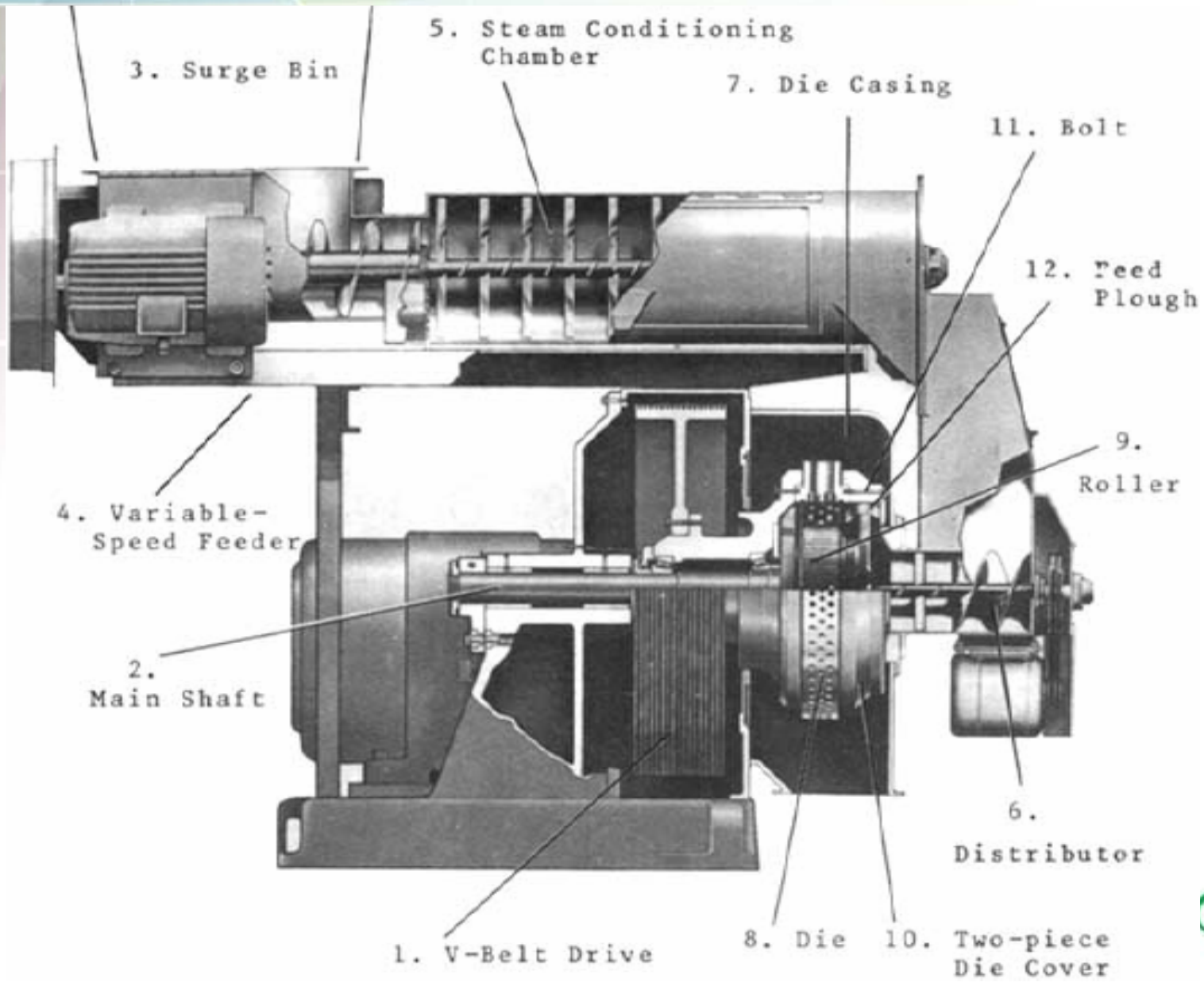
Straws - ~85

Wood pellet – 40 to 85

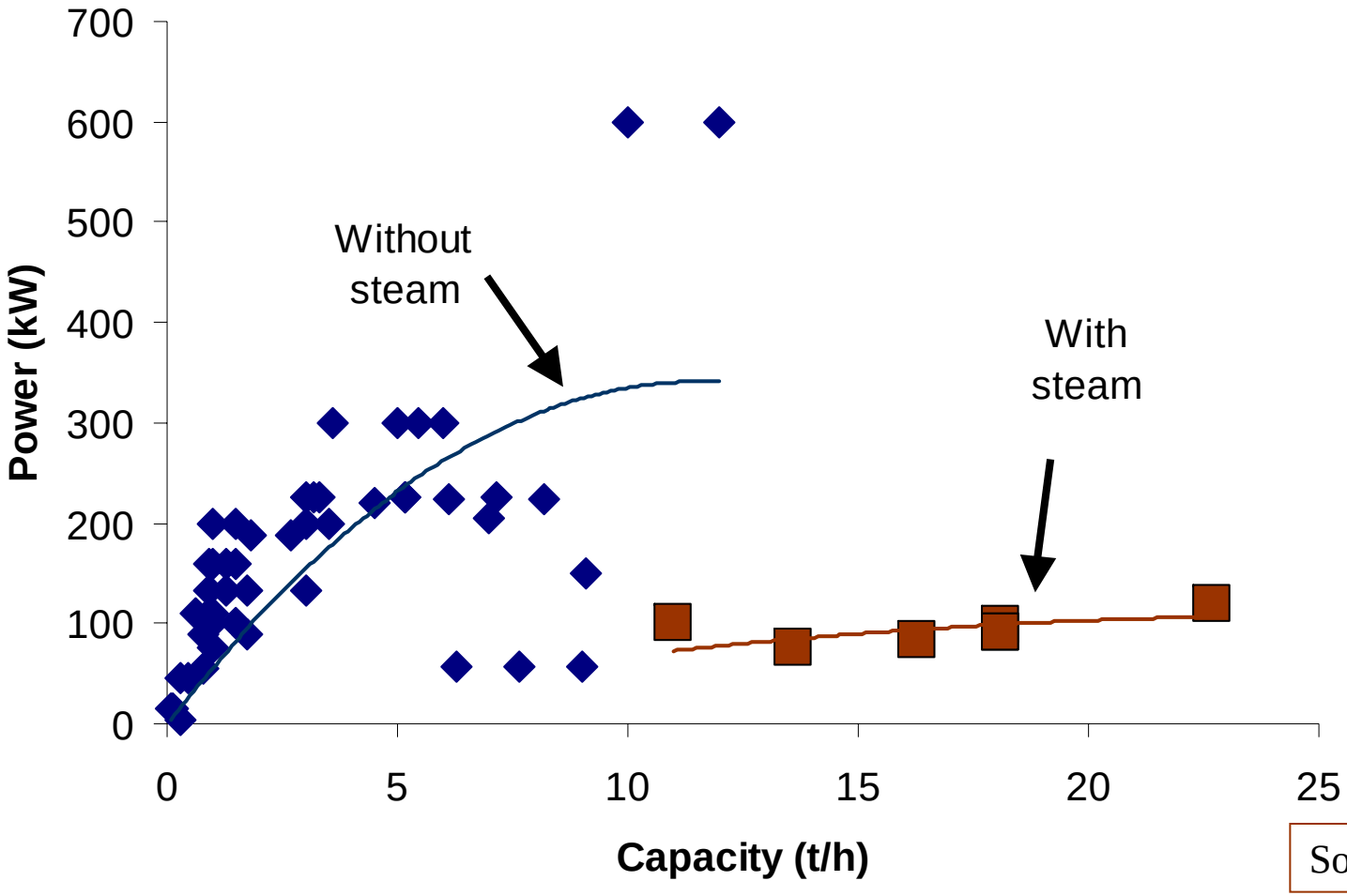
Conceptual design of new roller compactor for biomass densification



Steam conditioning during pelleting

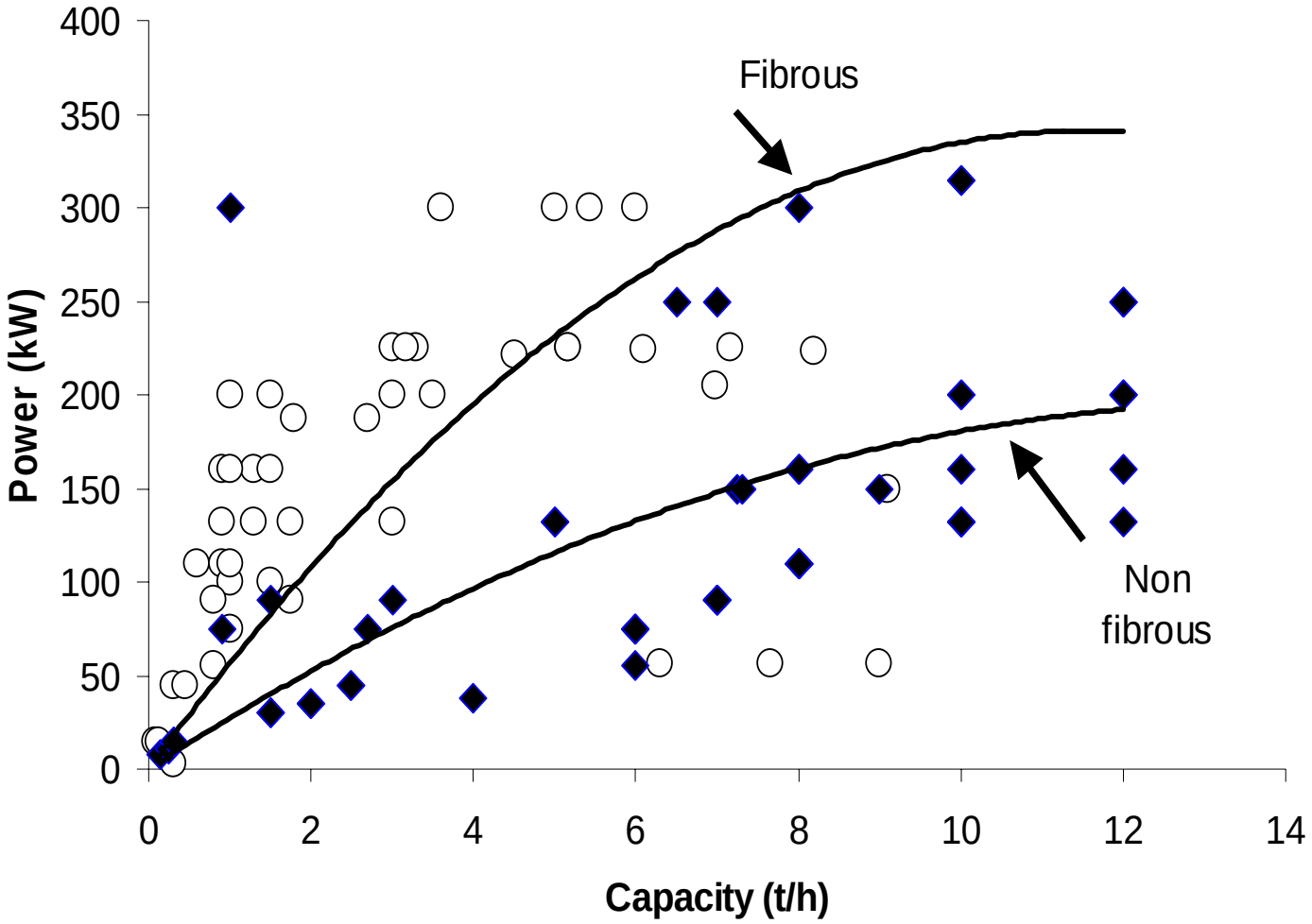


Effect of steam treatment on power requirement for densifying biomass



Source: Hausmanis (2003)

Power vs. capacity for pelletizing biomass and animal feed



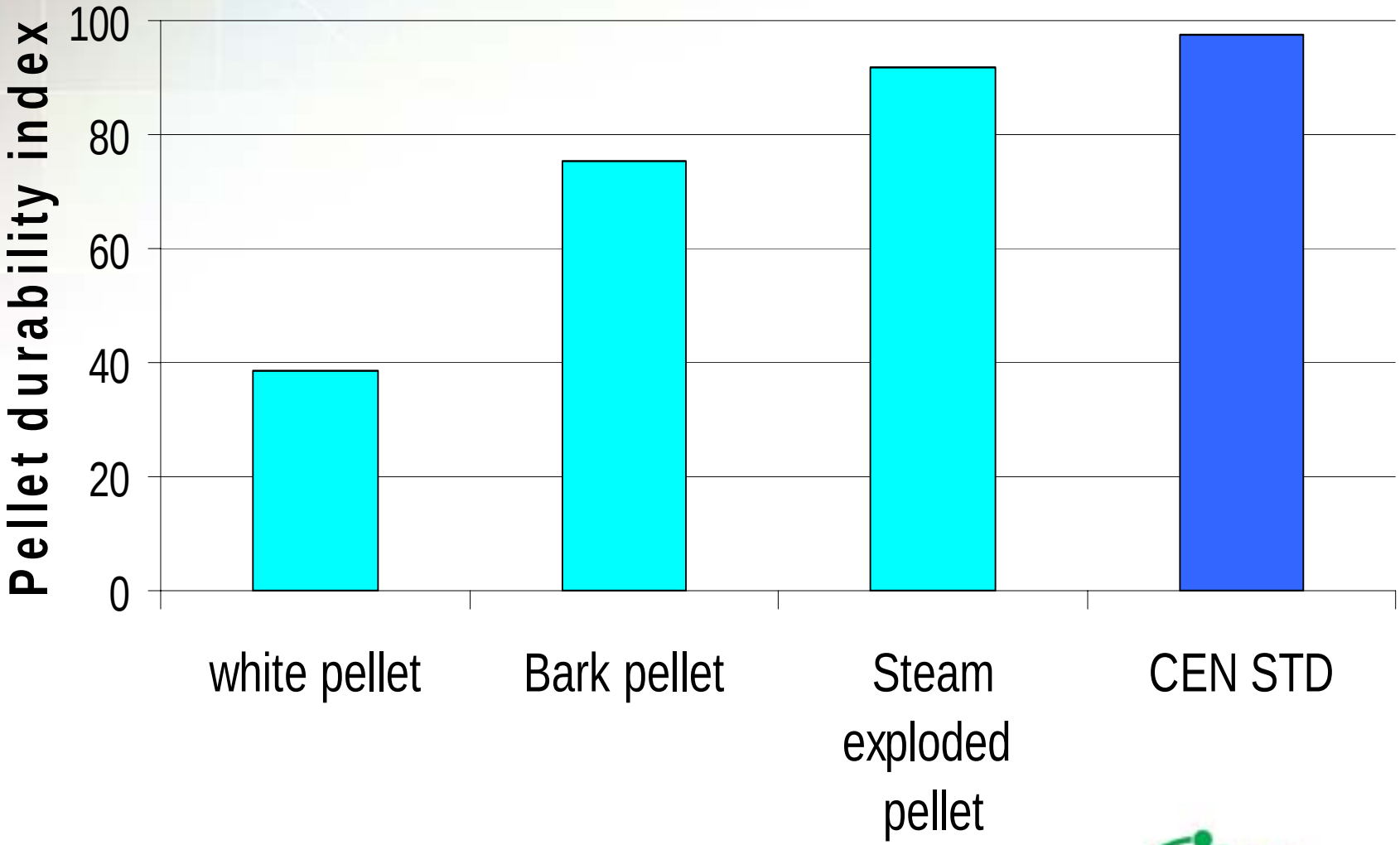
Source: Hausmanis (2003)

Comparison of white pellet vs steam exploded pellet properties

Pellets	M. C., % wb	% fines	L, mm	Pellet Density, kg/m^3
White	3.7(0.1)	12.5	18.6(2.2)	1099(33)
Bark	6.6(0.1)	1.5	32.9(8.3)	1167(47)
Steam exploded	**1.5**	**0**	**34.9 (2.9)**	**1347(19)**
CEN STD[1]	<10	1-2	<30 -35	

[1]**Source: Alakangas et al. (2006), European committee for Standardization**

Pellet durability



Torrefaction Process

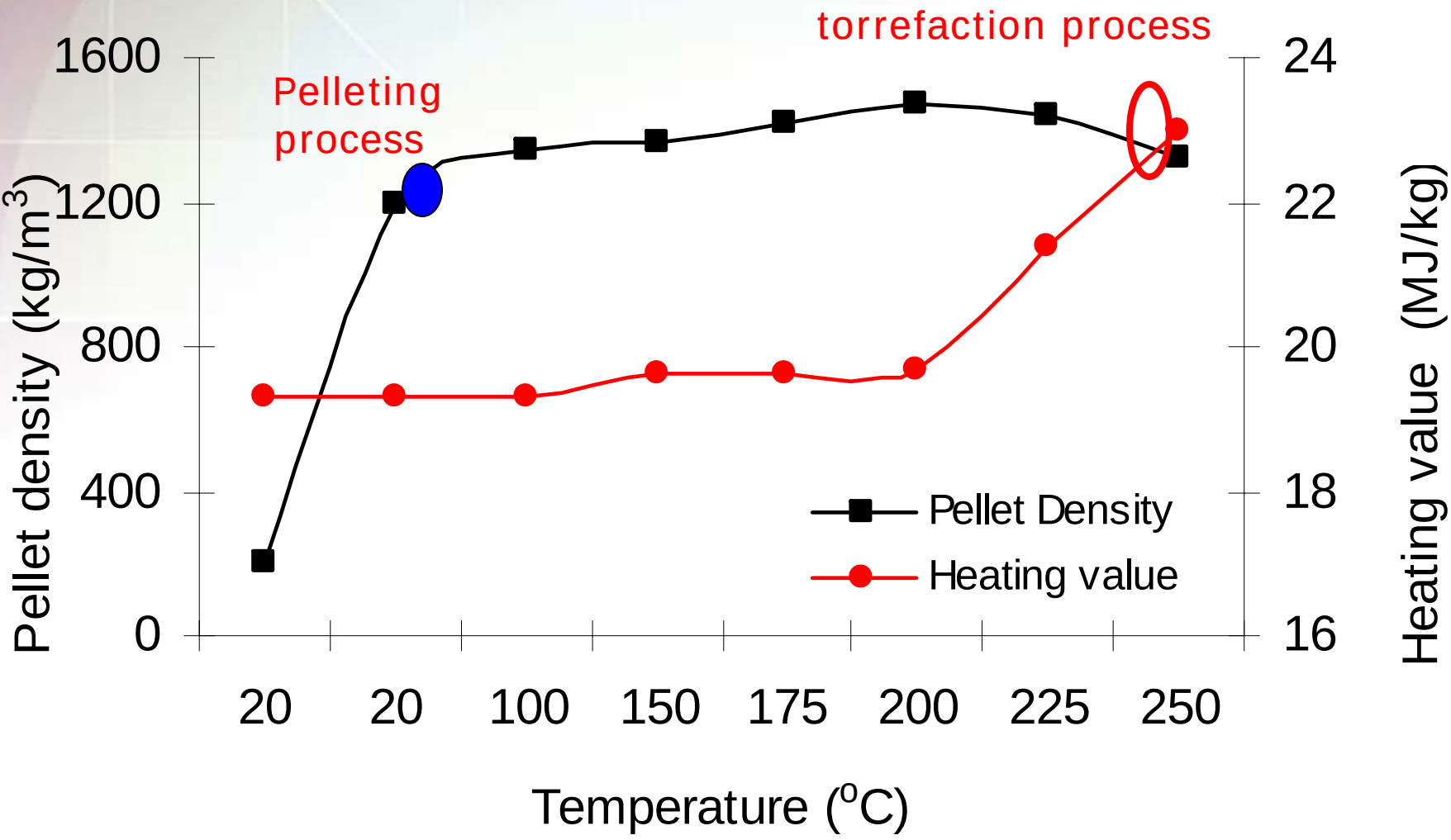
- Torrefaction – Slow thermal (heat) treatment of biomass from 200-300^{o}C in the absence of air (oxygen)
- Mild or slow pyrolysis process, roasting etc.
- The thermal treatment yields a solid product with 70-80% of the original weight and 90% of the original heat content, called “torrefied biomass or Biocoal”
- The process removes the smoke forming and highly reactive compounds from biomass
-

$$\text{Biomass} \xrightarrow{\text{heating}\,(200-300^{o}\,\text{C})\ \text{without}\ O_2} \text{Biocoal} + CO + CO_2 + H_2O + \text{acetic acid etc.}$$

Pellet Properties Comparisons

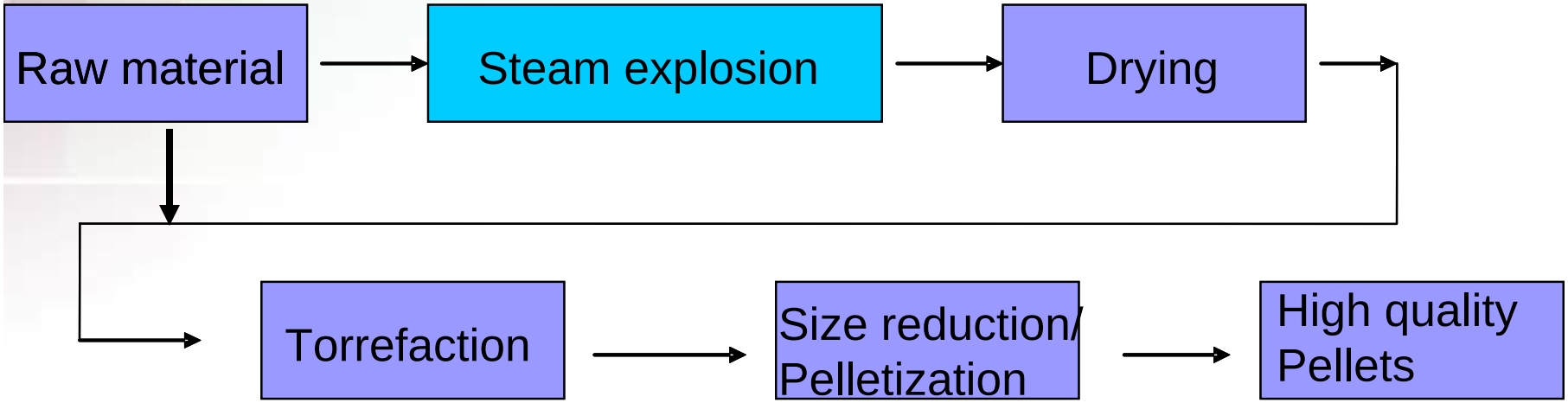
Properties	Saw dust	Wood pellets	Steam exploded pellets	Torrefied pellets
Moisture content, %	40	7-8	2-3	1
Heating value, MJ/kg	10	19	20	22.7
Bulk density, kg/m^3	180	650	800	850
Energy density, GJ/m^3	1.8	12.4	16	19.3
Moisture uptake	high	high	low	Very low

Improved Pellet Characteristics

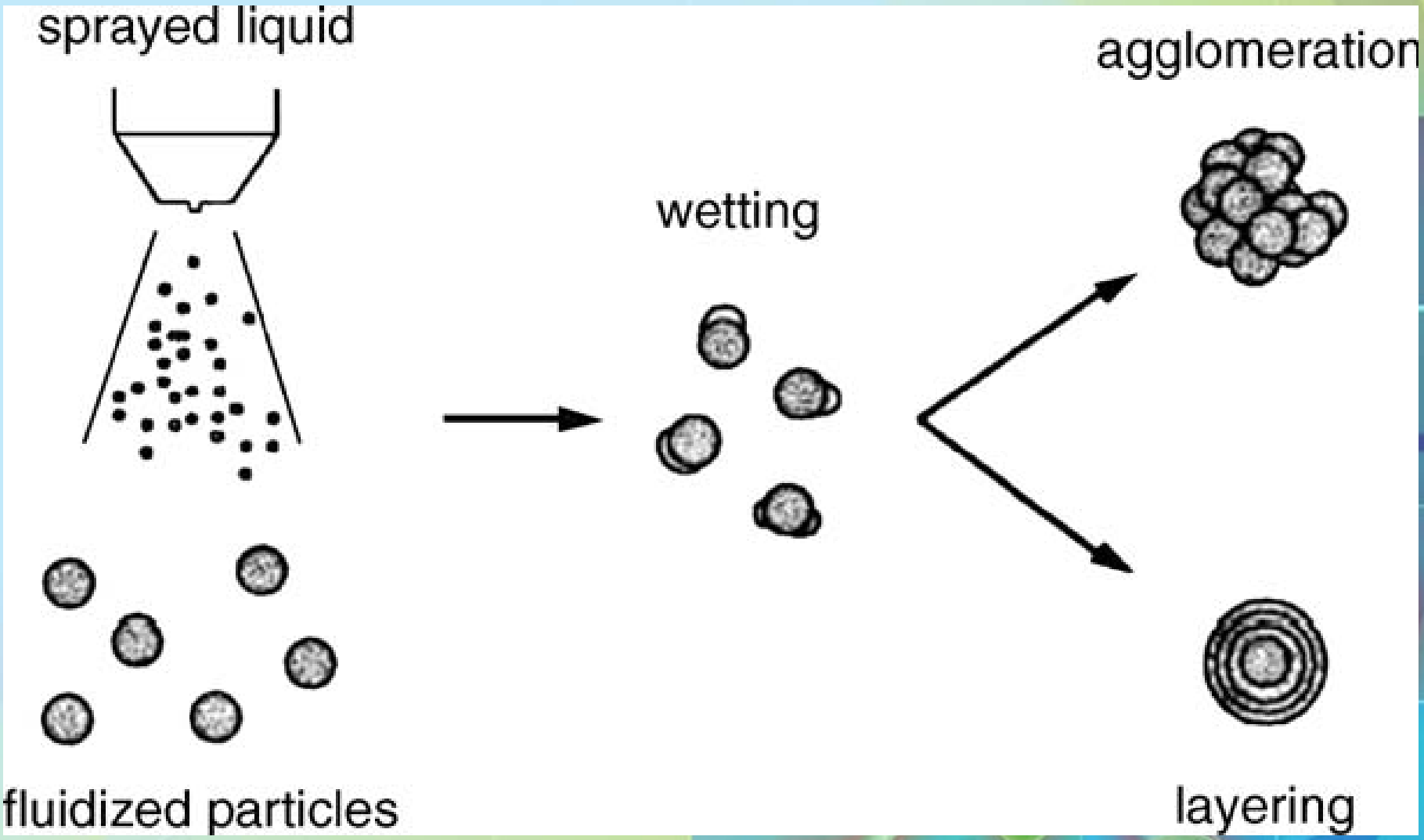


Reed, 2003: US Patent

Improved Pelleting Process



Granulation/Agglomeration Process



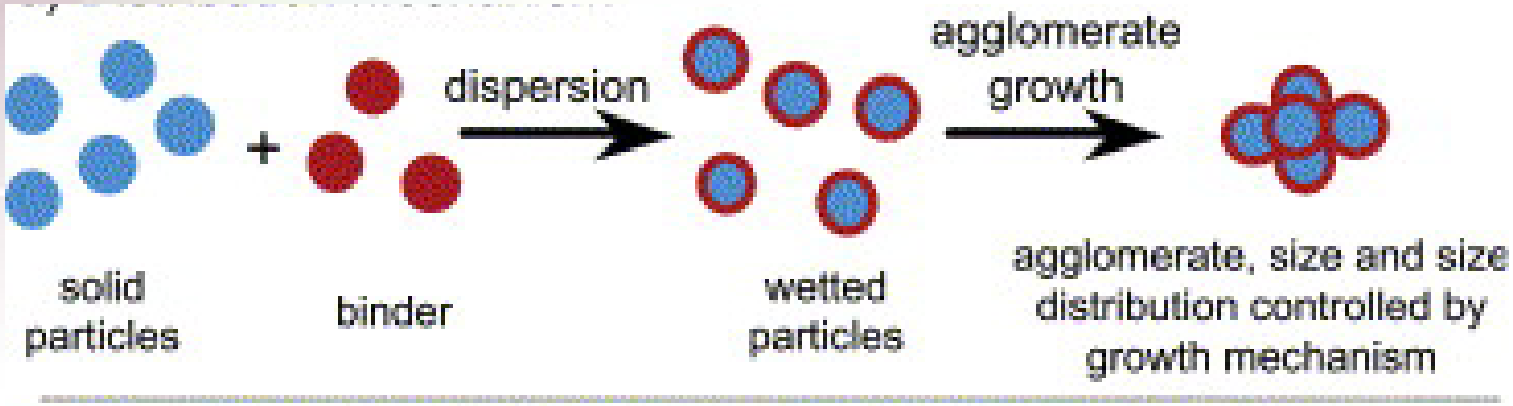
Proposed mechanisms for pellet/granules formation

- Attraction forces between solid particles;
- Interfacial forces and capillary pressure in movable liquid surfaces;
- Adhesion and cohesion forces at not freely movable binder bridges;
- Mechanical interlocking;
- solid bridges.

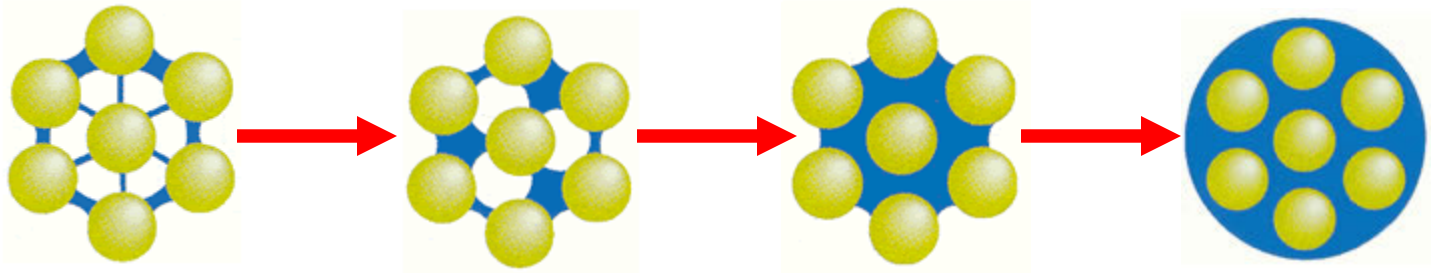
Rumpf (1966)

Granulation/agglomeration process

- A process of combining small particles into large particles using liquid binders and high shear forces.

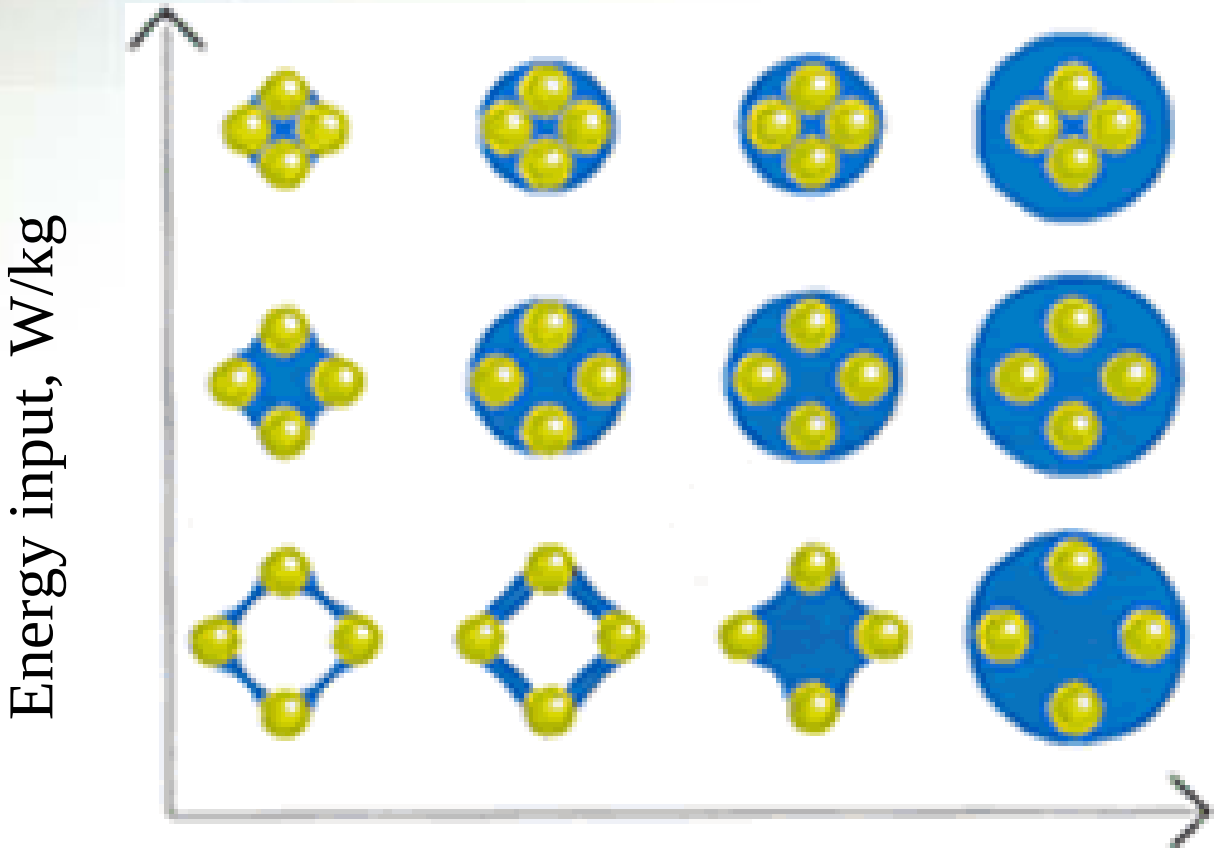


Adapted from Mort, 2005



Increasing the addition of binders, kg/kg

Granulation growth model



Adapted from GEA Niro Inc.

Granulation equipment

Rotary drum granulator

Rotary disk granulator

Adapted from \Feeco Inc.

Pelleting vs. Granulation/Agglomeration

Characteristics	Pelletization	Granulation
Particle size requirement	< 1 mm	< 200 µm
Bonding forces	Compression forces	High shear forces
Bulk density	650 kg/m^3	400-500 kg/m^3
Percent fines	Up to 10%	No fines
Binders requirement	0-5%	Up to 30%
Specific Energy requirement	50-100 kW/t	~40 kW/t

Conclusions

- Biomass pelletization is the promising technology to reduce transport cost and improve the fuel quality for biofuels production
- Current pelleting technology has many technical challenges and requires further research and development
- Steam treatment and addition of low cost binders could improve the energy density of biomass significantly.
- Granulation of biomass looks very promising, but requires further research on optimizing binder requirement and modifying the surface characteristics of biomass
- Opportunities still exits for reducing the cost of making densified products without compromising the bulk density of biomass

Thank You

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