Biomass: Strategic Issues in Supply Chain Logistics

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Overview and Contents

This report provides a strategic overview of the issues involved in the transportation of biomass.

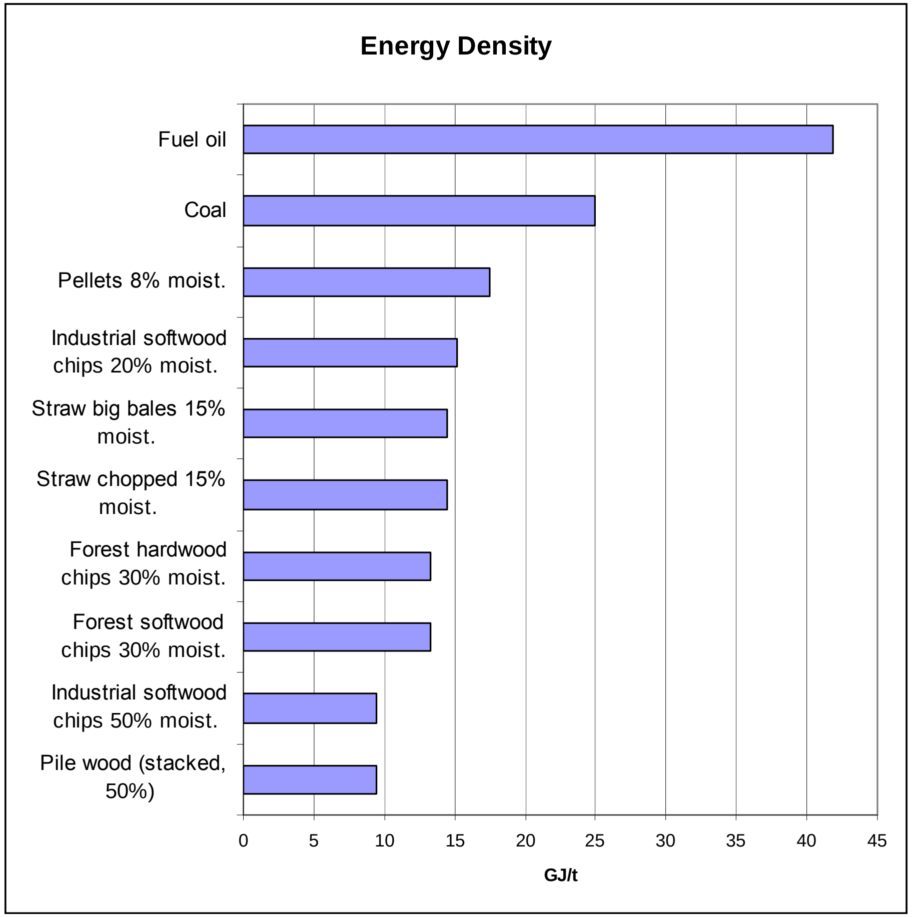
The contents and structure of the report are as follows:

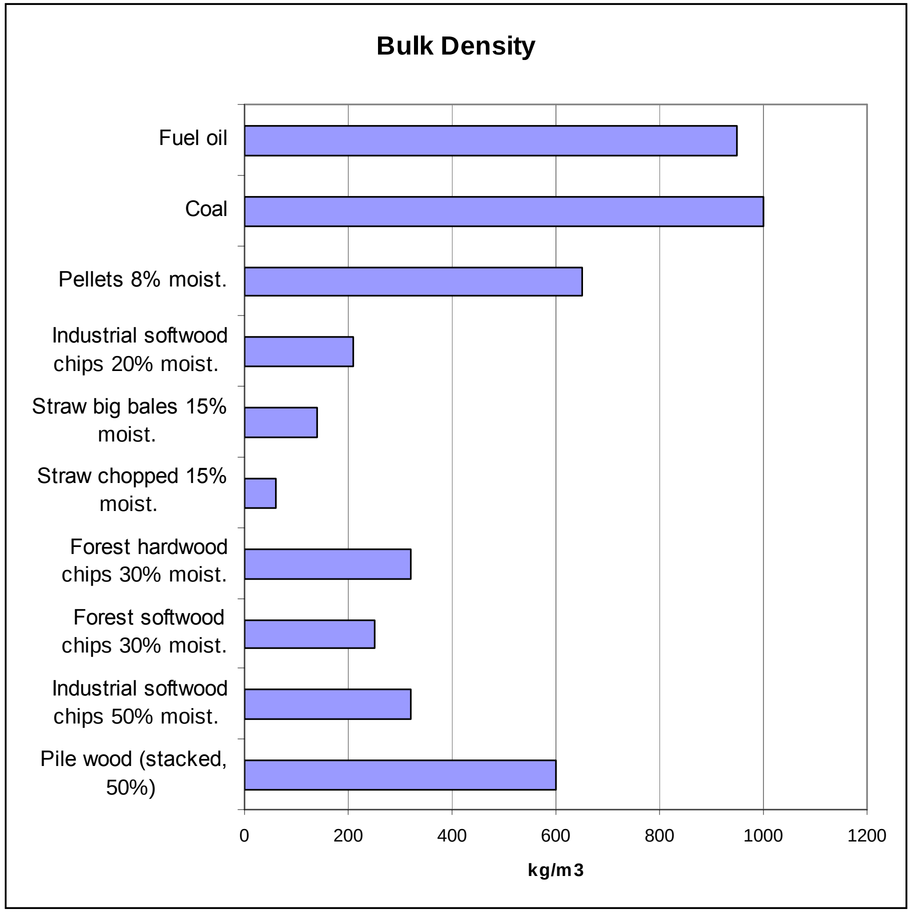
Introduction

Biomass Logistics In Context

Critical characteristics for logistics

Biomass is less dense than fossil fuels in both its energy content and weight

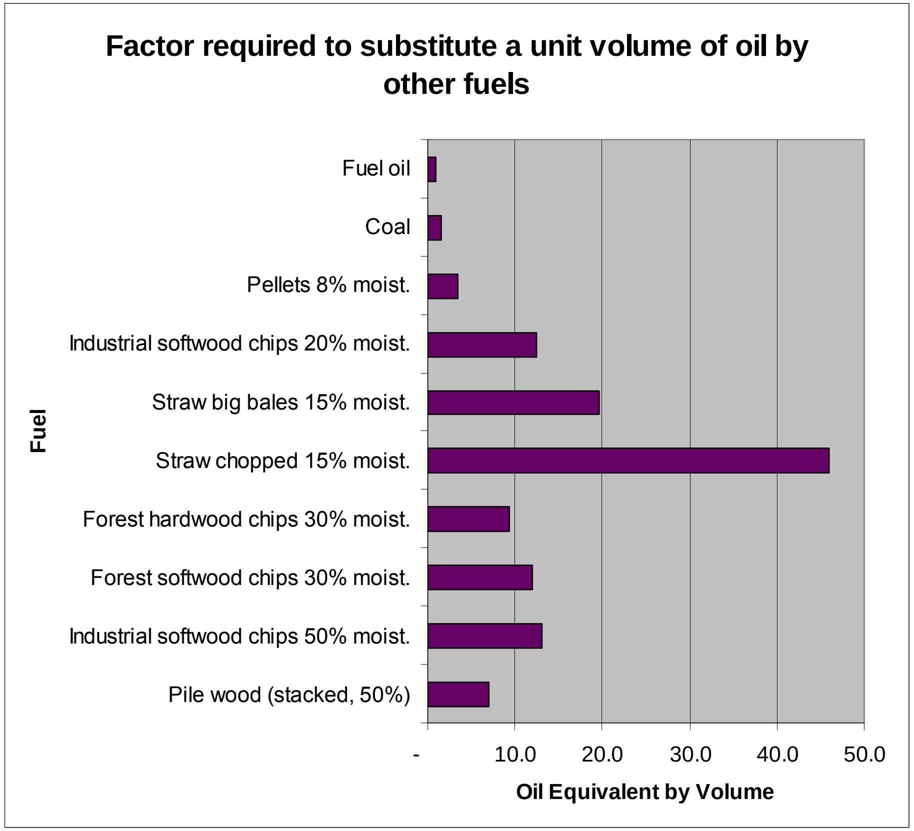


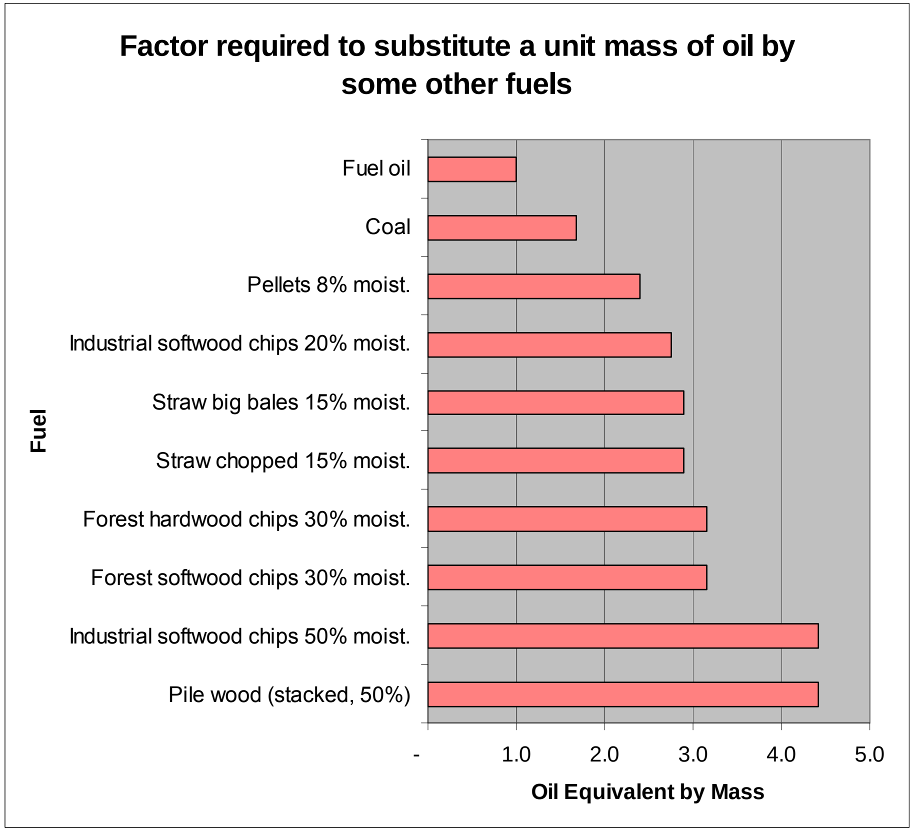


- Biomass contains less energy per tonne than conventional fuels
- A given volume of Biomass is lighter than conventional fuels

Biomass Is A Relatively Demanding Freight Task

Biomass is far more expensive to transport than fossil fuels over a given distance

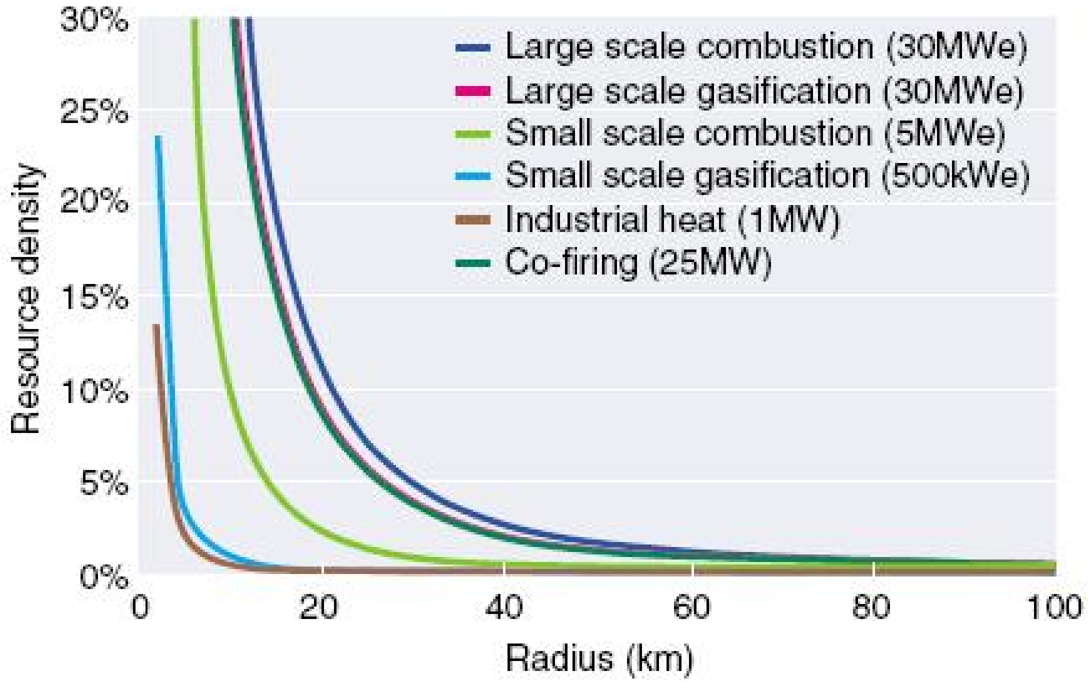




- The tonne of oil equivalent (toe) is a unit of energy: the amount of energy released by burning one tonne of crude oil, approximately 42 GJ (as different crude oils have different calorific values)
- The volume of biomass needed to produce as much energy as the same volume of oil is between 3.5 times (Pellets) and 46 times (Chopped Straw) as great. The weight of biomass needed to produce as much energy as the same weight of oil is between 2.4 times (pellets) and 4.4 times (pile wood and industrial softwood))

Typically – biomass should be converted close to source to minimise logistics costs

Resource densities for biomass stations by collection radius



Source: ROYAL COMMISSION ON ENVIRONMENTAL POLLUTION – BIOMASS AS A RENEWABLE ENERGY SOURCE, Figure 4-II

- In the case of biomass, a higher resource density allows fuel to be sourced close to the plant, leading to lower transport costs and environmental impact. In addition, smaller plants become more viable.

- The resource density is the proportion of land within a specified area that can be used to provide a fuel. For example, a peat power facility that is built on a bog will have a high resource density (e.g. Edenderry Power Plant). In contrast a power facility built away from its primary fuel will have a low resource density. In Ireland, the resource for coal fired stations (Moneypoint) and oil fired stations (Poolbeg) is low, since their fuel is typically transported hundreds of miles from source. As a result, these stations are built on the coast to minimise transportation costs

Biomass Transportation vs. Local Conversion

Some researchers have attempted to quantify the relative benefits of local conversion

Source: Applied Biochemistry and Biotechnology, The Relative Costs of Biomass Energy Transport, Flynn et al

- In terms of minimising logistics costs, it is ideal when both the source of biomass and the demand for the energy produced are in the same region
- Frequently, the source of the biomass is remote from the point of ultimate consumption of the energy. In such instances, it is typically more efficient to convert at source – especially for ethanol production.
- In North America, research suggests that conversion to ethanol and transport by land is the best option. Ethanol pipelines and the construction of electrical plants are also viable – especially for large projects.

Local Conversion is not always possible

Significant transportation and handling activity may be required

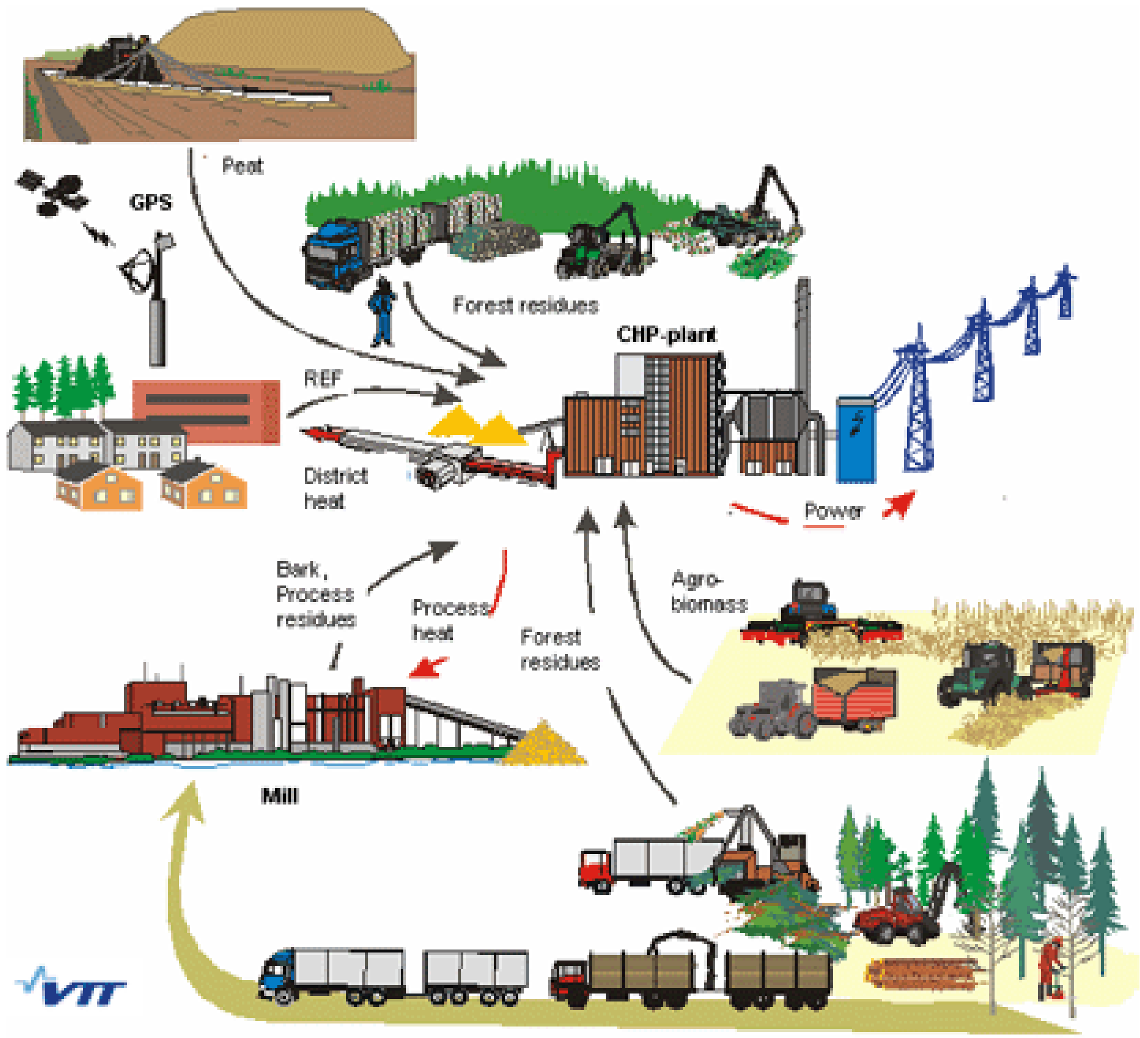
- The resource density may be so low that the conversion plant inevitably lies a long distance from at least some of the feedstock
- Higher prices for feedstock may be available in areas remote from the resource.
- Environmental concerns (e.g. odours and emissions in urban settings from municipal firing plants) may require biomass to be converted in more remote areas
- The biomass may be required for co-fueling at existing plants (e.g. Bord Na Móna peat plants)
- The cost of constructing and staffing and operating a plant remote from population centres and high capacity infrastructure (e.g. transmission)
- Economies of scale: A conversion plant may wish to realise benefits associated with a large scale integrated processing of biomass

Supply Chain Management

Reducing the cost of transport through collection methods and pre-processing

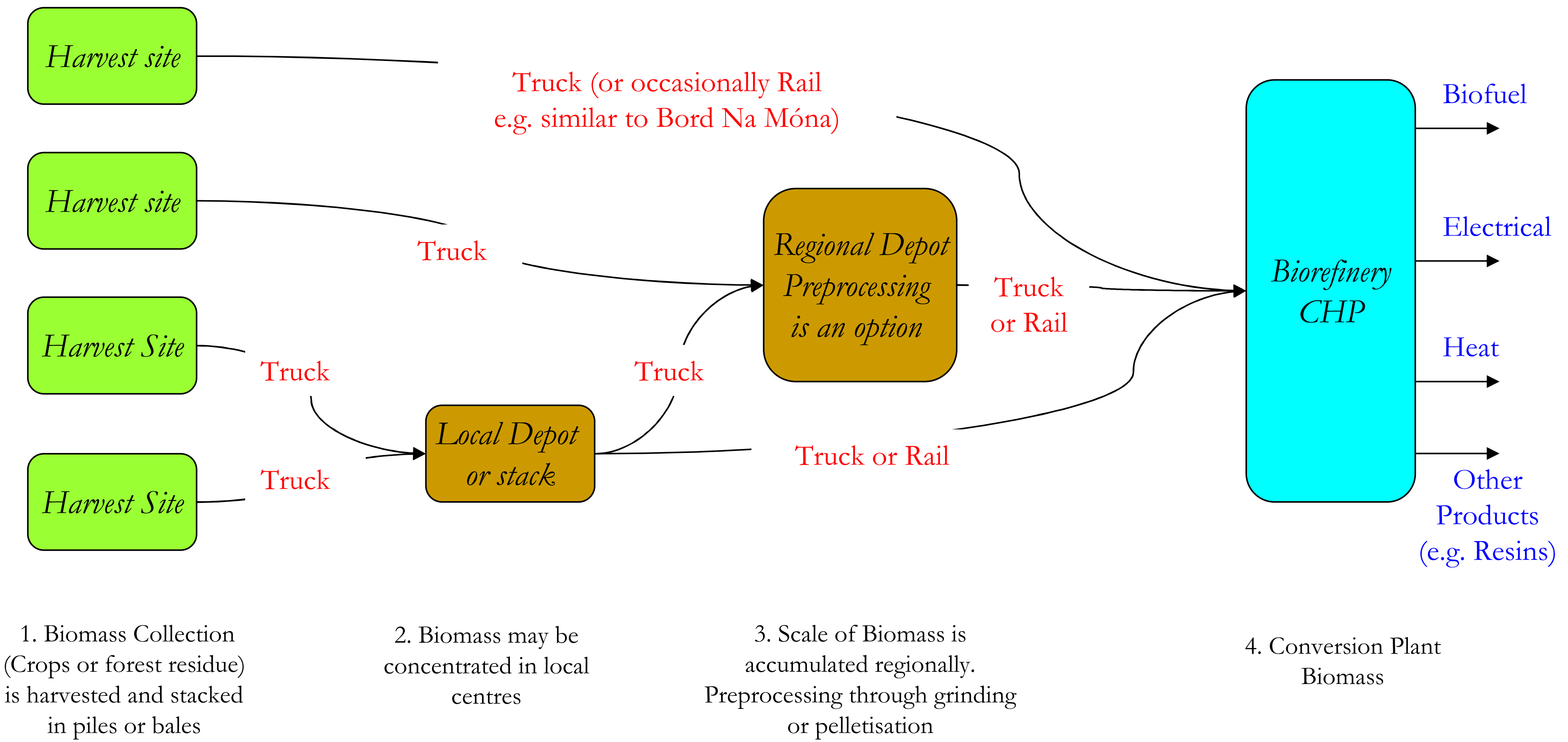
Supply chains are complex

Overview of a Finnish supply chain for wood biomass



Supply Chain (energy crops/ forest residue)

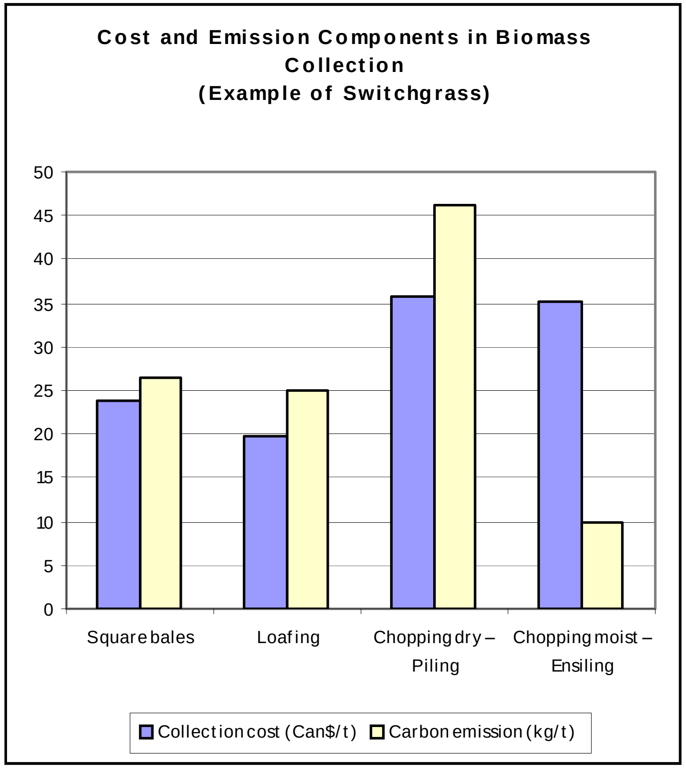
A simplified supply chain highlights the key links in the chain – and the potential for pre-processing



- The point of initial biomass collection may offer opportunities for increasing the density of the feedstock
- As the quantity of biomass builds up in the supply chain, the option of intermediate pre-processing at a regional depot may be viable

Collection Costs: Variation by methodology

Research suggests that the cost and emissions caused by collection varies widely with the method used

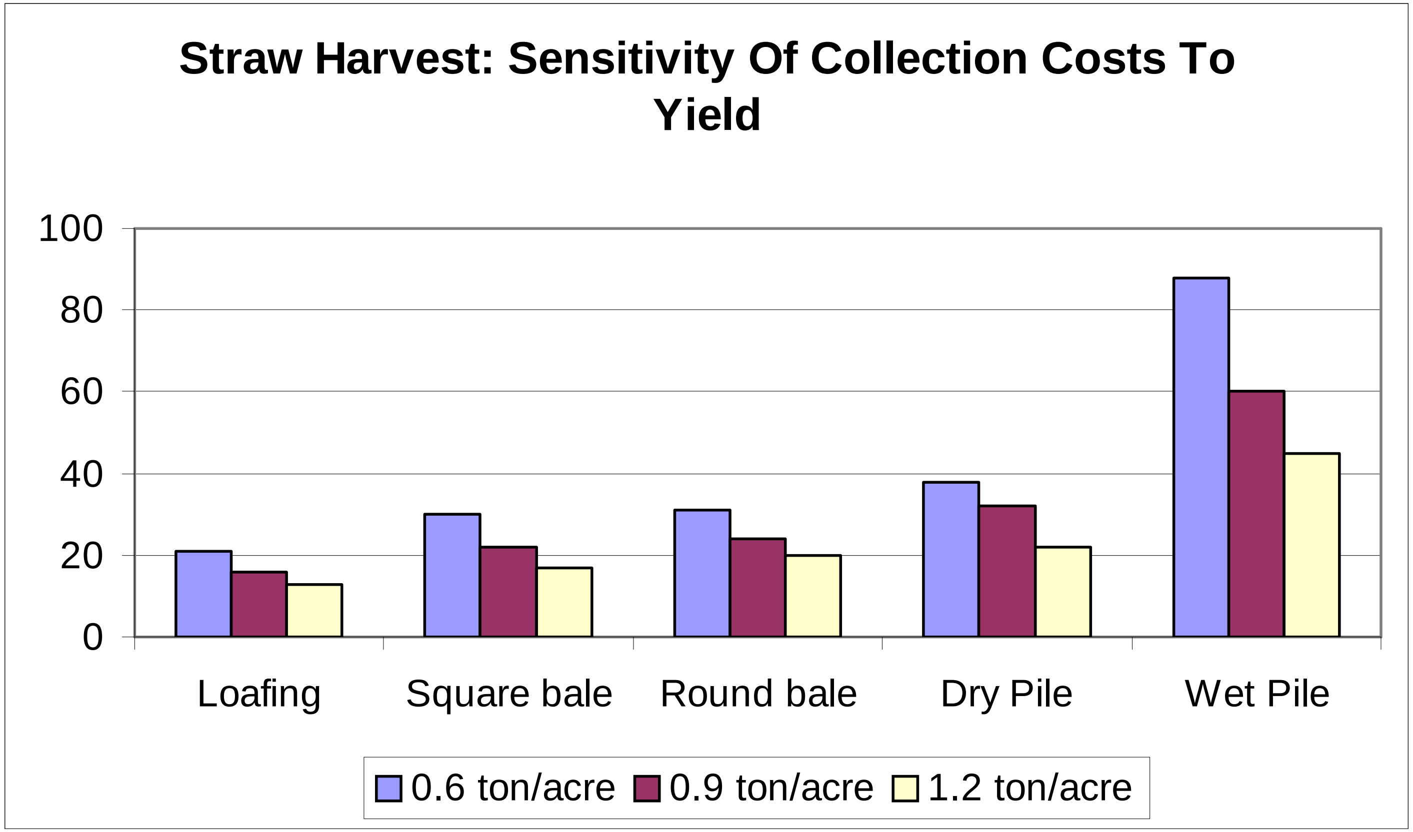


- Collection is the harvesting, packing and transportation to a nearby site for temporary storage. The graph shows the cumulative cost of collecting switch grass using four collection options in Canada. The actual payment for the crop is excluded.
- The low cost of loafing is due to the reduced number of machine operations in collection. Mowing and raking operations are eliminated in silaging collection, but this is offset by the extra cost of the silage pit and packing the silage

Source: Cost-Benefit of biomass supply and pre-processing, Biovap Canada, 2006

Collection Costs: Variation by Yield

Collection costs fall with higher yield



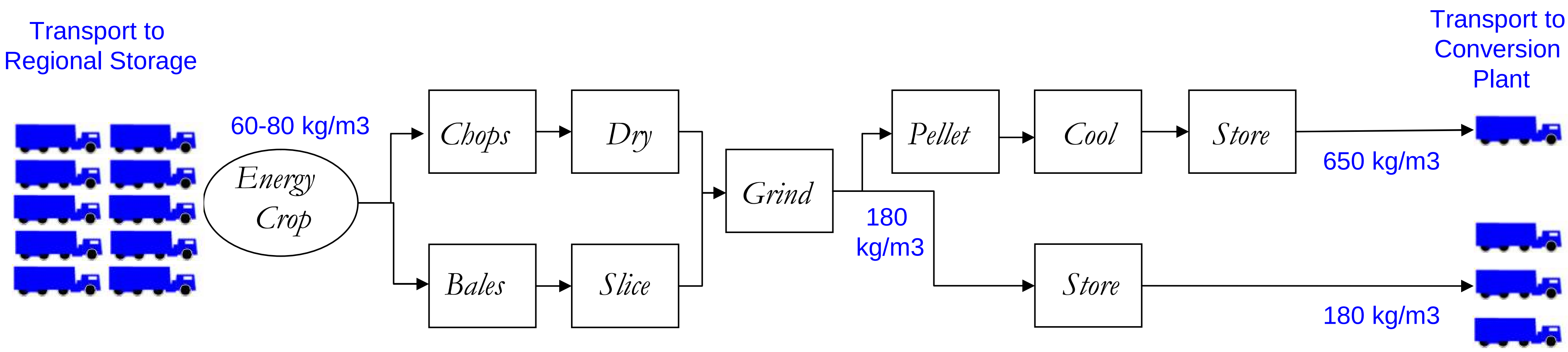
- Not surprisingly, the greater the yield, the more efficient and lower the cost of collection
- The collection of wet piling and ensiling falls particularly sharply with higher yield

Source: BIOMASS FEEDSTOCK INTEGRATION FOR AN EMERGING BIO INDUSTRY IN CANADA NSERC Strategic (2006-2008), University of British Columbia , Shahab Sokhansanj

Pre-processing: increases the specific weight

Increasing density without reducing the energy content makes the biomass cheaper to transport

- Pretreatment seeks to make the biomass material more dense without compromising its energy value. Drying biomass with a high moisture content will reduce its weight. Compacting biomass through baling (at time of collection) and through grinding and pelletisation at a later stage will reduce the volume`.



- The flowchart shows how an energy crop such as straw can be made more dense through pretreatment. This is typically typically carried out in a number of phases. The biomass arrives in relatively low density (60-80kg/m3) at a regional centre, either as chops or bales. This is then prepared for grinding by drying or chopping. Once ground, the density of the biomass increases to about 180kg/m3.
- If the regional centre is a significant distance from the conversion plant then the grindings may be subjected to further densification in the form of pelletisation. This increases density to between 500 and 700 kg/m3 and significantly reduces transportation costs.

Source: Cost-Benefit of biomass supply and pre-processing, Biovap Canada, 2006

Pre-processing costs: e.g. pellet production

Analysis identifies critical costs in pellet production from chopped switchgrass

Table: Cost of biomass pellet production in US$ (2004)

Pellet process operations	Capital cost	Operating cost	Total cost	Total cost	Energy use	Energy use
	($/t)	($/t)	($/t)	% breakdown	(GJ/t)	% breakdown
Drying operation	2.46	7.84	10.3	33.4%	0.35	42.6%
Hammer mill	0.25	0.7	0.95	3.1%	0.1	12.2%
Pellet mill	1.43	1.88	3.31	10.7%	0.268	32.6%
Pellet cooler	0.13	0.21	0.34	1.1%	0.013	1.6%
Screening	0.11	0.05	0.16	0.5%	0.006	0.7%
Packing	0.56	1.37	1.93	6.3%	0.006	0.7%
Pellet Storage	0.07	0.01	0.08	0.3%	0.026	3.2%
Miscellaneous equipment	0.42	0.33	0.76	2.5%	0.052	6.3%
Personnel cost	0	12.74	12.74	41.3%	0	0.0%
Land use & building	0.21	0.05	0.26	0.8%	0	0.0%
Total Cost (including drying)	5.64	25.18	30.83	100.0%	0.821	100.0%
Total Cost (excluding drying)	*3.18*	*17.34*	*20.53*		*0.471*	

Source: Cost-Benefit of biomass supply and pre-processing, Biovap Canada, 2006

Assumptions:

- Capacity of 6t/hr and 45,000t/annum
- Annual utilisation of 85% based on 24hr operation for 310 days

Points of Interest

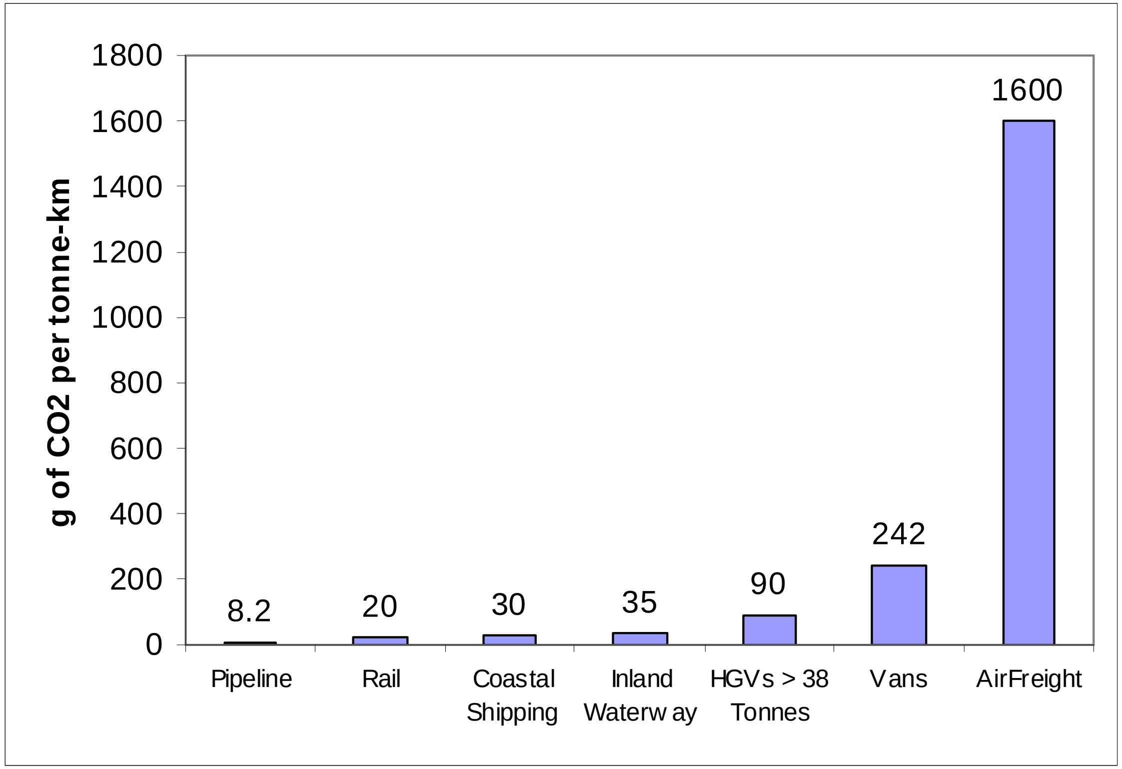
- Drying and pelleting are the most costly part of the process
- The entire energy used in the production of one tonne of pellets (0.821GJ) equates to 5% of the energy content in a tonne of biomass (dry switchgrass). The most energy consuming process is the dryer (42.6%). Next is the pelleting process followed by the grinder.
- If the grinding process occurred at the point of collection then a bulk density of 128kg/m3 could be achieved which would reduce the cost of transport and give almost the same density as baling.

Sustainable Transport

The case for rail and water

Sustainable Transport: CO2 Emissions by Mode per Tonne-km

Estimates for the UK

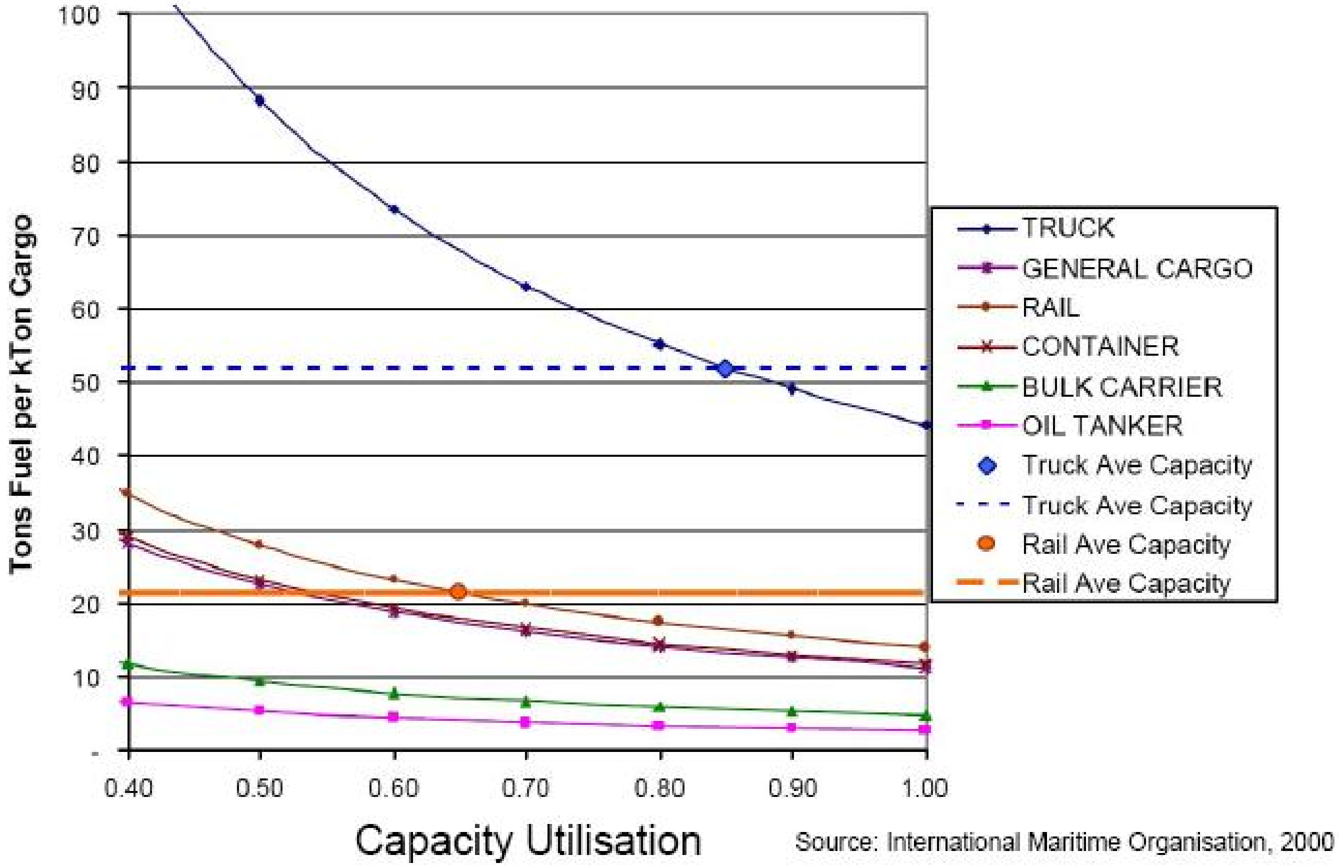


- Pipelines (which can be used to transport products such as wood chip in solution or ethanol) are the most efficient transport mode in terms of CO2 emissions
- Estimates are sensitive to assumptions regarding
  - Line haul capacity versus door to door
  - Capacity utilisation
  - The emissions associated with construction and maintenance

- *Source: CO2 Emissions from Freight Transport in the UK: Report prepared for the Climate Change Working Group of the Commission for Integrated Transport, Professor Alan McKinnon, Logistics Research Centre, Heriot-Watt University*

Introduction

Effect of Capacity Utilisation on Fuel Efficiency of Freight Modes

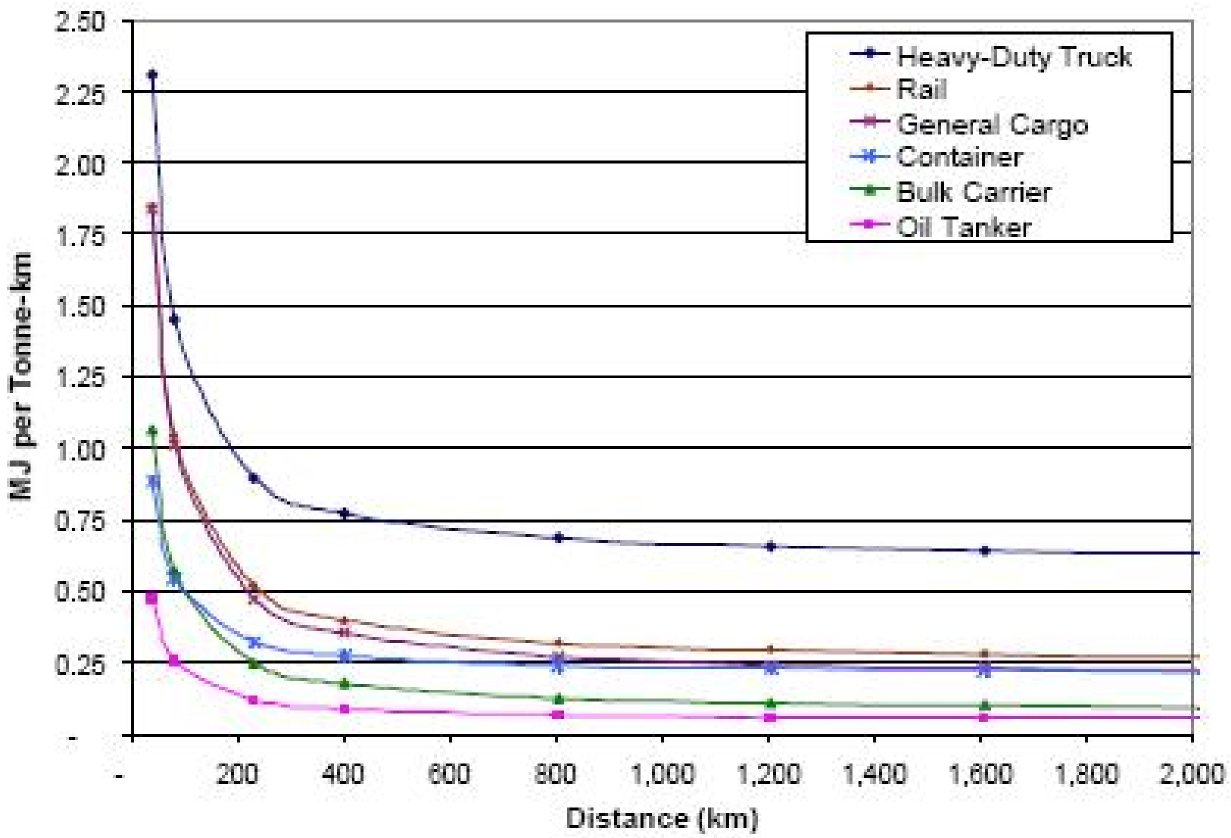


- Using average capacity factors, trucks consume more than twice as much fuel per ktonne as rail.
- Capacity factor has a significant effect on the fuel consumption per ktonne cargo: the effect is greatest for trucks.
- The transport of oil (or other bulk commodities such as ethanol or biomass) by ship is the most fuel efficient

Source: International Maritime Organisation; Study of Greenhouse Gas Emissions From Ships, Fig 4.10, Marintek et al, 2000

Sustainable Transport

Change in Modal Energy Intensity with Variation in Distance Travelled (Model Run with Average Capacity Factor for All Modes)

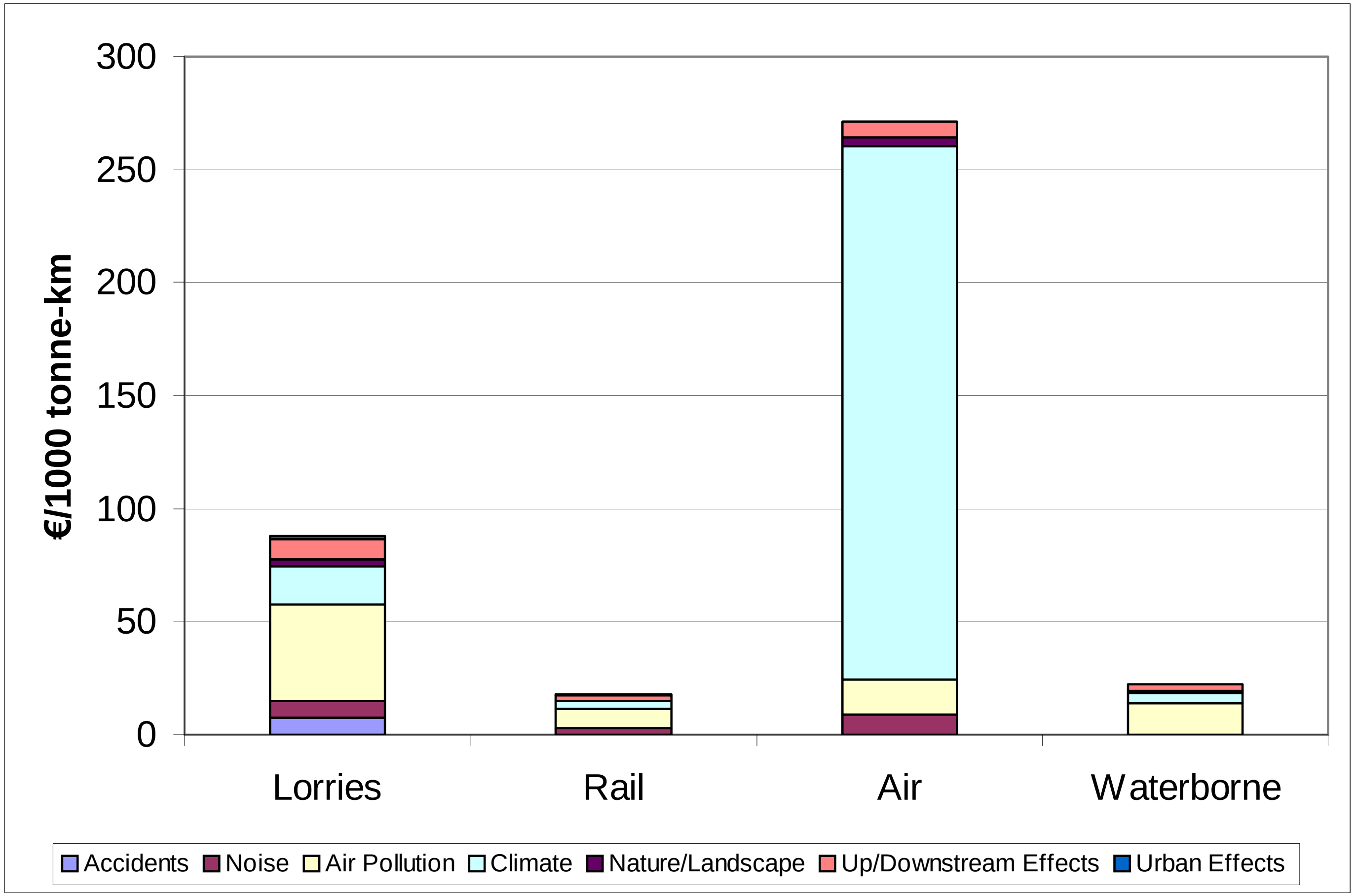


- Energy intensities for each mode vary with distance, where the same cargo moved over shorter distance results in higher energy intensity per tonne-km. This is a result of the greater effect of energy consumed by a vessel, vehicle or train during turn-around on the total energy intensity at shorter distances.
- However, at distances greater than about 500 km, the curves become more linear.

Source: International Maritime Organisation; Study of Greenhouse Gas Emissions From Ships, Fig 4.9, Marintek et al, 2000

Sustainable Transport

Average External Costs of Transport in the EU

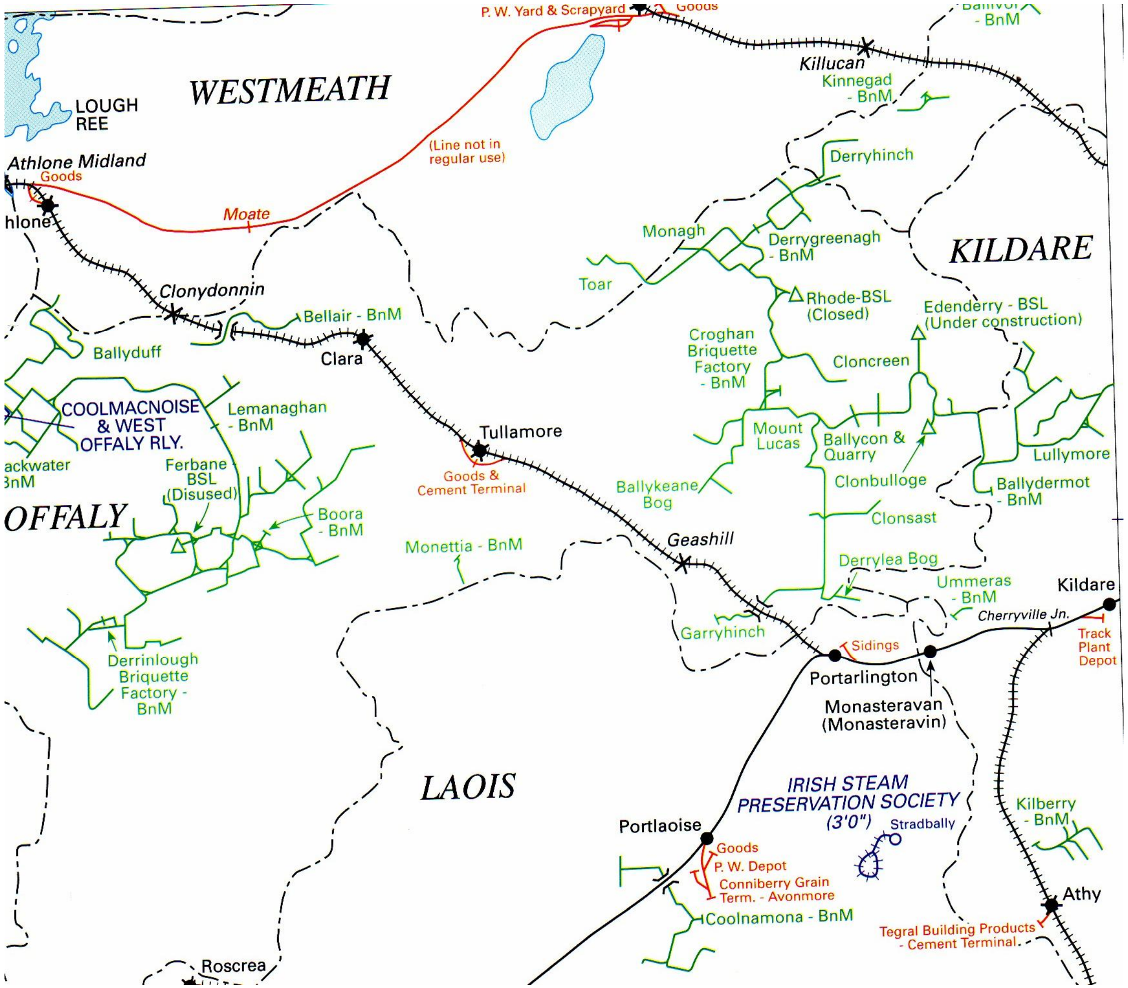


- Private Costs + External Costs = Social Costs
- Private Costs: Costs paid directly by the user for the use of resources e.g. the cost of operating a vehicle. A market price is usually available.
- External costs: Costs that have to be indirectly paid for by third parties e.g. accidents, noise. Often a market price is not available and so a cost has to be imputed (i.e. a shadow price).
- Social Costs (or True Costs): The sum of private and external costs. An optimum allocation of resources occurs where the users of transport are paying the full social cost.

Source:: External Cost of Transport, INFRAS, IWW, 2004

Ireland’s rail-freight infrastructure

Rail freight facilities throughout Ireland are under exploited



The map shows Iarnród Éireann’s rail lines.

Moving freight onto Ireland’s railways is challenging. Market share for rail has fallen from 10% to 1% of freight in the past 15 years. Unlike most of Europe, no separate subsidy for rail freight is ring fenced – instead it is lost in the general subsidy to CIÉ. Rolling Stock is ageing and many depots have been closed.

Iarnród Éireann are not the only rail operators in Ireland. Bord Na Móna already operates Europe’s largest private rail network – with 850km of permanent track and the ability to lay extensive additional sections. The density of the network in Ireland’s bogs is extensive.

Designing for rail at an early stage in a project (e.g. Tara Mines) can insure that rail is the most competitive solution. Retrospective design for rail freight is more difficult.

Source:: OTC Map

Transportation Modes

Factors influencing the choice of transportation mode

Transportation Mode

Factors influencing the choice of transportation mode

The choice of mode is influenced at all stages of the chain by:

Transport costs – road is generally the cheapest for short haul transportation – especially when the external costs are ignored

Absolute scale – the converging and consolidating quantities at the later stages of the supply chain can make certain modes viable (e.g. rail)

Bulk density – the weight and volume of the biomass at a particular point in the supply chain

The distance to the conversion plant – different modes are competitive over different distances

Form of the biomass - the handling and storage requirements

Existing infrastructure – where transportation infrastructure already exists (e.g. storage yards or rail sidings), only the marginal cost of transporting an incremental amount of cargo is typically considered.

Seasonality – supply patterns may mean that large volumes are harvested over a very narrow time frame: this may mean that there is a sharp burst in transport demand, especially if the biomass must be stored at a different point. If demand from the conversion plant is seasonal (e.g. district heating) and on-site storage is not available, there may be a need to transport feedstock from remote locations.

Transportation: Other issues

The choice of transportation

The cost of transportation may not always be incremental:

Example 1: If no alternative use is to be made of forest residues, they can often be left to decompose at or near the site of harvest without any transportation costs being imposed. In this case, the cost of haulage from forest to a conversion plant is entirely incremental.

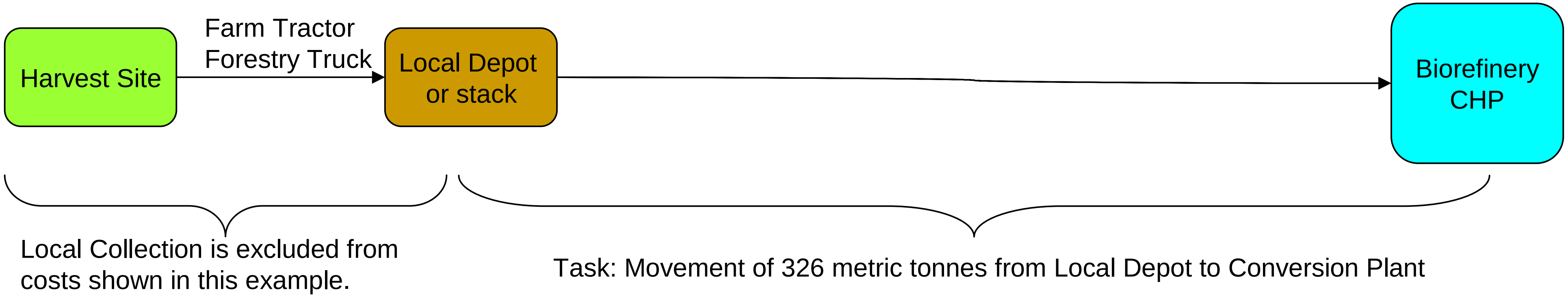
Example 2: For wood sourced from construction waste in municipal areas, transport by road is typically a requirement to move material from construction sites to landfill. Therefore, there may be no additional (or marginal) cost of transportation to divert waste to a centralised, locally located district heating or CHP scheme. Indeed, construction firms may deliver themselves and pay biomass operators to take their waste if it is cheaper than the corresponding waste disposal cost.

Costing Transport Solutions

A worked example

Rail and Road: Example

Consider the task of moving a payload of biomass from a local depot to a conversion plant

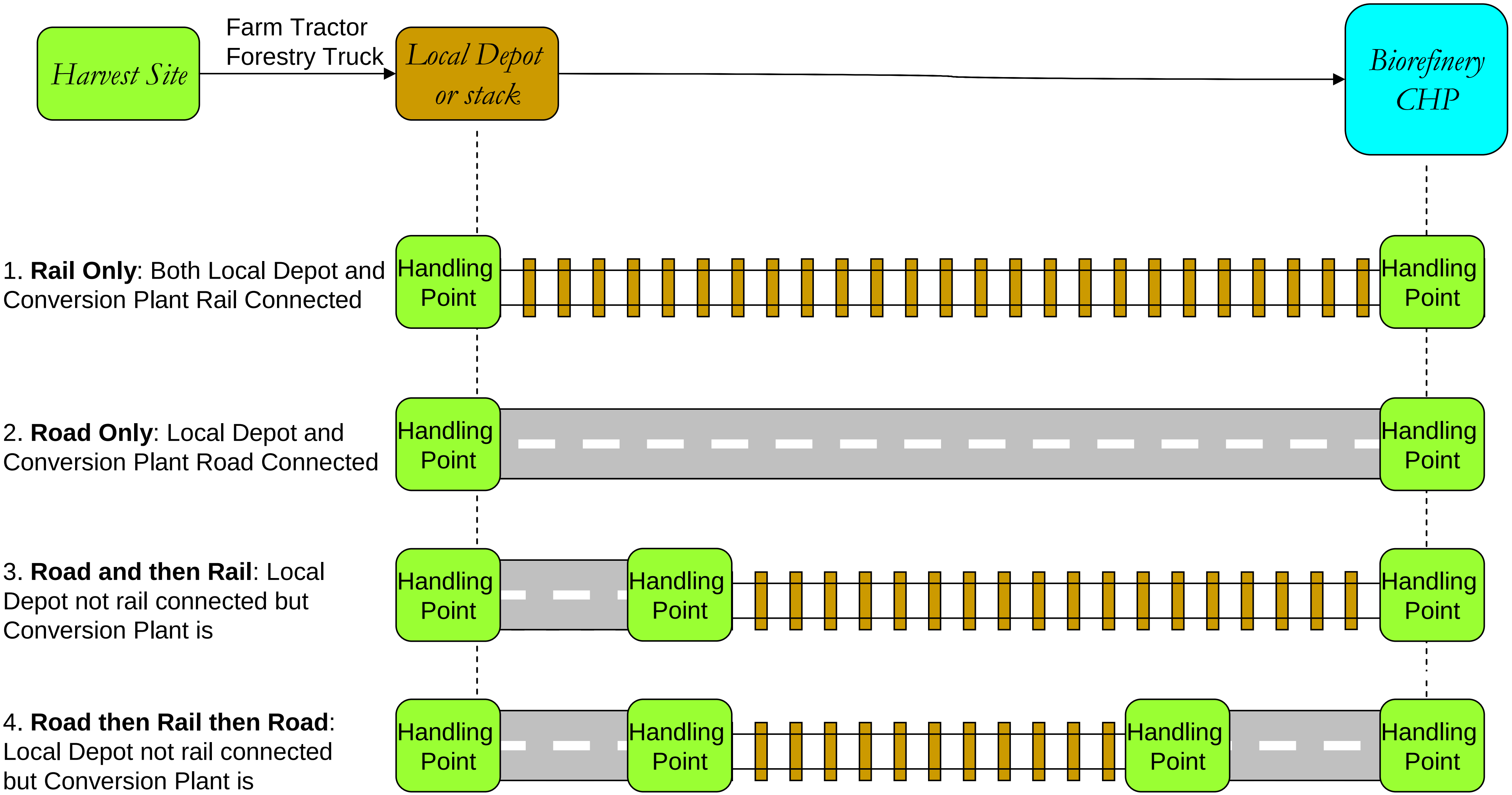


Assumptions:

- The biomass is initially delivered by farm tractor or forestry truck to a local stacking point or depot. It is assumed that this may take place gradually over a number of weeks or months. This collection method is assumed to be common to all scenarios and the relevant cost is not included in the example.
- The total payload under consideration amounts to 326 metric tonnes at a density of 300kg/m3. This payload matches the capacity of a freight train of 18 wagons of 40' length.
- It takes 18 large HGVs (i.e. with 40' beds) to carry the equivalent payload. (Note: If the roads at any part of the journey were not capable of carrying such large trucks then it may be that 36 smaller HGVs were needed. However, this scenario is not considered in this example)
- Multimodal units are not used: i.e. the biomass must be transferred in bulk from one mode to another – it is not packed at the beginning of the journey in containers that can be swapped between truck and train. Such an option might reduce the cost of handling.

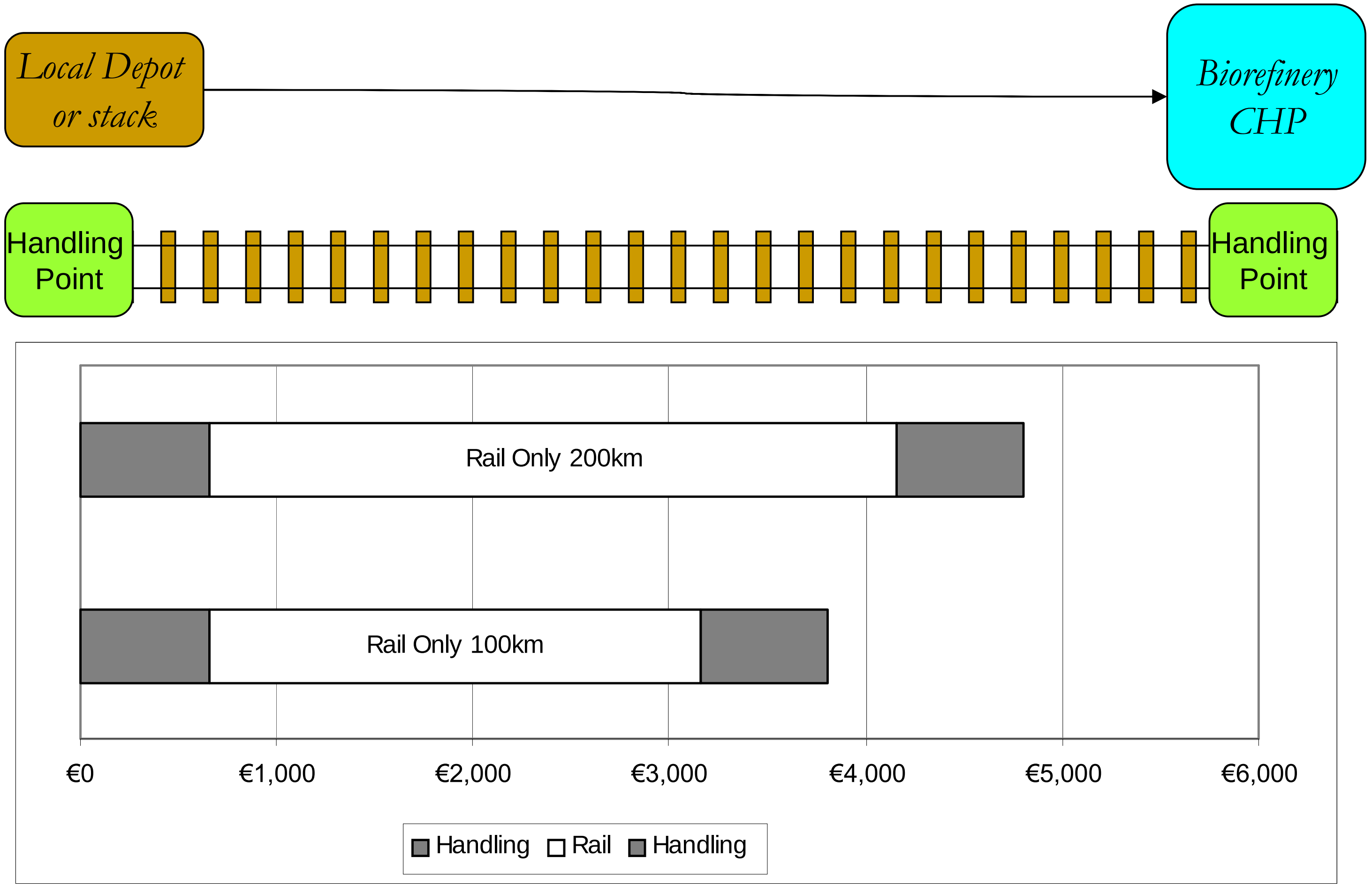
Rail and Road: Potential Transport Options

Key cost drivers are the number of handling points and the distance travelled



Scenarios 1 & 2: Rail Only over 100 and 200km

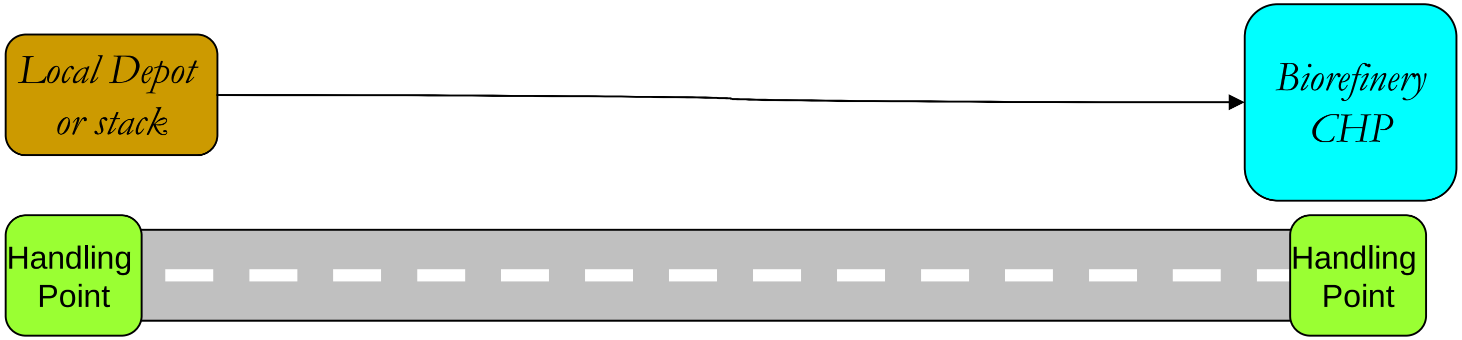
Both Local Depot and Conversion Plant Rail Connected



- Handling is a significant cost but only necessary at both ends of journey
- Rail transport is only modestly more expensive over 200km compared to 100km – high fixed costs but low per km cost

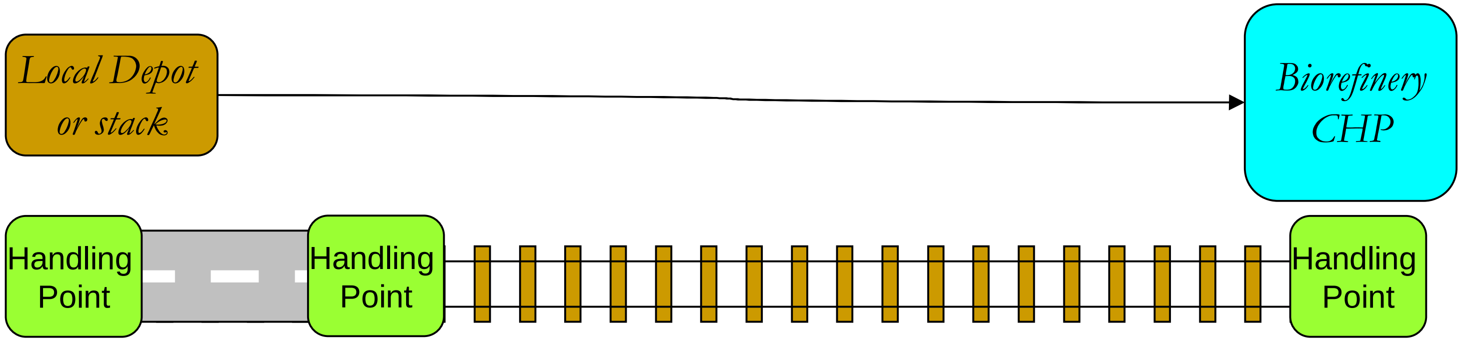
Scenarios 3 & 4: Road only over 100 and 200km

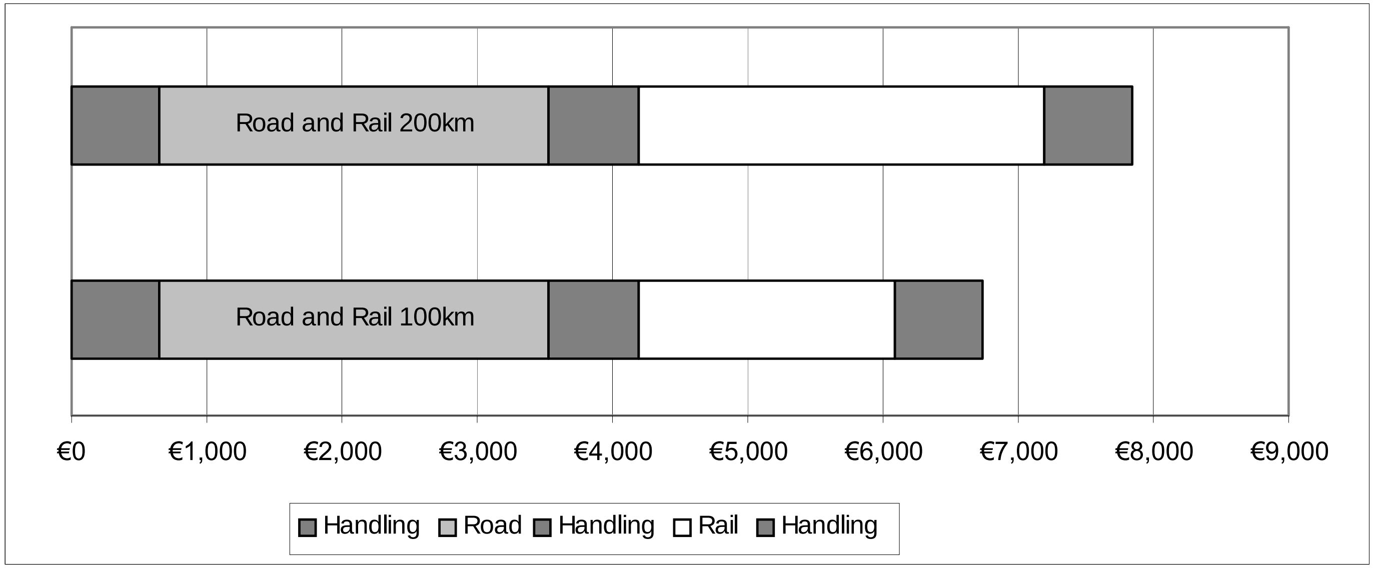
Both Local Depot and Conversion Plant are road connected



- Handling only necessary at both ends of journey
- Road transport increases significantly with distance – low fixed costs compared to rail, but higher per km cost

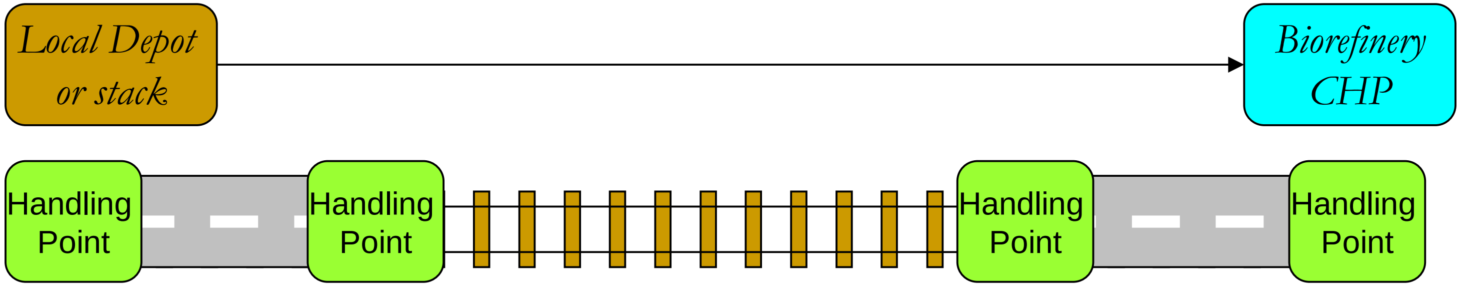
Scenarios 5 & 6: Road then rail over 100 and 200km *The Local Depot is not rail connected, but the Conversion Plant is rail connected*





- A third, intermediate handling activity arises at the transhipment point between road and rail
- Overall transport costs rise as both road and rail costs have fixed elements that are independent of distance

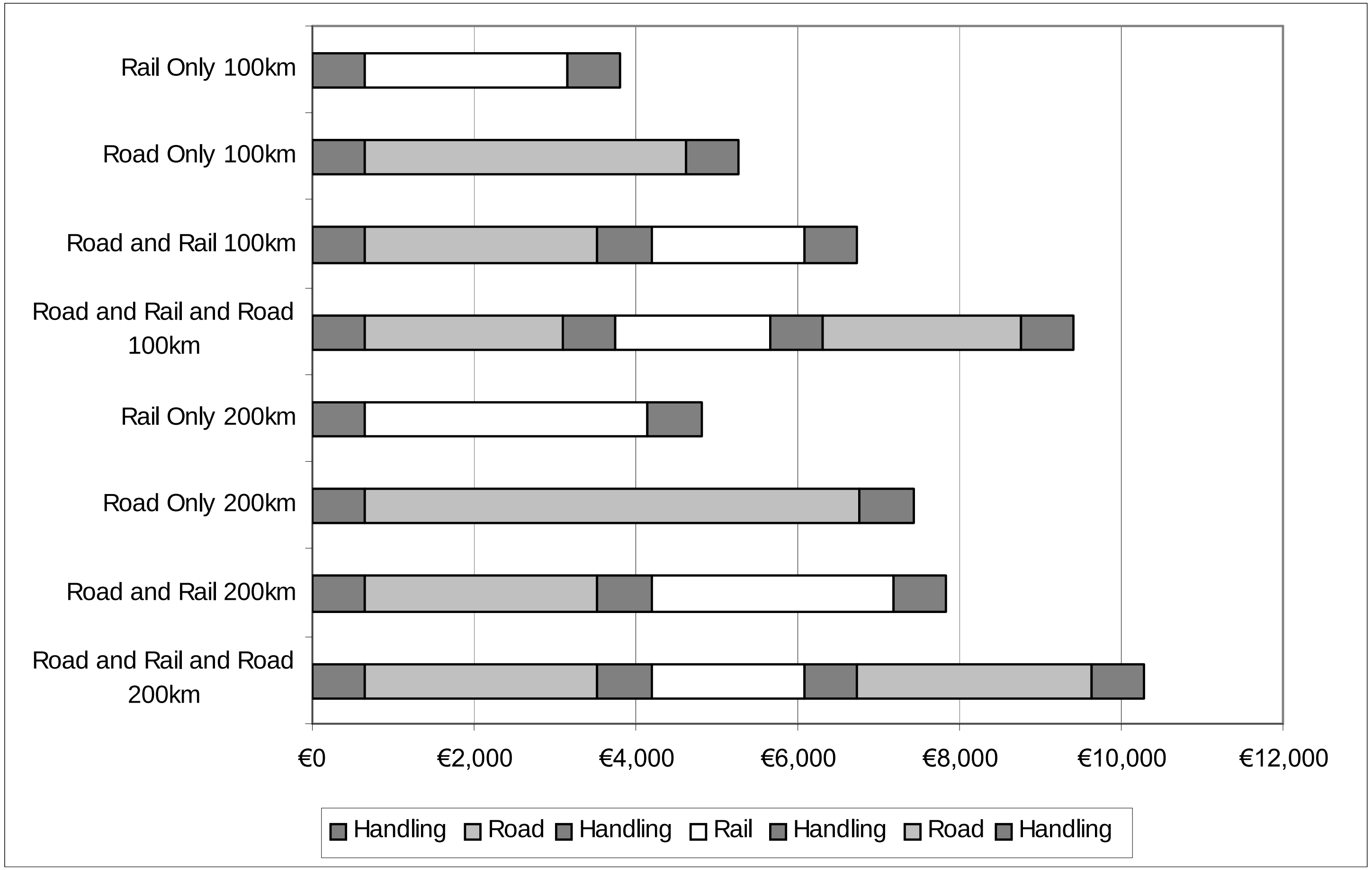
Scenarios 7 & 8: Road then rail then road over 100 and 200km: *Neither the Local Depot or the Conversion Plant is rail connected*



- There are four points of handling activity
- Overall transport costs are very high as changing between modes over relatively short distances carries a penalty

Rail and Road: Comparison of scenarios 1-8

An evaluation of transport options over distances of 100km and 200km



- Direct rail links between the point of biomass collection and a conversion plant can minimise transport costs
- Rail is less competitive when some road haulage is necessary – but less so over longer distances
- Minimising handling activity and costs is important

Innovative Transport Solutions

Alternative options may exist for a fledgling industry

The Freight Multiple Unit (FMU)

A competitive alternative to road for smaller payloads carried with high frequency

Picture: CargoSprinter FMU, Deutsche Bahn AG, Germany

- Traditionally, rail has needed not only distance but large payloads to compete with road haulage. Light weight trains pioneered in Germany and Australia may offer an alternative
- No locomotive: The FMU can be driven from either end. The unit consists of two driving and power units, each fitted with a full width cab and two Volvo truck engines for propulsion, which operate in a push pull mode, with up to seven trailers in between.
- Own weight: 118 tons & Payload max: 160 tons : Half the overall weight of most freight trains
- None currently within the Iarnród Éireann fleet

The use of FMUs for bulk transportation

Trials of transporting forestry products by FMU in Wales have proven the viability

Picture: FMU hauling forest products in Wales, 2006

- FMUs used on trial basis in Wales in 2006
- Timber products transported between Aberystwyth and mill at Kronospan Chirk
- Well suited to frequent trips with smaller payloads

Co firing of biomass at Ireland's peat stations

Is there an opportunity for innovative use of rail freight

- Bord Na Móna owns and operates Edenderry Power Plant. Bord Na Móna also supplies two ESB peat powered stations: West Offaly (Shannonbridge) and Lough Ree (Lanesboro). Proposal already exists to co-fuel Edenderry with Biomass and MBM
- Peat is harvested in the summer and stocks required during the winter are stored at Bord na Móna's harvesting sites, which are close to the plants. The existing logistics infrastructure is based on delivering about 16 trainloads a day to each plant.
- The use of rail freight to transport biomass from various existing railheads to the plant could prove viable.
- In addition, does the transportation of high moisture content fuel in such an efficient manner offer a model for new CHP plants in urban areas?

Summary & Conclusions

- Biomass is relatively expensive to transport compared to fossil fuels. Biomass should usually be converted close to source to minimise logistics costs.

- Local Conversion is not always possible and the significant transportation costs need to be carefully managed

- The choice of collection method, and the incorporation of pre-processing into the supply chain can reduce logistics costs. Drying and pelleting are the most costly part of the densification process: they can equate to 5% of the energy content in the biomass

- Pipelines, rail and water transport are far more sustainable transport modes than road – but road is usually cheaper over short distances. In particular, a direct rail links between the point of biomass collection and a conversion plant can minimise transport costs. Furthermore, minimising handling activity will reduce costs

- Innovative solutions may exist for transporting biomass – especially if they are designed in at an early stage

Further Queries or Clarifications

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