for business
bioenergy

Biomass logistics – supply chains for heat generation

Training material for B4B seminars
Prepared by: Danish Technological Institute
2016

Overview

- Solid biofuels
  - Feedstock
    - Wood
    - Agricultural residues
    - Energy crops
- Biomass Logistics and supply chains (harvesting, handling and storage)
  - Woody biomass
  - Agricultural biomass
  - Security of supply
  - Safety aspects
  - Quality control and standardization
  - Modelling of biomass supply chains
- Best practice examples

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Solid biofuels

- **Different types of biomass**
  - **Wood based**
  - **Agricultural residues**
  - **Energy crops**

- **Different shapes**
  - **Pellets**
  - **Briquettes**
  - **Chips**
  - **Bales**
  - **Loose**
  - **Powdered**

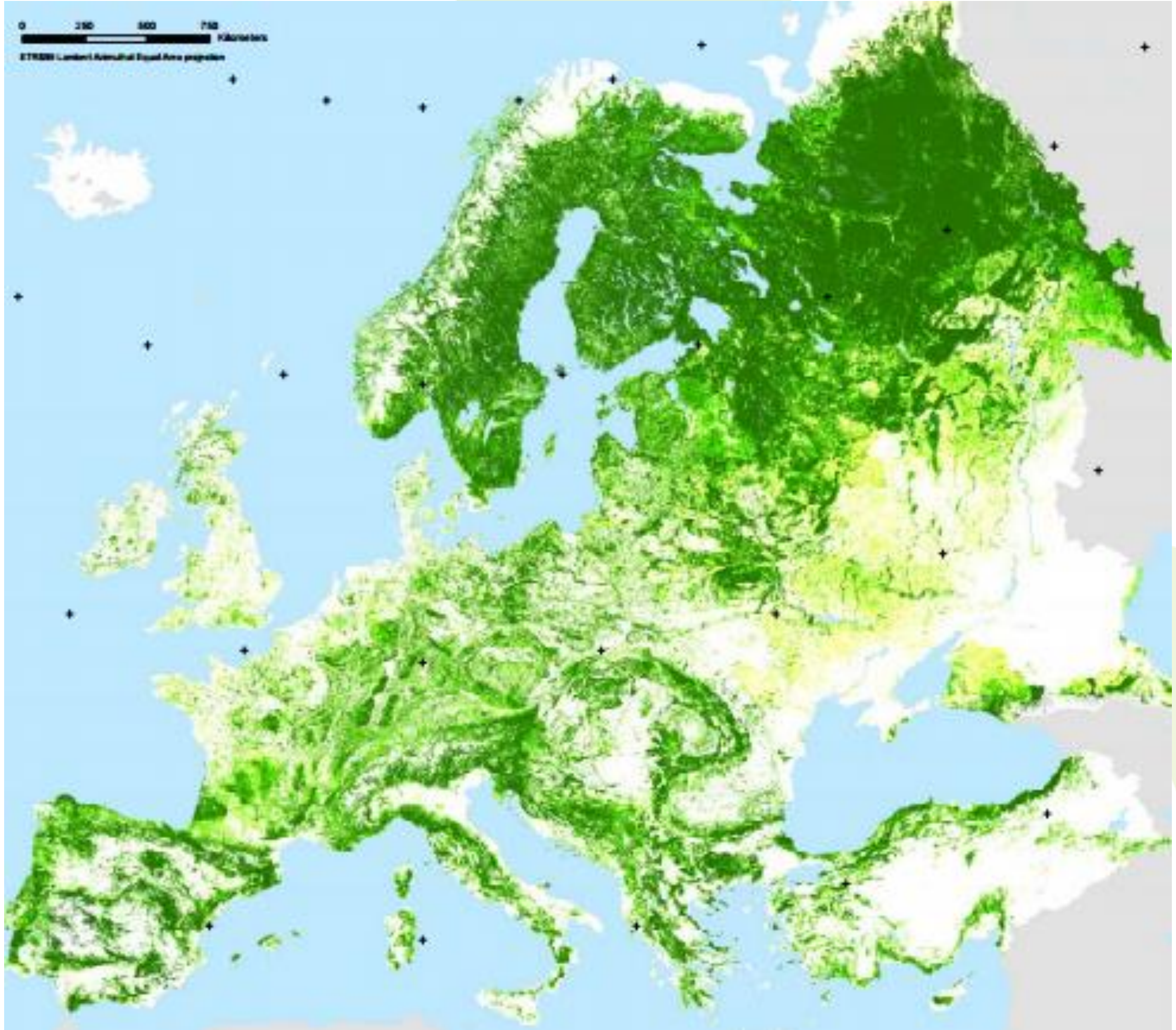
Wood based biofuels

- Woody biomass
  - Forest / plantation wood
    - Whole trees
    - Stemwood
    - Logging residues
    - Stumps / roots
    - Bark
  - By products from wood processing industry
    - Saw dust / shavings
    - Treated and untreated
  - Used wood
    - Building / construction material / furniture etc...

Feedstock for wood based biofuels

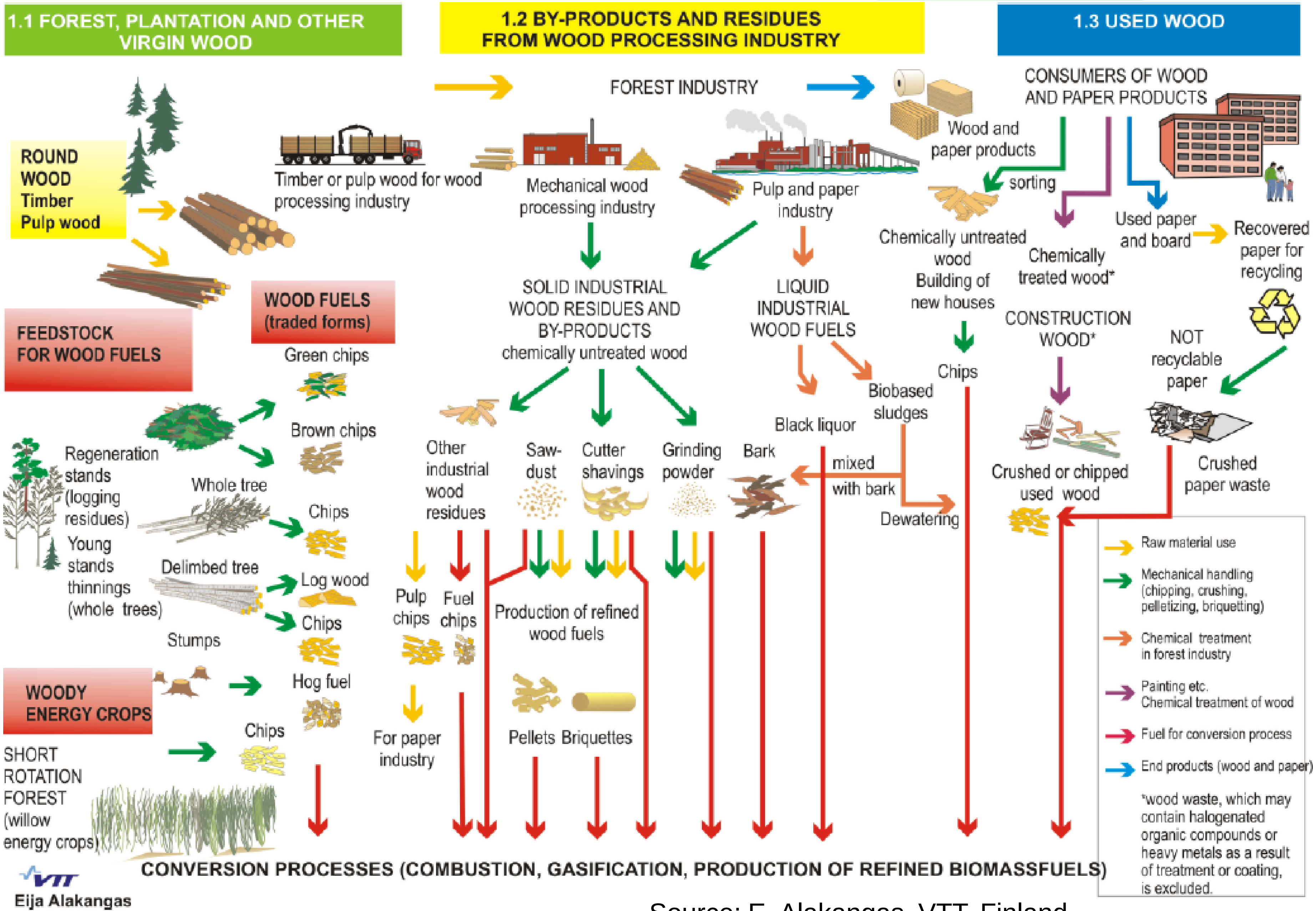
Forest map of Europe

- Highest forest density in North-East
- But forest grow much slower in the North than in South of Europe
- Forest density is not the same as availability
- Many different applications for wood
  - Construction material
  - Furniture
  - Pulp & paper
  - Energy



Forest map of Europe - Source: European Forest Institute, 2011

Feedstock for wood based biofuels



Source: E. Alakangas, VTT, Finland

Feedstock for wood based biofuels

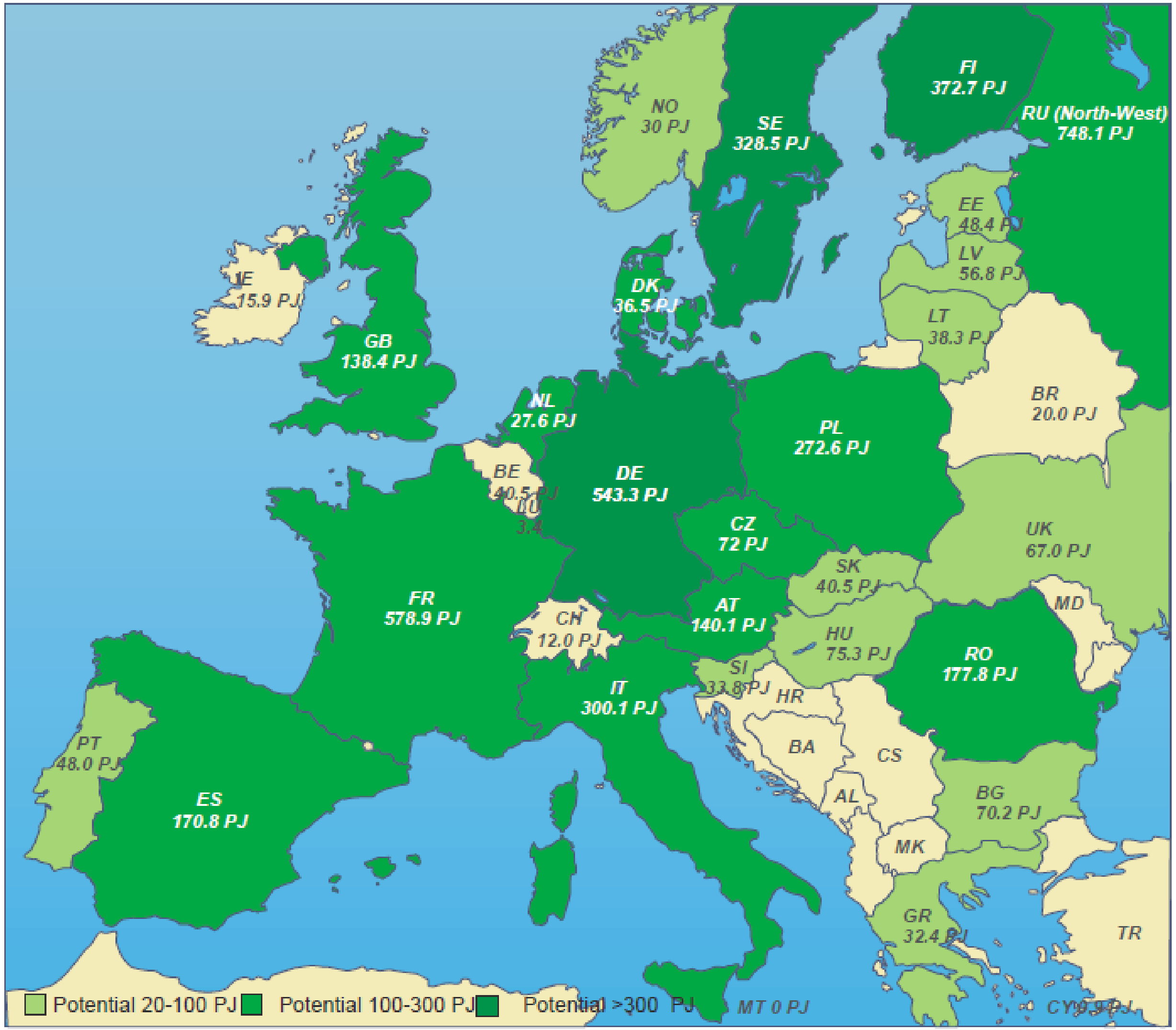
Biggest potentials of available wood for energy production in:

- **Germany**
- **France**
- **Finland**
- **Sweden**
- **Poland**

Outside EU

- **Russia**
- **Canada**
- **US**

Wood potential in Europe



Technical wood potential in EU-27. Those marked by beige color are less than 20 PJ. (Source: VTT, Finland)

Feedstock for wood based biofuels

Total wood Potential is a sum of available:

- Stem wood
- Primary forest residues
- By products
- Used wood

Country	1,000 m^3				
	Stem wood	Primary forest residues	By-products from forest industries	Used wood	Total
Austria	8 104	5 735	5 525	1 100	20 464
Belgium	668	1 012	1 638	2 100	5 418
Bulgaria	4 262	4 072	785	100	9 219
Cyprus	19	9	2	100	130
Czech Republic	1 272	4 351	3 445	700	9 768
Denmark	2 407	1 038	295	1 300	5 040
Estonia	3 538	2 140	908	200	6 786
Finland	19 320	23 434	14 207	1 200	58 161
France	40 311	21 050	6 725	6 300	74 386
Germany	27 749	25 903	12 942	8 700	75 294
Greece	2 012	1 076	280	900	4 268
Hungary	5 908	2 407	505	500	9 320
Ireland	34	883	607	600	2 124
Italy	23 833	5 982	1 712	6 200	37 727
Latvia	2 106	3 409	1 987	300	7 802
Lithuania	2 117	1 971	886	300	5 274
Luxembourg	213	124	121	0	458
Malta	0	0	0	0	0
Netherlands	704	419	156	2 500	3 779
Poland	13 394	14 477	7 912	3 500	39 283
Portugal	577	2 810	2 334	700	6 421
Romania	11 683	6 658	2 650	1 700	22 691
Slovakia	608	2 850	1 728	200	5 386
Slovenia	2 699	1 370	459	100	4 628
Spain	6 763	7 222	3 995	4 200	22 180
Sweden	10 089	21 506	18 382	1 000	50 977
United Kingdom	5 264	4 528	1 984	7 500	19 276
EU-27	**195 656**	**166 438**	**92 164**	**52 000**	**506 258**

m^3 is solid cubic meter.

Wood potential in Europe.
Technical potential in 1000m^3
Source: VTT, Finland

Feedstock for wood based biofuels

Most common feedstock for heating applications:

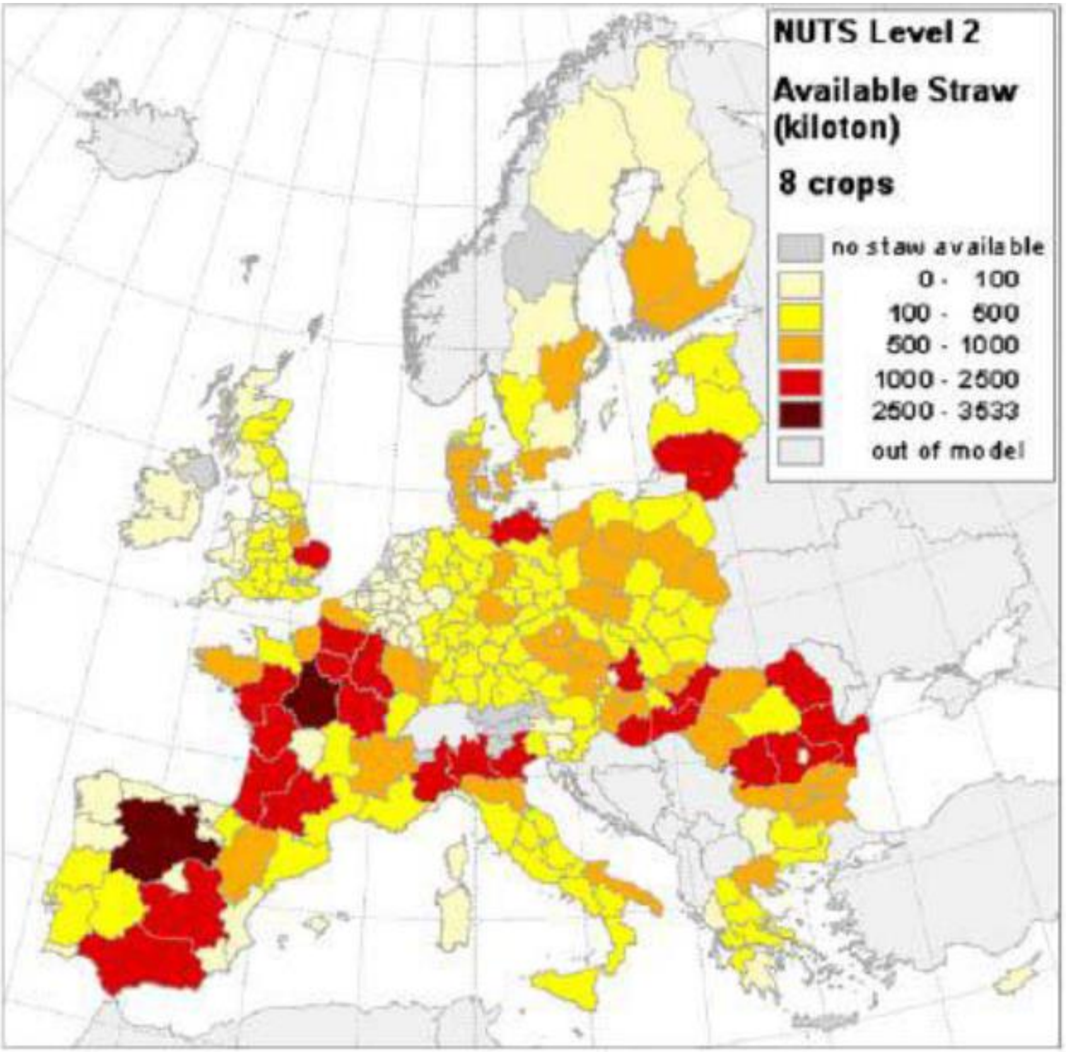
Raw material	Average Water content	Origin	Used for:
Saw mill residues	15 – 50%	Regional saw mills	Premium wood chip production, pellets
Round wood	20 – 50%	Forest, regional saw mills	Premium wood chip production
Forest residues	45 – 55%	Private and municipal and federal forests	Industrial wood chips, and maybe premium wood chips
Landscaping material	45 – 60%	Private and municipal landscaping companies	Industrial wood chips
Short rotation coppices	45 – 55%	Short rotation coppices	Industrial wood chips, and premium wood chips
Stalk material	15 – 20%	Agricultural byproducts	Straw fired plant

Source: B4B project 2nd brochure

Biofuels based on agricultural residues

- Agricultural residues
  - Cereal crops and grasses
    - Whole plant
    - Straw part
    - Seeds
    - Shells
    - Stones / kernels
  - For heat and power production straw is the most important agricultural feedstock

Straw as a bioenergy feedstock



Available straw potential in Europe in 1,000 tons. Monforti et al. (2013)

Country	Available potential PJ/a
Austria	6.4
Belgium	5.2
Bulgaria	12.1
Cyprus	0
Czech Republic	15.8
Denmark	19.3
Estonia	1.8
Finland	8.9
France	111.5
Germany	92.9
Greece	8.7
Hungary	15.7
Ireland	5.1
Italy	40.3
Latvia	3.5
Lithuania	6.6
Luxemburg	0.4
Malta	0
Netherlands	3.6
Poland	39
Portugal	1.5
Romania	18.7
Slovakia	6
Slovenia	0.5
Spain	74.4
Sweden	10.5
United Kingdom	52
EU-27 TOTAL	560.4

Technical potential of straw residues in Europe (Böttcher et al. 2010)

Energy crops as a feedstock

- Plants grown for energy production
    - Reed canary grass
    - Miscanthus
    - Woody energy crops
        - Poplar
        - Short rotation coppice

Aebiom, 2009

Solid biofuels

- Biomass is often converted into an energy carrier of defined size and shape to ease trade and handling of biofuels
  - Pellet
  - Briquettes
  - Chips
  - Logs
  - Bales

Pelletization of biomass

- Conversion of a low density bulk material into pellets
  - Increase of density (straw: 40 kg/m^3 → 750 kg/m^3)
  - Decrease of transportation, storage, handling costs
  - Standardized size → International standards
  - more homogeneous material → process automatization

Briquetting of biomass

- Alternative process to compact biomass into a solid energy carrier
- Robust and easy to implement process
- Increase the density / lower the volume of the biomass for cheaper transportation and storage of biomass
- Used for all types of biomass: wood, straw, husks, peels

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Biomass logistics and supply chains

- Biomass logistics and biomass supply chains are important for
    - Stable supply of biomass fuels around the year
    - Predictable price
    - Stable quality
    - Trade and contracting
    - Planning and maintance of the heating system

Biomass demand of bioenergy systems

Typical scale of operation for various sizes and types of bioenergy plants

Type of plant	Heat$_{(th)}$ or power$_{(e)}$ capacity ranges, and annual hours of operation.	Biomass fuel required (oven dry tonnes/year)	Vehicle movements for biomass delivery to the plant	Land area required to produce the biomass (% of total within a given radius).
Small heat	100 - 250 kW$_{th}$ 2 000 hr	40 - 60	3 - 5 / yr	1 - 3% within 1 km radius
Large heat	250kW$_{th}$ - 1 MW$_{th}$ 3 000 hr	100 - 1200	10 - 140 / yr	5 - 10% within 2 km radius
Small CHP	500 kW$_{e}$ - 2 MW$_{e}$ 4 000 hr	1 000 - 5 000	150 - 500 / yr	1 - 3% within 5 km radius
Medium CHP	5 - 10 MW$_{e}$ 5 000 hr	30 000 - 60 000	5 - 10 / day	5 - 10% within 10 km radius
Large power plant	20 - 30 MW$_{e}$ 7 000 hr	90 000 - 150 000	25 - 50 / day and night	2 - 5% within 50 km radius

Source: International Energy Agency – Best practice guideline: Bioenergy Project Development Biomass Supply

Solid biomass fuels supply chain options according to end-user sector

End-user and average annual fuel consumption	Biomass fuel	Quality requirements	Technology for energy conversion
Households (<50 kWh) Annual fuel consumption <30 MWh	Wood pellets	Good mechanical durability Low ash content	Pellet boilers Pellet stoves
	Wood briquettes	Low ash content, packaged	Stoves and fireplaces
	Wood chips	Low moisture content, < 35w-%	Stoker boiler
	Log wood	Low moisture content, 15-20 w-%	Stoves and fireplaces, boilers
Farms, large buildings (<1 MWh) Annual fuel consumption < 3 GWh)	Wood chips from whole trees or delimbed trees	Low moisture content, less than 35 w-%	Stoker burners Grate firing
	Straw bales	High quality bales, low moisture content (< 18 w-%)	Grate combustion, also whole bales
	Wood pellets	Good mechanical durability Low ash content	Pellet boilers Stoker boilers
District heating plants (<5 MW_{th} or power plants (<5 MW_e) Annual fuel consumption <35 GWh (DH, CHP) or 85 GWh (power only)	Wood chips from forest residues or whole trees	Moisture content usually less than 40 w-%	Grate combustion Fluidised bed combustion Gasification
	Straw or energy grass bales	Moisture content, less 20 w-%	Cigar combustion Crate combustion, also whole bales
CHP and power plants (>5 MW_e) Annual fuel consumption from 85 GWh to several TWh	Wood fuels from forest residues, stumps	Boiler and handling equipment based requirements	Usually cofiring with coal or peat Fluidised bed combustion Gasification
	Wood or straw pellets	Boiler and handling equipment based requirements	Cofiring with coal Pulverised combustion
	Herbaceous biomass (straw or energy grasses, like miscanthus and reed canary grass)	Big bales, moisture content less than 20 w-%	Cigar combustion Grate combustion Fluidised bed combustion Cofiring with coal
	Olive residues	Boiler and handling equipment based requirements	Grate firing Cofiring with coal in fluidised bed boiler

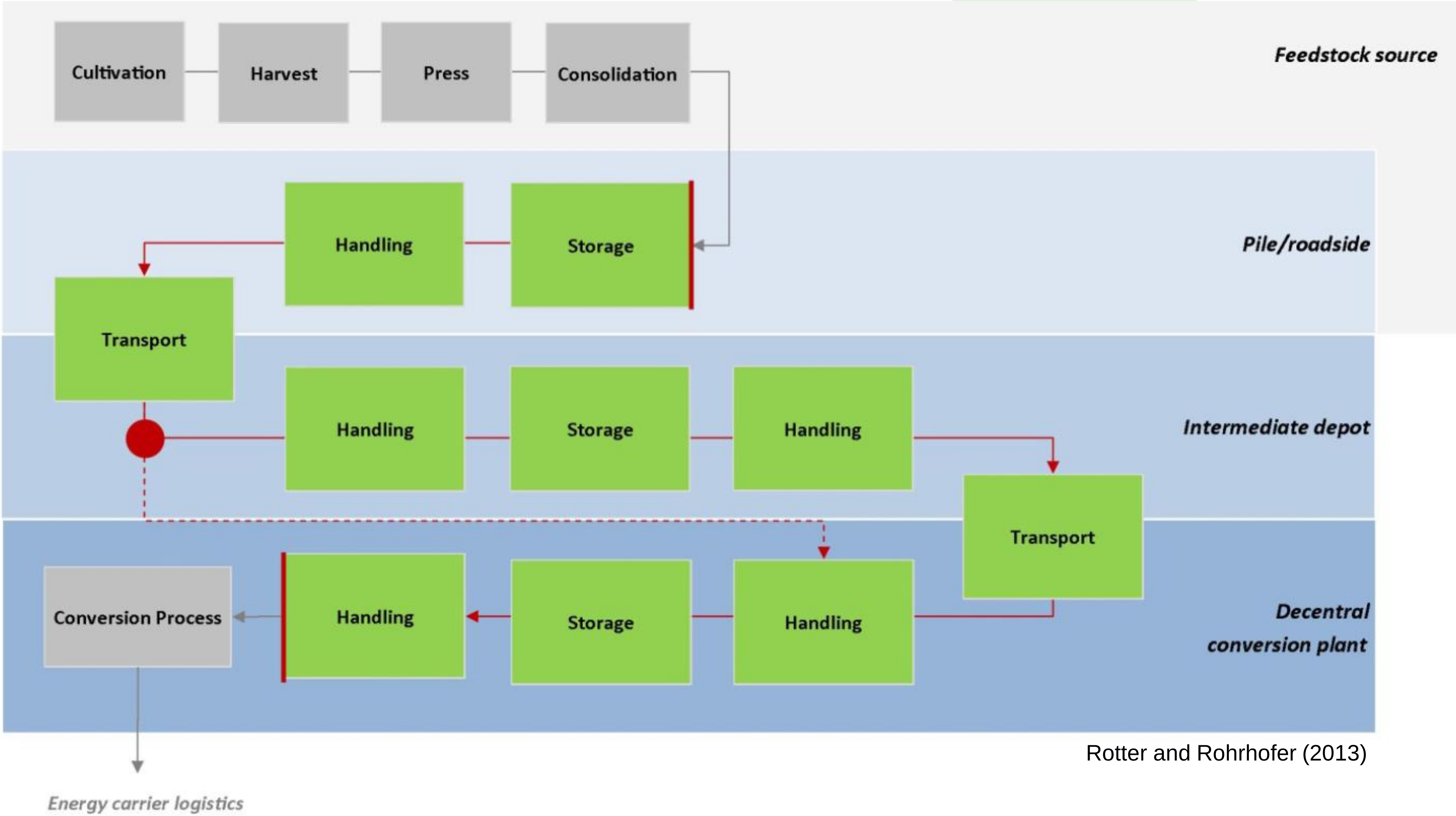
Source: E. Alakangas, VTT, Finland - EUBIONET II project

Biomass supply chains

- Biomass supply chains
  - Cultivation
  - Harvesting
  - Drying
  - Pre-treatment
  - Loading and un-loading operations
  - Transport
    - Short distance
    - Long distance
  - Storage
    - Intermediate
    - Longterm

Biomass supply chains

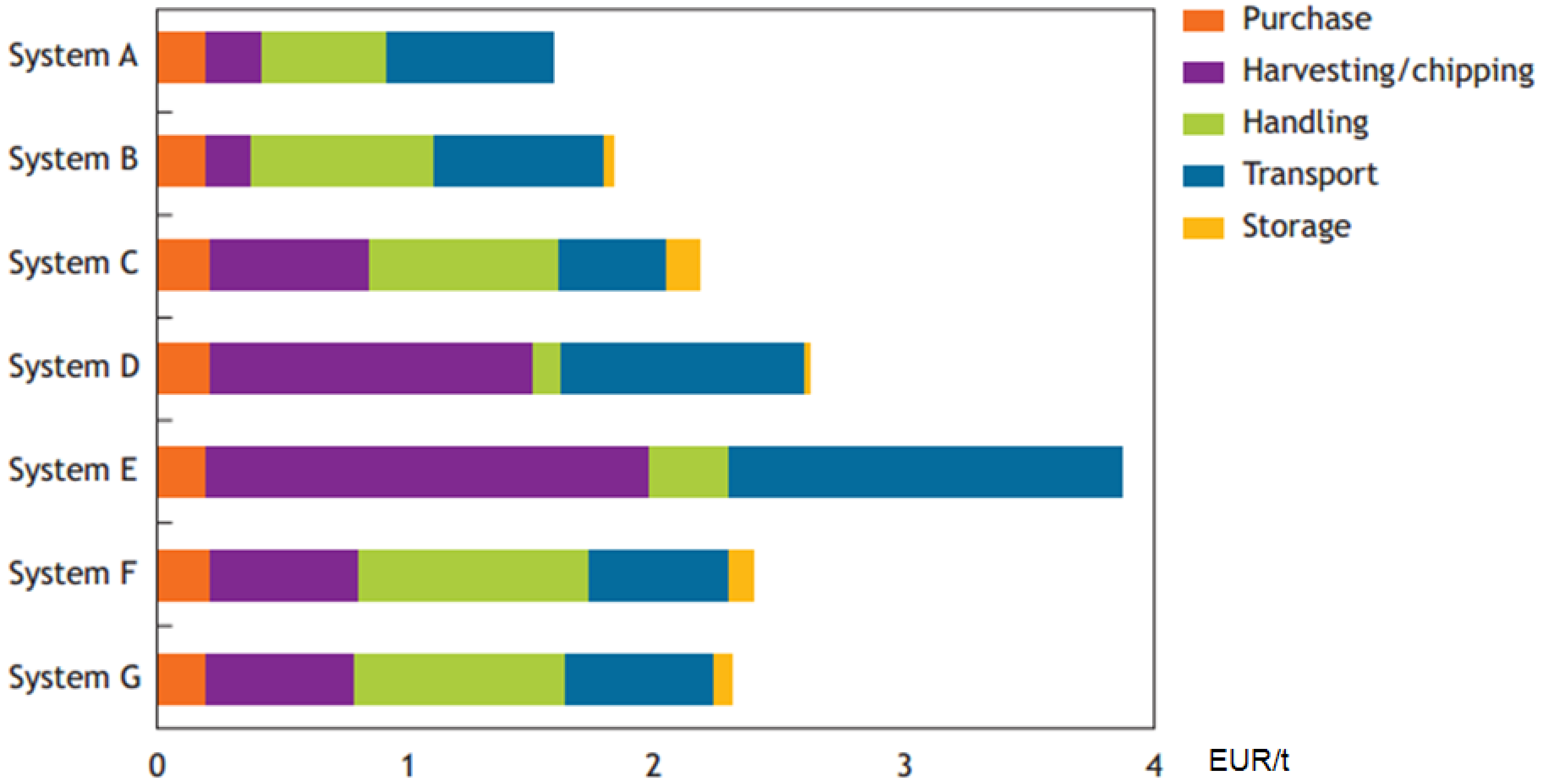
Typical steps in a biomass supply chain



Rotter and Rohrhofer (2013)

Biomass supply chains

Logistic chains can look very different, and vary greatly in their costs



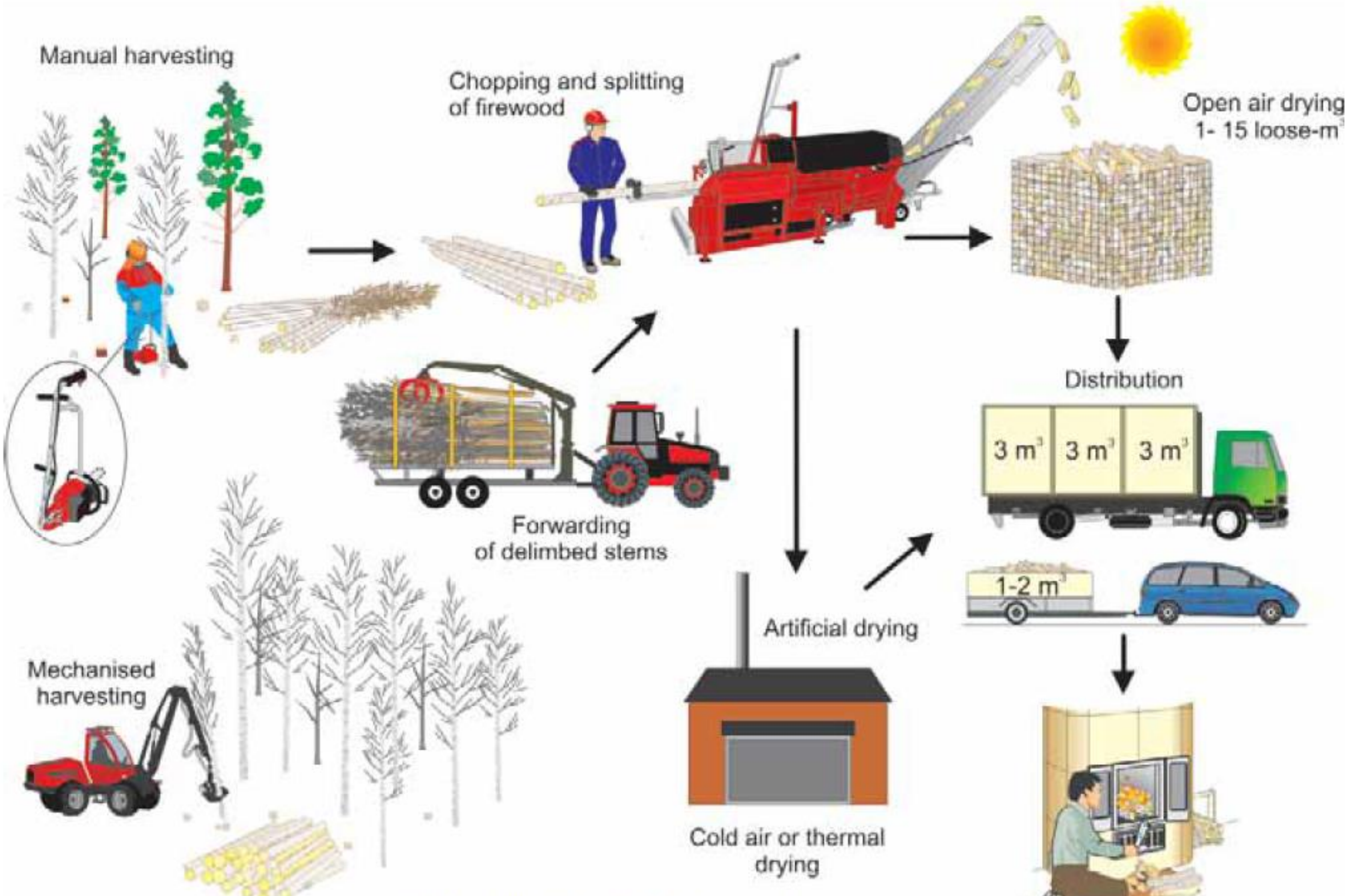
Source: International Energy Agency – Best practice guideline: Bioenergy Project Development Biomass Supply

Cost factors of biomass supply chains by country

Index for		Labour costs				Fuel costs		Vehicle investment costs	
Country Code		Gross hourly wage (EUR/h)	Social security contribution ratio (% of gross hourly wage)	Total hourly wage (EUR/h)	**Labor costs index**	Diesel fuel gross price (EUR/l)	**Fuel cost index**	Index by sales expert (100 = Mean in Europe)	**Investment cost index**
BE	Belgium	39.3	47%	57.8	1.44	1.42	1.00	103	1.00
SE	Sweden	39.1	52%	59.4	1.49	1.67	1.19	108	1.05
DK	Denmark	38.9	15%	44.7	1.12	1.48	1.05	106	1.03
FR	France	34.2	50%	51.3	1.28	1.37	0.97	97	0.94
LU	Luxembourg	33.7	15%	38.8	0.97	1.26	0.89	103	1.00
NL	Netherlands	31.1	30%	40.4	1.01	1.47	1.04	106	1.03
DE	Germany	30.1	28%	38.5	0.96	1.50	1.07	99	0.96
FI	Finland	29.7	28%	38.0	0.95	1.55	1.10	108	1.05
AT	Austria	29.2	37%	40.0	1.00	1.41	1.00	103	1.00
IE	Irland	27.4	18%	32.3	0.81	1.58	1.12	105	1.02
IT	Italy	26.7	41%	37.6	0.94	1.71	1.21	107	1.04
ES	Spain	20.6	37%	28.2	0.71	1.36	0.96	89	0.86
UK	Great Britain	20.1	16%	23.3	0.58	1.73	1.23	100	0.97
CY	Cyprus	16.5	21%	20.0	0.50	1.34	0.95	86	0.83
GR	Greece	16.4	29%	21.2	0.53	1.44	1.02	89	0.86
SI	Slovenia	14.4	17%	16.8	0.42	1.40	0.99	105	1.02
PT	Portugal	12.1	26%	15.2	0.38	1.45	1.03	105	1.02
MT	Malta	11.9	10%	13.1	0.33	1.40	0.99	89	0.86
CZ	Czech Rep.	10.5	37%	14.4	0.36	1.43	1.01	109	1.06
SK	Slovakia	8.4	36%	11.4	0.29	1.44	1.02	109	1.06
EE	Estonia	8.1	37%	11.1	0.28	1.40	0.99	91	0.88
HU	Hungary	7.6	34%	10.2	0.25	1.52	1.08	109	1.06
PL	Poland	7.1	20%	8.5	0.21	1.36	0.96	91	0.88
LV	Latvia	5.9	27%	7.5	0.19	1.38	0.98	91	0.88
LT	Lithuania	5.5	40%	7.7	0.19	1.32	0.94	91	0.88
RO	Romania	4.5	31%	5.9	0.15	1.33	0.94	109	1.06
BG	Bulgaria	3.5	19%	4.2	0.10	1.31	0.93	109	1.06
CH	Switzerland	41.9	20%	50.3	1.26	1.62	1.15	109	1.06

Rotter and Rohrhofer (2013)

Wood fuel supply chain



Supply chain for firewood. Source: VTT

Wood fuel supply chain

Example: thinning in coniferous stand:

- **Felling**
- **Full tree skidding**
- **Mechanized processing at the landing site**
- **Loading logs on truck and trailer**
- **Transporting logs to biomass trade center (90 km)**
- **Unloading logs from truck and trailer**
- **Natural seasoning**
- **Chipping logs**
- **Delivery of chips (90 km one way)**

Wood fuel supply chain

Working phase	Equipment	Productivity (bulk m^3/h)	Cost (€/bulk m^3)
Felling	2 chainsaws	35	0.5
Full tree skidding	2 tractors and winch	17	5.9
Mechanized processing at the landing site	processor on tractor	24.3	1.4
Loading logs on the truck and trailer	truck and trailer	121.5	0.6
Transporting logs to the biomass trade centre (back&forth 90 km)	truck and trailer	36.5	2
Unloading logs from the truck and trailer	truck and trailer	145.8	0.5
Natural seasoning	—	—	0.3
Chipping logs	high power chipper	100	1.4
Delivery of chips (back&forth 90 km)	truck and trailer	24.4**	2.0
TOTAL			14.6

Aebiom, 2009

Wood fuel supply chain – Equipment and Machinery

Chainsaw
purchase cost: 500-900 €
productivity in high forest:
1-1.2 solid m^3/h (thinning)
2-2.5 solid m^3/h (main felling)
productivity in coppice:
0.4-0.7 stacked m^3/h (average cond.)
0.8-1.8 stacked m^3/h (good cond.)
fuel consumption per hour:
0.6-1 l (petrol and oil mixture)
hourly cost: ≈ 18-20 €


Tractor and winch
tractor purchase cost: 45,000-60,000 €
winch purchase cost: 3000-4200 €
productivity in high forest: 2.5-6 solid m^3/h
productivity in coppice: 3-7 stacked m^3/h
fuel consumption per hour: 4-9 l
hourly cost: ≈ 45-50 € (2 operators)


Tractor and trailer
tractor purchase cost: 45,000-60,000 €
trailer purchase cost: 8,000-25,000 €
loading capacity: 5-15 t
productivity: 5-12 solid m^3/h
(depending on hauling distance)
fuel consumption per hour: 5-10 l
hourly cost: ≈ 40-50 €


Woodfuels Handbook, Aebiom, 2009

Wood fuel supply chain – Equipment and Machinery

Cable crane with mobile tower yarder
light
purchase cost: 40000-120,000 €
max traction power: 2,000 daN
productivity: 3-6 solid m³/h
fuel hourly consumption: 5-6 l
hourly cost: ≈ 25-40 €
medium
purchase cost: 100,000-220,000 €
max traction power: 5000 daN
productivity: 3-12 solid m³/h
fuel consumption per hour: 6-10 l
hourly cost: ≈ 40-80 €


Harvester
purchase cost: 300,000-370,000 €
max cutting diameter: 65-70 cm
max delimbing diameter: 45-60 cm
max negotiable slope: 35% (wheels)
60% (tracks)
(with optimal soil bearing capacity)
productivity in high forest: 8-20 solid m³/h
fuel consumption per hour: 11-16 l
hourly cost: ≈ 90-120 €


Forwarder
purchase cost: 180,000 – 270,000 €
loading capacity: 10 - 14 t
max negotiable slope: 30 - 35%
logs length: up to 6 m
productivity: 12-20 solid m³/h
(depending on hauling distance)
fuel consumption per hour: 7-11 l
hourly cost: ≈ 65 - 80 €


Woodfuels Handbook, Aebiom, 2009

Wood fuel supply chain – Equipment and Machinery

Hybrid harvester
purchase cost: 240,000 €
max cutting diameter: 55 cm
max delimbing diameter: 50 cm
max negotiable slope: 45-50%
productivity: 10-15 solid m^3/h
fuel consumption per hour: 10-12 l
hourly cost: ≈ 80 €


Skidder
purchase cost: 120,000 – 150,000 €
skidding capacity: up to 3 t
max negotiable slope: 20%
productivity: 8 - 12 solid m^3/h
(depending on hauling distance)
fuel consumption per hour: 6-10 l
hourly cost: ≈ 55 - 65 €


Tractor-mounted processor
tractor purchase cost: 30,000 €
processor purchase cost: 45,000 €
max cutting diameter: 48 cm
max delimbing diameter: 40 cm
productivity: 10-15 solid m^3/h
fuel consumption per hour: 4-5 l
hourly cost: ≈ 35 €


Francescato V, et al. Wood fuels handbook. AIEL, Italien Agriforestry Energy Association, 2008

Wood fuel supply chain – Equipment and Machinery

Excavator-based processor
excavator purchase cost: 170,000 €
processor purchase cost: 60,000 €
max cutting diameter: 65 cm
max delimbing diameter: 60 cm
productivity: 15-40 solid m^3/h
fuel consumption per hour: 15 - 17 l
hourly cost: ≈ 85 €

Chipper
small power
purchase cost: 3,500-35,000 €
working diameter: max 20 cm
productivity: 2-3 t/h
fuel consumption per hour: 5-8 l
medium power
purchase cost: 15,000-75,000 €
working diameter: max 30 cm
productivity: 4-7 t/h
fuel consumption per hour: 10-14 l
high power
purchase cost: 31,000-250,000 €
working diameter: > 30 cm
productivity: 13-20 t/h
fuel consumption per hour: 34-38 l
hourly cost: ≈ 150-190 €

Woodfuels Handbook, Aebiom, 2009

Wood fuel supply chain – Equipment and Machinery

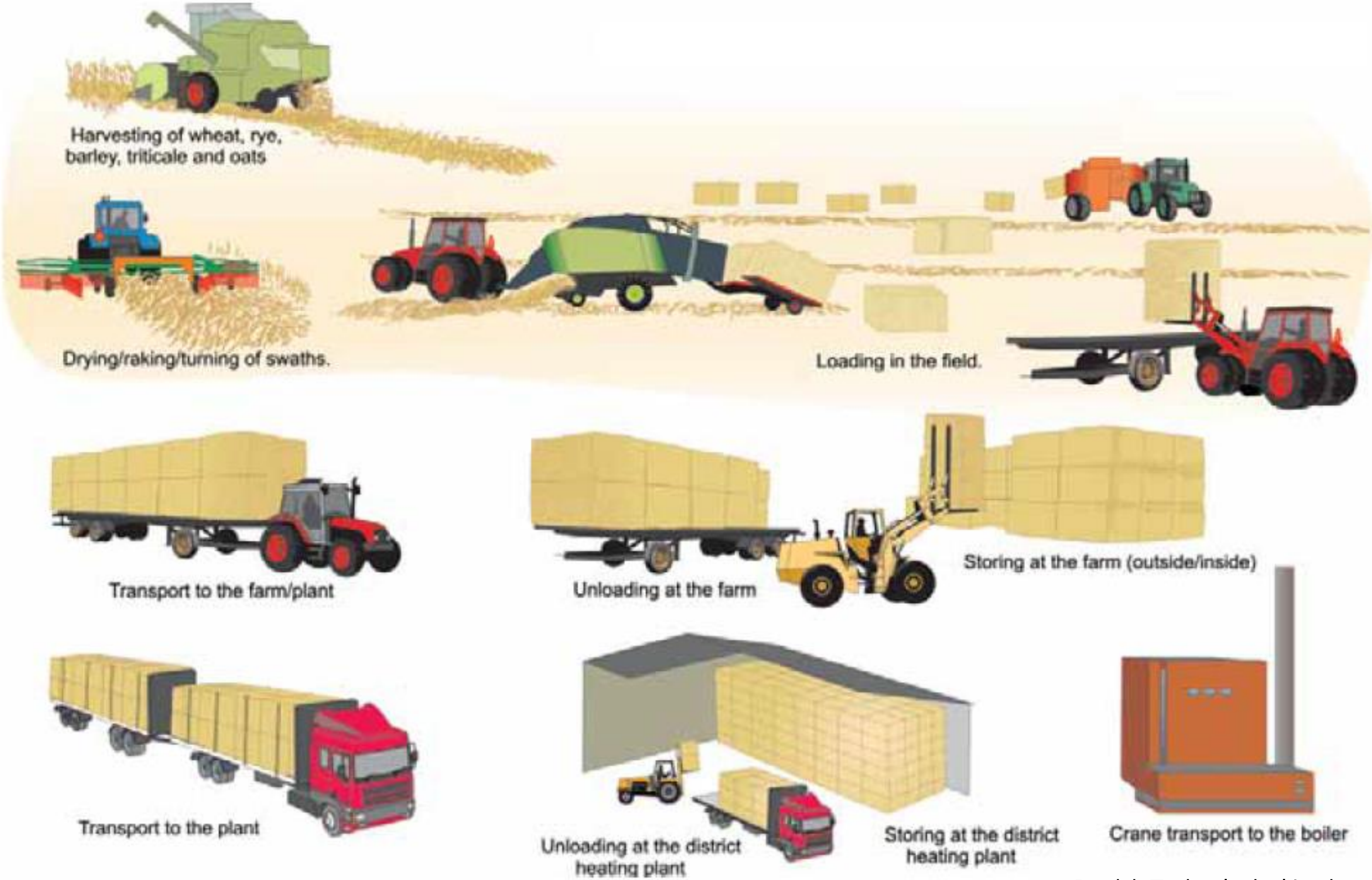
Saw wood
purchase cost: 600-2,000 €
working diameter: 14-25 cm
Split wood
purchase cost: 1,500-14,000 €
working log length: 0.3-4 m
Combined (saw-split wood)
purchase cost: 7,000-70,000 €
working diameter: 25-60 cm
working log length: 2-6 m
hourly cost: ≈ 70-150 €

Truck and trailer (log transport)
truck purchase cost: 110,000-150,000 €
trailer purchase cost: 20,000-30,000 €
loading capacity: 18-20 t
fuel consumption: 2.5-3.5 km/l
hourly cost: ≈ 60-75 €

Truck and trailer (wood chips transport)
truck purchase cost: 100,000-115,000 €
trailer purchase cost: 45,000 €
loading capacity: 20-22 t (85-90 bulk m^3)
fuel consumption: 2.5-3.5 km/l
hourly cost: ≈ 65-70 €
with clamshell bucket loader
purchase cost: 205,000 €
loading capacity: 81 bulk m^3
hourly cost: ≈ 70-75 €

Woodfuels Handbook, Aebiom, 2009

Straw supply chain



Straw fuel supply chain

Example: cereal straw for biomass boiler

- Harvesting of cereal straw
- Drying / turning of swaths
- Baling
- Loading on field
- Transport to fiel storage / farm storage
- Unloading at storage
- Stacking
- Loading of truck
- Transport to end user
- Storage at end user
- Internal conveying and combustion

Straw fuel supply chain

Harvesting with a combined harvester chaff cutter

Drying, raking and turning of swaths

Tracktor propelled bale press

Straw fuel supply chain

Loading and unloading of transport truck/trailer to storage

Truck/Trailer transport to storage

Plastic covered outside storage

Straw fuel supply chain

Truck transport to end-user

Unloading and storage at end user site

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Transport

Vehicle-trailer combination		Feedstock type	Max. cargo space / payload
Farm tractor and (two) tippers		Wheat straw and wood chips	70 m³ / 21.4 t
Farm tractor and platform trailer		Wheat straw	89 m³ / 18 t
Farm tractor and hook lift trailer for roll-off containers		Wood chips	40 m³ / 23 t
Truck and drawbar trailer		Wheat straw and wood chips	115 m³ / 25 t
Truck and drawbar/hook lift trailer for roll-off containers		Wood chips	60 m³ / 26 t

Rotter and Rohrhofer (2013)

On/Off Loading

Handling equipment	
Front-end loaders (farm tractor)	
Telescopic handler	
Forklift truck	
Gantry crane	

Rotter and Rohrhofer (2013)

Storage

Storage locations (biomass logistics)		Square bales	Wood chips
1	Piles/roadside landing		
2	Intermediate depot		
3	Decentral conversion plant		

Rotter and Rohrhofer (2013)

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Security of supply

- Contracting of biomass suppliers
  - Delivery contacts for biomass fuels
    - Ensuring a timely delivery of the fuel
    - Ensuring the quality of the fuel
    - Ensuring price stability of the fuel
    - Reimbursement in case of contract breach (quality, amounts, time, etc.)

- Storage space
  - Trade off between fuel supply security and investment costs
  - Storage should cover a minimum of one week fuel supply.
  - In many cases bigger storage space is recommended to limit the number of transports and to bridge periods without supply possibility

Safety aspects

- Biomass can be a potentially hazardous material if handled incorrect
  - Self heating of biomass in storage (biological reactions, chemical oxidation)
    - Keep biomass dry and monitor temperature on a regular basis
    - Fresh biomass tends to be more reactive than ”old” biomass
  - Oxygen depletion and off-gassing
    - Biomass removes oxygen and releases hazardous gases if strored in closed compartments (carbon monoxide, aldehydes)
    - Ventilation of the storage room before entering.
  - Dust formation during handling of biomass
    - Inhalation of dust is very unhealthy for lungs and respiratory system
    - Dust can form explosive atmoshpeheres (dust-explosion)
    - Wear dust masks and prevent open fire/light in dusty zones. ATEX regulations may apply in biomass storage/handling zones

Quality control

- Standards for solid biofuels
  - EN 14961: Technical specifications
  - EN 15234: Quality assurance

  - Size, shape
  - Mechanical durability (fines and dust formation during handling)
  - Moisture content
  - Bulk density
  - Heating value
  - Ash content
  - Ash composition / Ash melting behaviour

  - Certification schemes for pellets/briquettes i.e. EN-plus certification

Overview

- Solid biofuels
    - Feedstock
        - Wood
        - Agricultural residues
        - Energy crops
- Biomass Logistics and supply chains (harvesting, handling and storage)
    - Woody biomass
    - Agricultural biomass
    - Security of supply
    - Safety aspects
    - Quality control and standardization
    - Modelling of biomass supply chains
- Best practice examples

Modelling of biomass supply chains

Biomass logistics - Challenges

Challenges

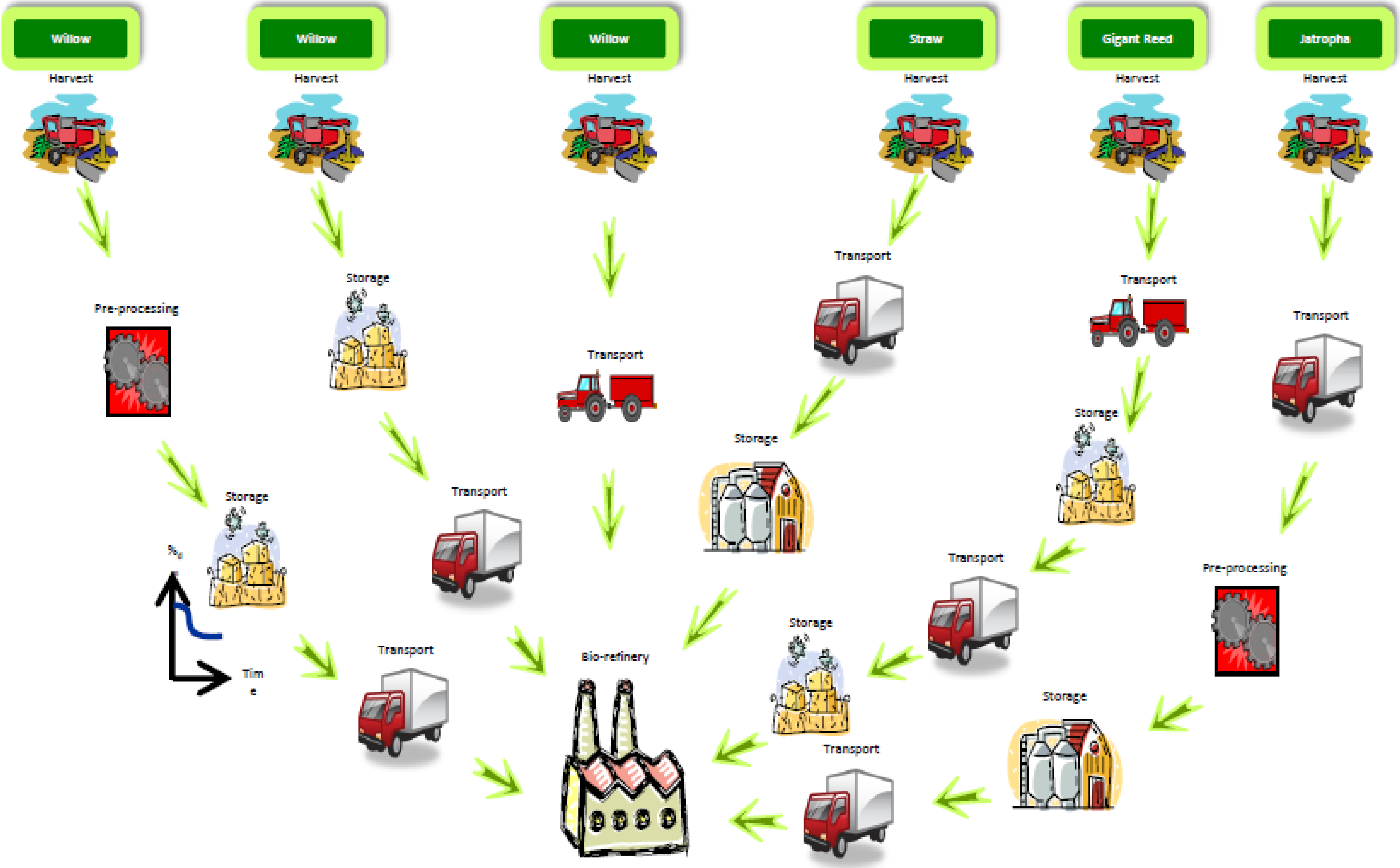
- Different types of biomass
- Seasonal variations (amount & quality)
- Limited storage time (decay)
- Low bulk density

Supply chain management to ensure…

- Availability at the right time
- In the right amounts
- In the proper quality

→ Stable and secure biomass supply at predictable (low) costs

Biomass supply chains



Modelling and optimization of biomass supply chains

Evaluation of different scenarios for an optimal supply of biomass to an end-user

- Stable and secure supply
- Quality
- Price

Biomass logistic tool:

- Developed in EUROBIOREF project (EU-FP7 project) by DTI
- Based on Excel and Gams platform
- Tool has been used in different projects and commercial activities
- High flexibility: feedstock, supply chain elements and output parameters

Example: Cereal Straw supply chain Scenario

Cereal straw from field to small scale CHP plant in DK

Field - > CHP plant

End user: Hillerød Kraft-Varme Værk (Hillerød, 50 km North of Copenhagen, DK)
Cereal straw harvested 25 km away from plant

Example: Cereal Straw supply chain Scenario

Cereal straw from field to heat and power plant

Supply chain

1. Harvesting
2. Baling
3. Loading
4. Field transport
5. Unloading / Stapling
6. Field storage (covered)
7. Loading
8. Truck transport
9. Delivery at end-user

Example: Cereal Straw supply chain Scenario

DANISH TECHNOLOGICAL INSTITUTE

This document is a data-sheet prepared to feed into the logistic model

Category:	Baling					
Crop:	CerealStraw			x		
Nomenclature | Sheet ID:	CerealStrawBaler		361	x		
Country:	Denmark	DK	2			Insert customised figures in green cells
Date:						
Contact:	Wolfgang Stelte, Technological Institute, wst@teknologisk.dk					
Details					**Source**	**Remarks**
Biomass	Cereal straw					
Short description/ID of machinery	Tractor propelled baling (500-600 kg/bale)			x		
Characteristics of equipment/machinery	Tractor propelled baling machine producing "big bales" (500-600 kg) from cereal straw. Bale dimensions app. 120 x 130 x 240 cm.					
Description of machinery	Can be used for baling of of straw, hay, and swathed grain crops					
Contractor	Baling is carried out by biomass growers or a contactor.					
Equipment can be applied for	Baling of straw, hay, and swathed grain crops					
Manufacturer	Several manufacturers, e.g. New Holland, Claas, John Deere, Fendt					
Website						
References	Straw for energy production report DK				**1**	
	Halm til energiformål. Technological Institute,				**2**	
	Kristensen E. F. (2006) Harvesting and handling of miscanthus. Danish institute of Agricultural Sciences. Research Centre Bygholm.				**3**	
	Joergensen K., Andersen J. T., Hansen B. O., and Maegaard E. (2011) Farmtal online. Danish Knowledge Centre of Agriculture.				**4**	
	Hinge J. et al. (2013). Assessment.				**5**	
Specifications and data	**Units**	**Range**	**Figure used**		*Ref*	
Biomass input						
Description			Swathed whole crop			
Dry matter content	% dry matter		87		*5*	
Bulk density	kg biomass/m^3		52			
Bulk density	kg dry matter/m^3	40-60	45			
Biomass output						
Description	kg		500-600 kg "big bales"		*5*	
Dry matter	% dry matter		87	x	*5*	
Bulk density	kg biomass/m^3	130-170	137		*1*	
Bulk density	kg dry matter/m^3		119	x	*5*	
Output-input ratio	**% DM output/input**		**98**	x	*5*	
Cost of basic machine	Euro	150.000-250.000	174.497		*5*	Tractor 200 kW
Cost of dedicated equipment	Euro	100.000-150.000	127.517		*4*	Baler
Total cost	Euro		302.013			
Net baling capacity	ton DM/hour		15,0			
Efficiency	%	50-80	80,0		*5*	Efficiency on field
Gross baling capacity on field	ton DM/hour		12,0			
Efficiency	%	50-90	90,0		*5*	Logistic set up - distance between fields
Gross baling capacity - actual scenario	ton DM/hour		10,8			
Overall efficiency	%		72,0	x		
Baling costs	Euro/ton DM		24,42	x		
Fuel consumption	l diesel/hour		30		*5*	
Cost of direct energy consumption	euro/l		0,78			1: Cost of diesel
Energy cost, euro/ton DM	euro/ton DM		2,16			Costs according to country code
Direct energy consumption	GJ/ton DM		0,10			
Indirect energy consumption	GJ/ton DM		0,08			Estimate
Total energy consumption	GJ/ton DM		0,18	x		
Direct CO_2 emission	kg CO_2/ton DM		8,75			
Indirect CO_2 emission	kg CO_2/ton DM		6,70			
Total CO_2 emission	kg CO_2/ton DM		15,45	x		
Security of supply	80 % probability that actual baling is not delayed more than [-] of weeks		1	x	*3*	
Data validity						
Minimum baling volume	tons DM/season	1.000-2.000	54	x	*3*	

Enter updated figures in green cells

x *Names and figures are exported for model calculations*

Calculation/verification of costs for internal assessment - use this or your own figure

Description		Basic equipment	Dedicated equipment			Total	Ref	**Remarks**
	Euro	174.497	127.517					
Utilisation	Hours/year	700	250				3	
Interest rate	%	4	4				*4*	Interest according to country code
Depreciation period	years	10	6				*4*	Period according to country code
Capital recovery factor	%	12,33	19,08					
Capital costs	euro/ton DM	2,8	9,0			11,86		
Fuel	euro/ton DM			1		2,16		1: Diesel; 2: Heavy fuel Oil; 3: elec. Costs acording to country code
Insurance, hydraulic oil etc.	euro/ton DM					0,11	*4*	Estimated 5 % of fuel costs
Driver	euro/hour	23,5	23,49					Costs according to country code
Driver	euro/ton DM	2,17				2,17		
Maintenance and repair	% of initial investment	5	5					
Maintenance and repair	euro/ton DM	1,15	2,36			3,52		
Miscellaneous	% of costs	10				1,63	3	
Estimated contractor profit	% of costs	15				2,97	3	
Total costs	**euro/ton DM**					**24,42**		
Indirect energy - machinery	GJ	1.309	956					
Indirect energy costs	**GJ/ton DM**	**0,017**	**0,059**			**0,08**		
Indirect CO_2 emission - machinery	kg CO_2	114.828	83.912					
Indirect CO_2 emission	**kg/ton DM**	**1,519**	**5,180**			**6,70**		

Data sheet for each step in supply chain

1. Harvesting
2. Baling
3. Loading
4. Field transport
5. Unloading / Stapling
6. Field storage (covered)
7. Loading
8. Truck transport
9. Delivery at end-user

Example: Cereal Straw supply chain Scenario

DANISH TECHNOLOGICAL INSTITUTE

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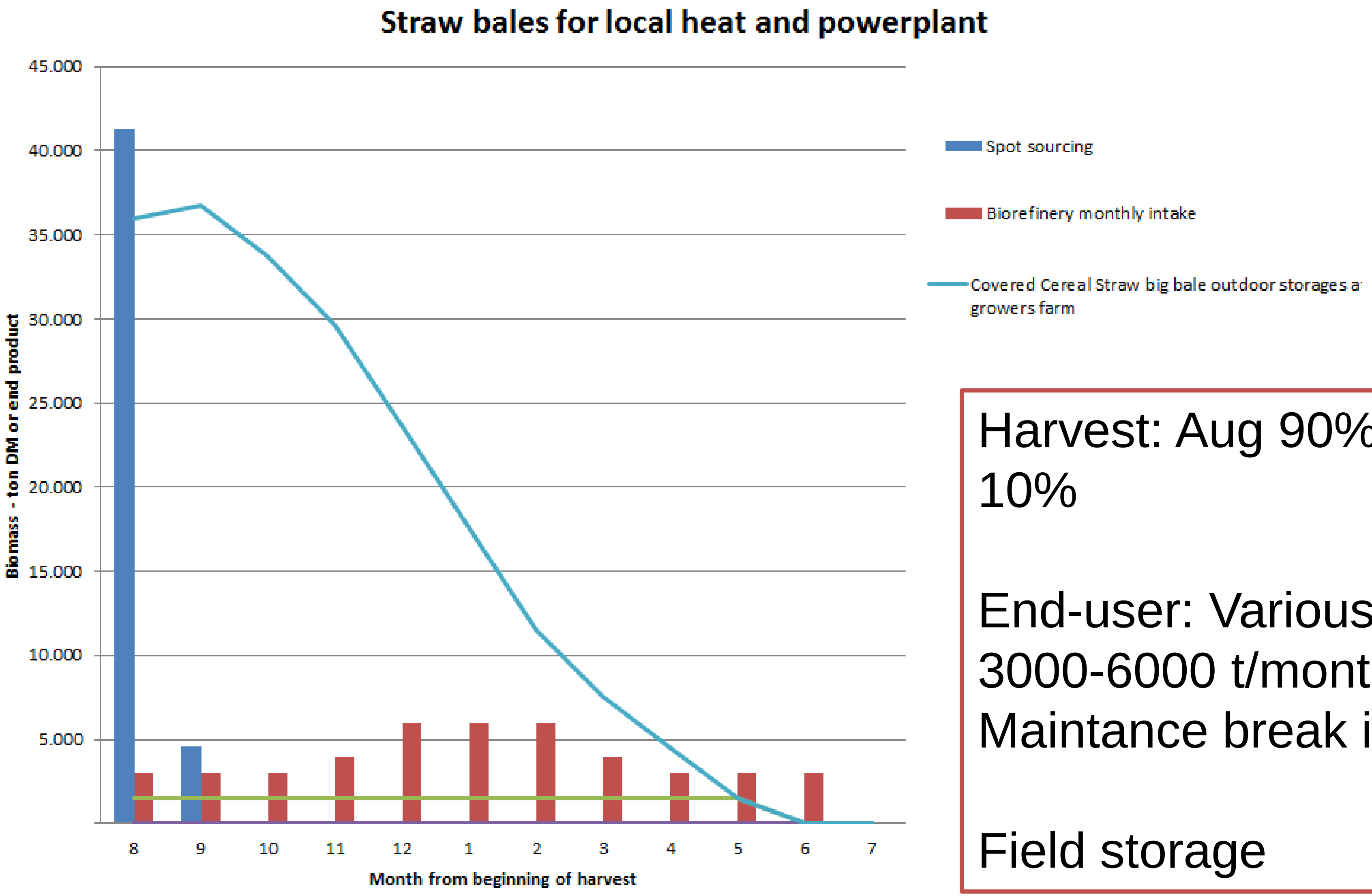
Indirect CO_2 emission	**kg/ton DM**	**1,519**	**5,180**		**6,70**		

Data sheet

- Process information
- Machinery
- Alternative uses of machinery
- References to literature / manufacturers
- Dry matter in and out
- Bulk density in and out
- Capacity
- Efficiency
- Losses
- Costs (machine, operation, indirect costs, fuel price, salaries, insurance, loans)
- CO_2 emissions

Example: Cereal Straw supply chain Scenario

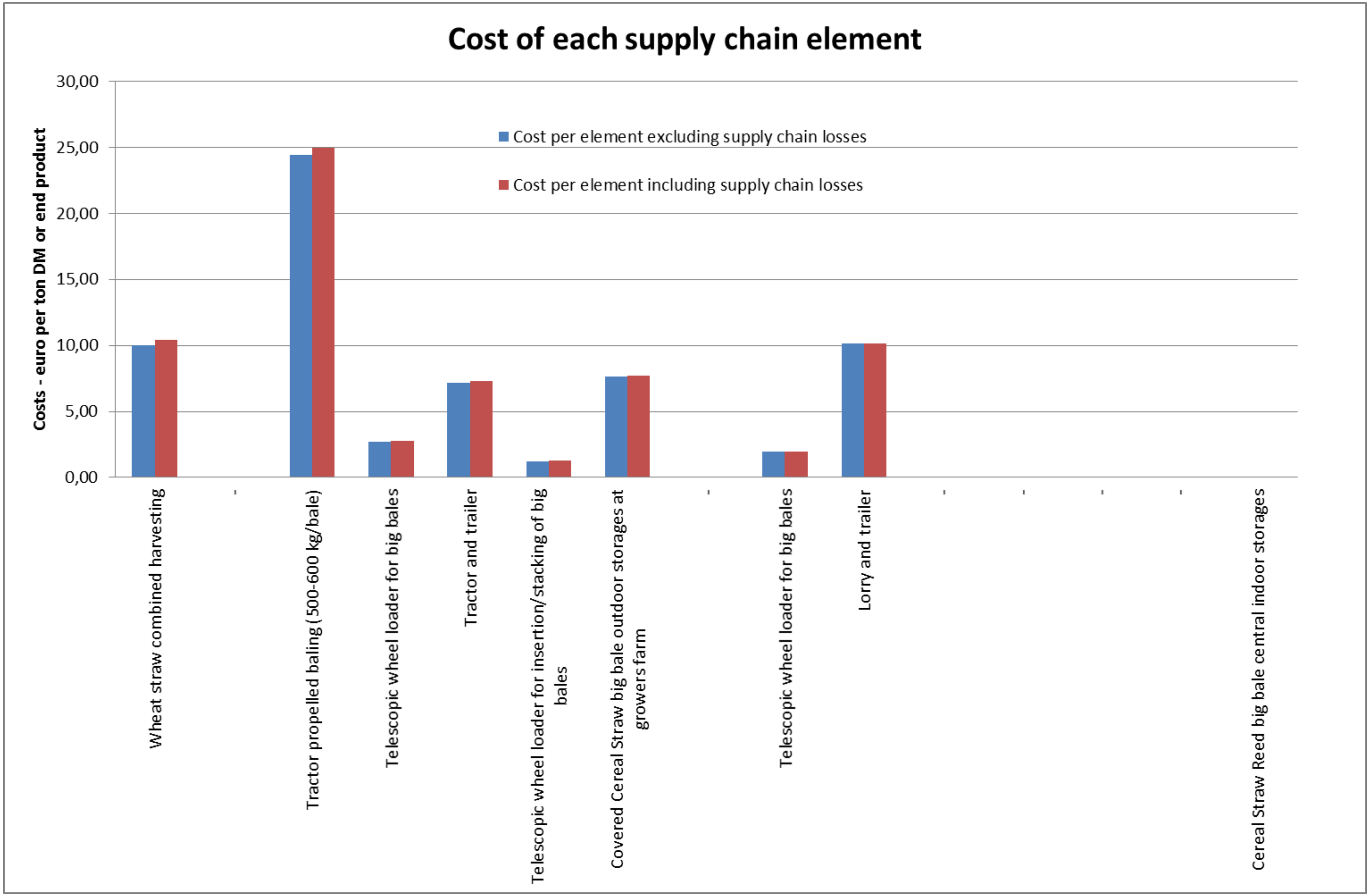


Harvest: Aug 90% / Sep 10%

End-user: Various amounts 3000-6000 t/month
Maintance break in July

Field storage

Example: Cereal Straw supply chain Scenario



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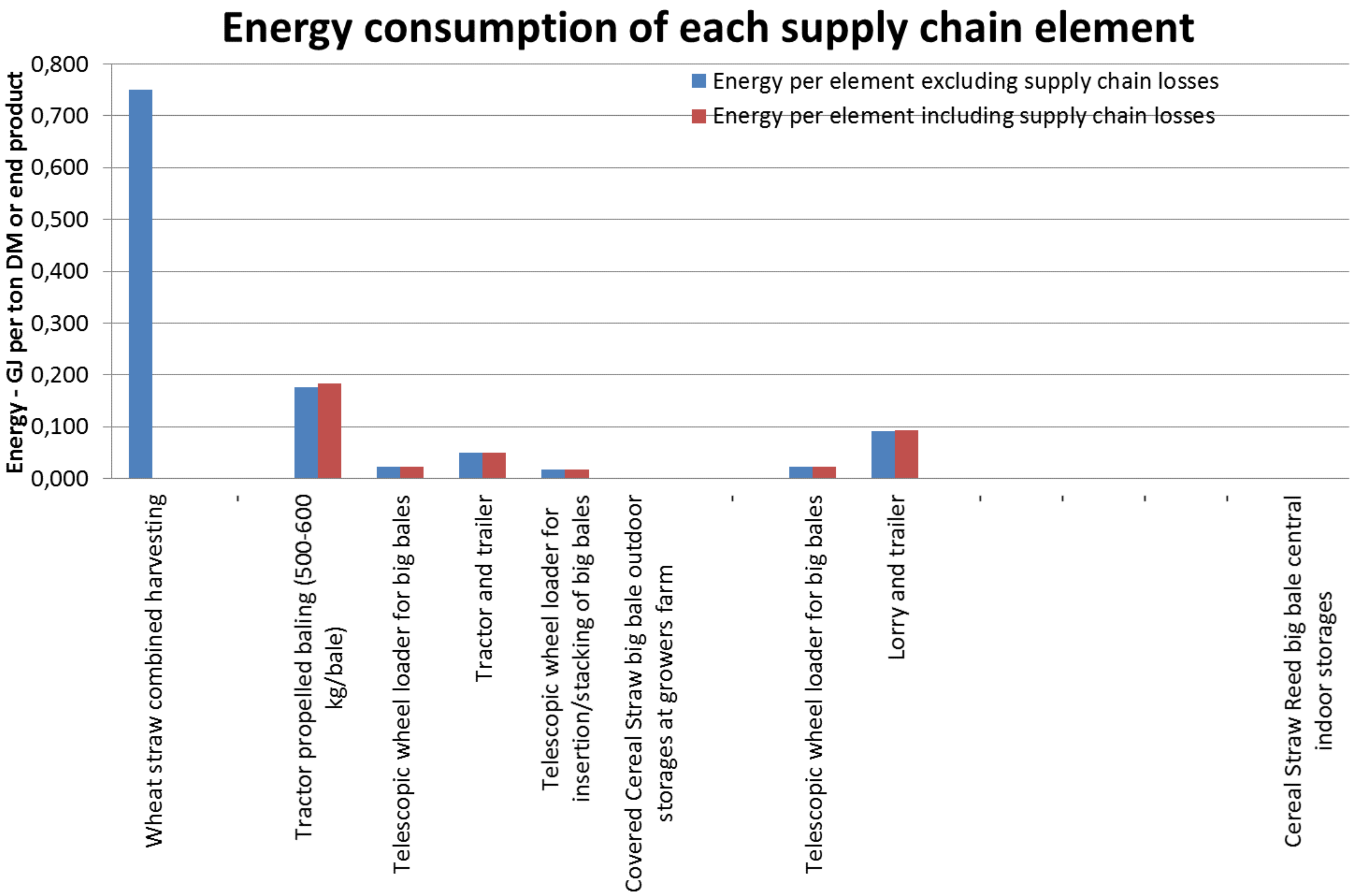

Example: Cereal Straw supply chain Scenario

The biomass supply chain modelling tool is available within the project consortium.

The tool can model supply chains for wood and aricultural residues and can be adapted to specific scenarios

The input data has to be exact, since the modelled data is always just as exact as the data you feed into the model

References and further reading

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