RWE / TKI BBE Circulair Congres – March 15th 2018

Development of Dutch biomass infrastructure

BioLogikNL

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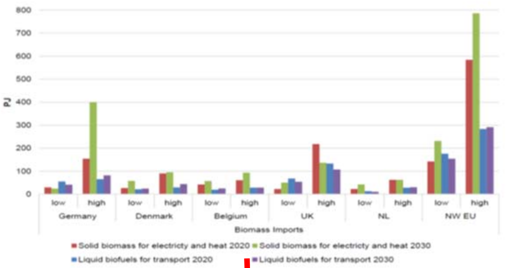
Biomass development in the EU

(Hugo du Mez, Port of Rotterdam Authority, 2014)

Biomass development in the EU

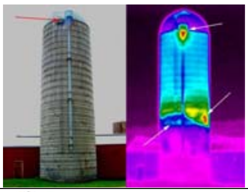


Biomass imports	Denmark	Belgium	Netherlands	Total [Mt]
2020	1.5 – 5.1	2.4 – 3.4	1.3 – 3.5	5.2 – 12 + DE heating + NL biorefinery
2030	3.3 – 5.4	3.2 – 5.3	2.4 – 3.5	8.9 – 14.2 + DE heating + NL biorefinery

(Review of solid and liquid biofuel demand and supply in Northwest Europe towards 2030 – A comparison of national and regional projections, Dafnomilis et al., 2017)

Problem statement

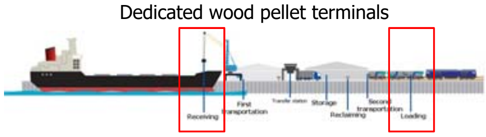
(www.mist-air.co.uk)



(Roy Bie, Stuve photography)

Self heating & ignition
(www.croberts.com)

Dedicated wood pellet terminals



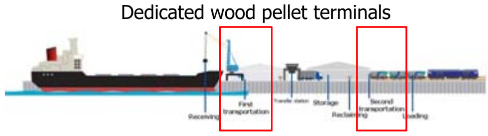
Transhipment

Performed via grabs & grab cranes, bucket elevators & CSUs (e.g. pneumatic)

Focus: pellet degradation

- Low speeds ✓
- 'Gentle' handling ✓
- Dedicated equipment (e.g. specially designed grabs) ×

Dedicated wood pellet terminals



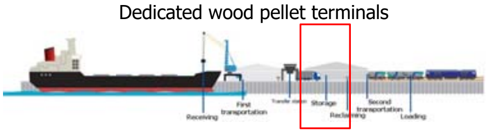
Transportation

Performed via conveying (belt, pipe, screw) or trucks

Focus: dust prevention and minimization, fire prevention & suppression

- Low speeds, minimize impact points ✓
- Enclosed transportation (no wind, spillage, rain) ✓
- Temperature monitoring, flash and smoke detectors ×
- Fire suppression systems ×

Dedicated wood pellet terminals



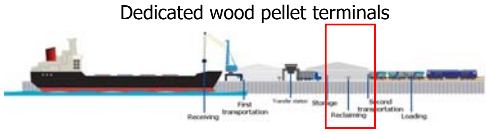
Storage

Performed via silos, domes, flat storage

Focus: pellet degradation, fire prevention & suppression

- Enclosed storage (no wind, spillage, rain) ✓
- Temperature monitoring, CO and O_2 detectors ×
- Fire suppression systems ×
- Extraction and recirculation of product ✓

Dedicated wood pellet terminals



Reclaiming

Performed via front loaders, gravity & underground hoppers, mechanical systems

Focus: pellet degradation

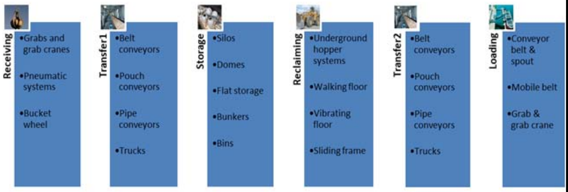
- Low speeds ✓
- 'Gentle' handling ✓
- Dedicated equipment (front loaders) ×

Summary

- Biomass imports and trade highly volatile
  - Dependent on government subsidies
  - Competition with other RES
  - Inconsistent policies
- Dedicated wood pellet terminals (most probably) needed
  - Bulk terminals used for now (in continental EU)
  - UK shows how to adapt
- Demanding and complex logistics
  - Minimal literature on optimization of equipment deployment
  - Numerous additional measures to take into account

Biomass terminal optimization

- Objective: determine configuration and utilization of equipment in order to minimize costs of terminal operations
- Discrete steps of terminal operations (specific equipment, capacities, CAPEX & OPEX)



Main assumptions

- Storage factor *sf*: 2% of AT
- Interest rate *IR*: 6%
- Effective utilization *η*: 0.8
- Lifetime of equipment *LT*: partner input, literature
- Technical = economic lifetime of equipment
- Operating hours *OPH*: 7000 h/year
- One way transfer
- Peak capacity: min(t) to unload maximum vessel size
- Max vessel size *VS* depending on AT

Annual throughput [Mt]	Vessel type	Max vessel size [t]	Service time window [h]
AT ≤ 3.5	Handymax / Panamax	65000	48
5. ≤ AT ≤ 7	Capesize A	100000	72
7 ≤ AT ≤ 10	Capesize B	140000	96
AT ≥ 10	Capesize C	180000	144

Biomass terminal optimization

Operational step	Equipment type	Capacity	Lifetime [y]
Receiving	Mobile crane 25t & grab 23m³	500 [tph]	20
	Mobile crane 50t & grab 42m³	880 [tph]	20
	Gantry crane 25t & grab 23m³	1000 [tph]	20
	Gantry crane 50t & grab 42m³	1750 [tph]	20
	Pneumatic unloader	500:500:2500 [tph]	7
Transport1	Belt conveyor	300, 600, 1000, 1200, 1500, 1800, 2000, 2200, 2500 [tph]	10
	Pipe conveyor	300, 600, 1000, 1200, 1500, 1800, 2000, 2200, 2500 [tph]	10
	Pneumatic conveyor	500:500:2500 [tph]	7
	Truck	25.5 [t]	10
Storage	Warehouse	15000 [t]	30
	Dome	15000 [t]	30
	Silo	20000, 110000 [t]	30
	Bunker	20000, 130000 [t]	30
	Floating barge	2500 [t]	15
Reclaiming	Underground hopper & belt conveyor , 200m length	300, 600, 1000, 1200, 1500, 1800, 2000, 2200, 2500 [tph]	10
	Underground hopper & pipe conveyor , 200m length	300, 600, 1000, 1200, 1500, 1800, 2000, 2200, 2500 [tph]	10
	Front loader	9 [t]	10
Transport2	Belt conveyor, 500m length	300, 600, 1000, 1200, 1500, 1800, 2000, 2200, 2500 [tph]	10
	Pipe conveyor, 500m length	300, 600, 1000, 1200, 1500, 1800, 2000, 2200, 2500 [tph]	10
	Truck	25.5 [t]	10
Loading	Loader	500:500:2500 [tph]	15

- 16 different types of equipment of 83 different sizes and capacities

Biomass terminal optimization

Quality of output is directly related to quality of input

Port authorities
Port of Rotterdam

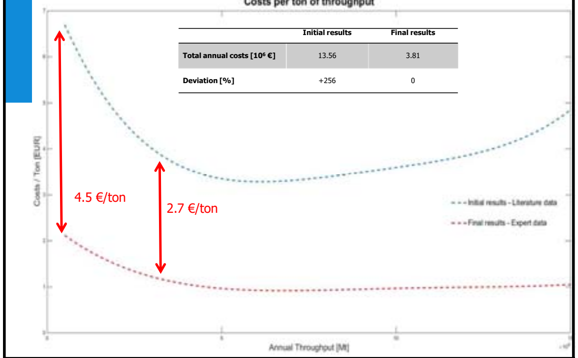
Utility providers
RWE Essent

Input parameters & assumptions

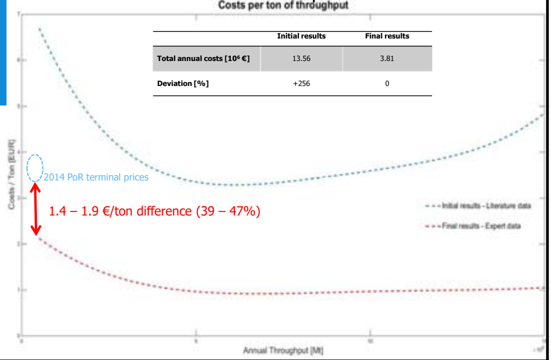
Terminal operators
EMO

Equipment & infrastructure
ESI Eurosilo, Nemag

Biomass terminal optimization



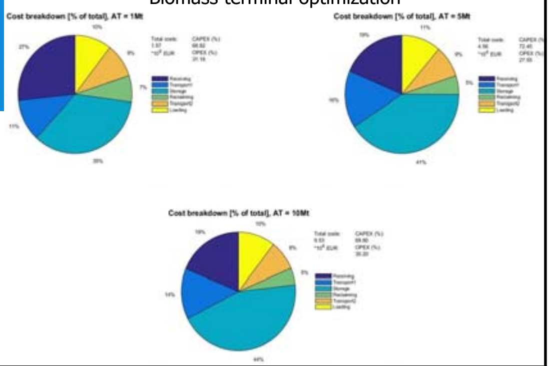
Biomass terminal optimization



Biomass terminal optimization

Annual Throughput	1 Mt		5 Mt		10 Mt	
	Equipment	Utilization	Equipment	Utilization	Equipment	Utilization
Receiving	Mobile crane 25t & 25m³ grab	0.32	Mobile crane 50t & 42m³ grab	0.9	Gantry crane 50t & 42m³ grab	0.91
Transfer1	300tph belt conveyor (1km)	0.53	1200tph belt conveyor (1km)	0.66	1800tph belt conveyor (1km)	0.88
Storage	Silo 20kt	1.00	Silo 110k t	1.00	2* Silo 110k t	1.00
	Floating barge 2250t	0.89	Floating barge 2250t	0.44	Bunker 20kt	0.11
Reclaiming	300tph hopper & conveyor (200m)	0.53	1200tph hopper & conveyor (200m)	0.66	2000tph hopper & conveyor (200m)	0.79
Transfer2	300tph belt conveyor (500m)	0.53	1200tph belt conveyor (500m)	0.66	1800tph belt conveyor (500m)	0.88
Loading	500tph loader	0.32	1000tph loader	0.79	2000tph loader	1.00

Biomass terminal optimization



Storage % increases with AT increase

Biomass terminal optimization

Conclusions

Detailed input data / informed assumptions are crucial to optimization – collaboration with industrial partners gave us this option

Importance of biomass storage infrastructure and utilization of equipment increases with terminal size

Wider implications: smaller number of medium to large terminals instead of multiple small ones

No considerable difference in terms of costs per ton whether to situate terminals in a central location or split them between respective importing countries

Other factors need to be considered (location, redundancy, environmental regulations)

Thank you for your attention!

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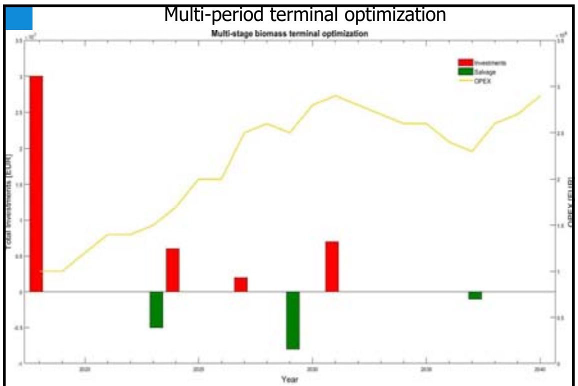
Multi-period terminal optimization



Biomass terminal optimization

$$\min Z = \left[\sum_{i=1}^{I}\left[\left[\sum_{j=1}^{J} n_{ij}\right] + m_i\right]\right] * CAP_{ij} + \left[\sum_{i=1}^{I}\sum_{j=1}^{J}[n_{ij} + x_{ij}] * AT * OP_{ij}\right]$$

(1) (2) (1) (3)

Decision variables		Sets	
Dedicated equipment	(1)	I	equipment type
Shared/partial equipment	(2)	J	operational step
Utilization of equipment	(3)		
Binary variables to control interdependent equipment			

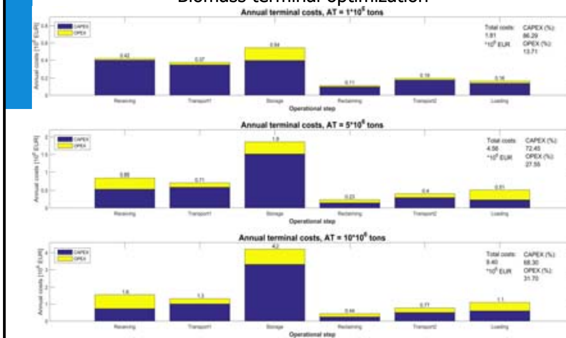
Biomass terminal optimization

- Capacity constraints $\sum_{i=1}^{I}(n_{ij} + m_i + x_{ij}) * EqC_i \geq AT$
- Peak constraints $\sum_{i=1}^{I}(n_{ij} + m_i + x_{ij}) * EPC_i \geq \max(VS)$
- Storage constraint $\sum_{i=1}^{I}(n_{ij} + m_i + x_{ij}) * EqC_{ij} \geq sf * AT$
- Continuous equipment $\sum_{i=1}^{I}(n_{ij} + m_{ij}) = 1$
- Interdependency of equipment $B_{ijkl} * (n_{ij} + m_i + x_{ij}) \leq B_{ijkl} * M * (n_{kl} + m_k + x_{kl})$
- Partial use $\sum_{i=1}^{I}\sum_{j=1}^{J} x_{ij} \leq m_i$
- Utilization $0 \leq x_{ij} \leq 1$

Biomass terminal optimization

AT	Annual Throughput	[Mt]	
TW	Time windows	[h]	
OPH	Operating hours	[h/y]	
$NEqC_i$	Nominal equipment capacity	[tph]	$i \in I$
VS	Vessel size	[t]	
EqC_i=$NEqC_i$*OPH	Equipment capacity	[t]	$i \in I$
EPC_i=TW*EqC_i	Equipment peak capacity	[t]	$i \in I$
SF	Storage capacity factor	[-]	
CAP_i	Capital costs	[€/y]	$i \in I$
OP_i	Operational costs	[€/t]	$i \in I$
L_i	Upper bound of equipment	[-]	$i \in I$
IR	Interest rate	[%]	
LT_i	Lifetime of equipment	[y]	$i \in I$

Biomass terminal optimization



Operational costs reach up to 32% of total and 55% of individual costs in certain operational steps
Storage still major contributor: enclosed storage can only go up to a certain size