Oil and Natural Gas Logistics

HIGHLIGHTS

■ **OIL LOGISTICS -** Oil logistics include transportation of crude oil from the production sites to refineries as well as transportation and distribution of oil products to the customers. Oil tankers serve the majority of the international trade of crude oil and oil products while pipelines are mostly used for domestic transportation. Rail and trucks are also used for short-distance oil transportation. Larger tankers usually carry crude oil while smaller tankers carry refined petroleum products. Oil tankers are mainly equipped with diesel propulsion. Large tankers use less fuel per km, hence emit less CO_2 compared to smaller tankers. As for pipeline transportation, crude oil is usually piped to refineries and oil products to large customers and distributors. The energy required for pipeline transportation depends inter alia on volumes, pipeline diameter and oil quality. Oil can be stored in land-based tanks and on-board oil tankers for either energy security reasons and profit purposes, the latter based on short-term variations of the oil price.

■ **NATURAL GAS LOGISTICS -** Quantity (volume) and distance are key elements to determine the most suitable and profitable transportation technology for natural gas. For larger volumes pipeline transport is profitable for short to medium distances and liquefied natural gas (LNG) – which has 600 times smaller volume compared to natural gas in gaseous phase - is profitable for larger distances. Several competing technologies including electricity production and compressed natural gas are suitable for small volumes. The LNG technology includes natural gas liquefaction, shipping by fleets, and regasification of natural gas at the receiving terminals. The natural gas is then delivered onshore by e.g. pipelines and distribution networks. The cost of the liquefaction plant has decreased significantly during the past decades due to improved technology and increased plant size. LNG fleets are traditionally fuelled with heavy fuel oil, however diesel propulsion has become more common during the past years. Natural gas can be stored underground and on-board LNG fleets for either energy security and commercial purposes.

■ **POTENTIAL DEVELOPMENTS AND BARRIERS -** Oil and natural gas are dominant components of the present energy system and are expected to remain so for decades. Future developments of oil and gas logistics depend on oil and gas market expansion, energy security and international trade issues. In general, oil and gas importing countries (typically OECD countries) have already mature oil and gas logistic infrastructure, which expansion is only considered for energy security purposes. By contrast, emerging economies such as China and India are quickly expanding their oil and gas infrastructure to meet their growing energy needs. Uncertainties on future developments of oil and gas infrastructure and possible structural changes relate to the impact of future climate policies and the recent focus on reducing greenhouse gas (GHG) emissions. For example – assuming a widespread use of carbon capture and storage (CCS) technologies - LNG fleets could not only be used to supply natural gas to consuming markets but also to transport CO_2 to suitable storage sites. Policies to mitigate greenhouse gas emissions could also lead to the need of CO_2 capture from the LNG liquefaction process as well as in the use of low-carbon fuels (e.g. biodiesel) to fuel both oil tankers and LNG carriers

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OIL LOGISTICS: PERFORMANCE AND COSTS - Oil logistics includes typically transportation of crude oil from the production sites to refineries as well as transportation and distribution of oil products to markets and customers. Oil logistics accounted for between 5% and 10% of the oil market value in 2005 [1]. However, its share of the total oil market declines with increasing oil prices. Technologies for “open-sea” transportation include oil tankers and pipelines, while land transportation is mainly based on pipelines, trains and trucks (for distribution). The majority of international trade is based on open-sea transportation by tankers while pipeline are more used for domestic transportation. The international trade of oil has increased significantly during the last decades and in 2009 has reached the level of 52,930 kilo barrels per day (kb/d) [2]. The Middle East was the largest exporting region, with 18,425 kb/d, i.e. 16,510 kb/d of crude oil and 1915 kb/d of oil products [2].

■ **Open Sea Transport –** Oil tankers for open-sea transport are categorised by the Dead Weight Ton (DWT), i.e. the total weight or mass of cargo, fuel, fresh water, ballast water, provisions, passengers and crew (see Table 1). Larger tankers usually carry crude oil while smaller tankers are used for refined petroleum products. Tankers of less than 100,000 DWT can transport both crude oil and petroleum products [3]. Oil tankers have usually a diesel propulsion system. The specific fuel consumption depends the oil tanker size; larger ships use less fuel per ton-km compared to smaller tankers. Specific fuel consumption and CO_2 emissions for various oil tanker sizes are shown in Table 2; a tanker above 200 kDWT consumes 42% less fuel per ton-km compared to a tanker between 75 and 120 kDWT. The annual availability of an oil tanker depends on speed, loading and service time. A typical speed for an oil tanker is 14 knot = 7.2 m/s [4]. Loading and unloading takes typically 24 hours [5]. The average productivity of tankers, given as tons of oil carried per DWT per year, has decreased from 7.7 ton per DWT\y in 2000 to 6.7 ton per DWT\y in 2008, with 7.1 and 7.5 in 2006 and 2007, respectively [6]. The average age of the oil tankers has also decreased over the past decade. In general, it is higher in developed countries

Please send comments to Pernille.Seljom@ife.no, Author, and to
Giorgio.Simbolotti@enea.it and Giancarlo Tosato (gct@etsap.org), Project Co-ordinators

(18.8 years) than in emerging or developing countries (14.2 years) [6]. As of the 1st of January 2009, the average age of oil tankers worldwide was 17.6 years, of which 22.1% were 0-4 year old, 14.8% 5-9 y, 11.1% 10-14 y, 12.2% 15-19 y and 39.7% 20+ year old [6]. The average age of wrecked tankers in the period 1998 to 2008 was 29.1 years, with age ranging from 31.5 years in 1999 to 26.2 in 2005 [6]. In 2000, the number of new delivered oil tankers was 154 while in 2008 it was 437 [6]. Their average size has decreased from 135 kDWT in 2000 to 77 kDWT in 2008 [6]. Also, the oil tanker surplus in the market has decreased since 1990 with 15.4 % to 13.5 % in 2008 [6]. The surplus in the market is correlated with the oil tanker price since the surplus indicates the actual demand for the tankers.

Typical prices for new-built tankers of different size from 1995 to 2008 are show in Table 3. From 2000 to 2007 the price increased steadily for all three tank sizes. The increasing prices reflect to some extent the increased demand for oil tankers during the last years.

■ **Pipeline Transport –** Crude oil is piped to refineries and oil products are piped to customers and distributors. Oil pipelines are usually made of steel or synthetic (plastic) materials and have an inner diameter between 4 to 48 inches (100 – 1200 mm) [7]. The capacity of oil pipelines varies widely; for example, the Norwegian Norpipe export pipeline has a capacity of 900,000 barrels per day (b/d) [8] and the Novorossiysk pipeline (from Chechnya to Novorossiisk, Russia) has a capacity of 100,000 b/d [9]. The oil flow, with typical speed of 1 to 6 m/s, is ensured by pump stations located along the pipeline [10] approximately every 32 to 160 km for onshore pipelines (depending on design, topography and capacity) [11]. Pumps can be driven by electric motors, diesel motors and gas turbines. The energy consumed by the oil pumps corresponds to about 0.5% of the energy transported [12]. The pressure drop in the pipeline depends on the oil viscosity, the roughness of the pipeline and the topography. Since the viscosity is a function of temperature, the pumping requirement is higher in areas with a cold climate compared to areas with a warm climate. Figure 1 show the pressure drop of a pipeline with an inner diameter of 6 inches for oil viscosity ranging from 100 to 600 Saybolt universal seconds. The typical lifetime of oil pipelines is 25 to 40 years [8].

Cost estimates for proposed oil pipeline projects in the United States (2008 and 2009) are shown in Table 4 where *Miscellaneous* cost stands for engineering, freight, taxes, supervision, etc., and *ROW* cost include rights-of-way costs and damage allowance. Estimates are based on 21 onshore projects, with an average cost of US$ 2,316,000 per km in 2009 [13]. The cost depends on pipeline length and terrain characteristics. Usually, the specific cost of a pipeline ($/km) decreases for longer pipelines and increases for pipelines crossing populated areas or challenging terrains.

Table 1 – Oil tanker categories [3]

Ship definitions	Dead Weight Ton
Panamax	50,000 – 80,000
Aframax	80,000 – 119,000
Suezmax	120,000 – 150,000
Very Large Crude Carrier (VLCC)	150,000 – 320,000
Ultra Large Crude Carrier (ULCC)	>320,000

Tab. 2 –Fuel Consumption and CO_2 Emissions of Oil Tankers, [4]

Size (kDWT)	Average weight (kDWT)	Average distance (km)	Fuel consump. (gr/t-km)	CO_2 emission (gr/t-km)
> 200	303	9000	2.2	3.8
120-200	155	5500	2.3	4.1
75 -120	98	2000	3.8	6.6

Table 3 – Prices of new built tankers, million USD, [6]

Vessel size	1995	2000	2005	2006	2007	2008
45 kDWT	34	29	43	47	52	48
110 kDWT	43	41	58	81	72	76
300 kDWT	85	76	120	130	145	151

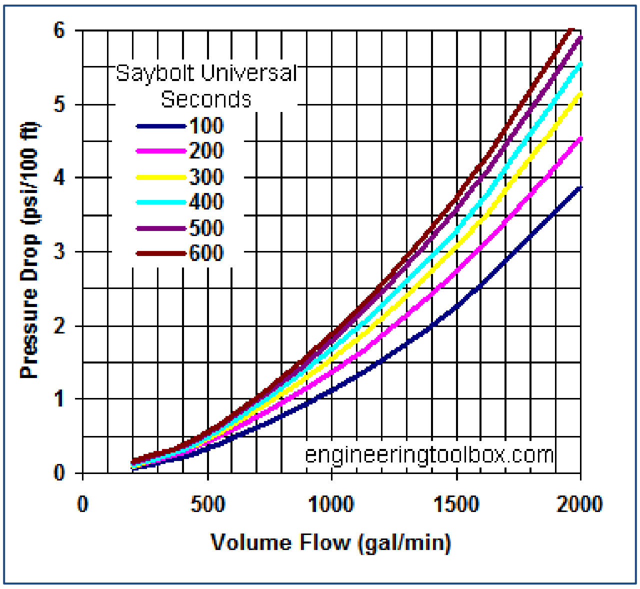

Figure 1 – Pressure drop in 6’’-inner-dia oil pipelines [12]

■ **Railway and Truck Transport –** Crude oil and oil products are transported by motor vehicles (tank trucks) and by rail (railroad tank car). Tank trucks are often used to transport crude oil from smaller producing wells to refineries or to distribution pipelines. A modern railroad tank car can contain up to 1.31 million litres, and the size of a tank truck typically varies from 1900 litres to 53,200 litres [14]. The energy consumed for railway transportation is about 1.0% of the energy transported. For transportation by trucks the energy consumption is about 3.2% [12].

Please send comments to Pernille.Seljom@ife.no, Author, and to
Giorgio.Simbolotti@enea.it and Giancarlo Tosato (gct@etsap.org), Project Co-ordinators

■ **Oil Storage –** Crude oil and oil products are stored in shallow or underground storage tanks, and in oil tankers. Oil tanks are normally located close to oil refineries or to oil terminals accessible to tankers. Storage in oil tankers usually occurs if there is a significant difference between the current oil price and the price expected in a near future. At the beginning of 2010, almost 140 million barrels of crude oil and oil products were stored in oil tankers [15]. In oil importing countries, oil is also stored for energy security and emergency purposes as well as to reduce vulnerability to market price fluctuations. For example, the Chinese government plans to build up enough oil storage to cover 90 days of domestic demand [15]. This is also the level of strategic petroleum reserves that is required by the European Union (EU) and by the International Energy Agency (IEA) to their Member Countries to deal with oil market emergencies [16].

Gas Logistics: Performance and Costs -

After natural gas is extracted from the well, it is processed to remove heavier hydrocarbons and impurities, and to produce dry, pipeline-quality natural gas that meets international sales specifications. It is mainly the distance and the quantities that determine the most profitable transportation technology for natural gas. Figure 2 shows the capacity-distance diagram for various natural gas transportation technologies. The overlap in Figure 2 reflects the external conditions that may affect the choice of the transportation technology. For large volumes (> 1 billion cubic metre, bcm) pipeline transport is profitable for shorter distances while liquefied natural gas (LNG) is most suitable for open-sea distances above 1000 km. In Norway, offshore pipelines are in general considered appropriate for large-volume transport over distances of less than 1000 km [17]. However, natural-gas pipelines are also used for longer distance (> 1000 km). For small volumes and long distances, an option to be considered is the refinery process that converts natural gas into liquid hydrocarbons such as gasoline and diesel (i.e. gas-to-liquid process, GTL). For small volumes and short distances, options to consider include compressed natural gas (CNG), gas-to-wire (GTW, i.e. the conversion of natural gas into electricity by a power plant or an engine), as well as the potential of natural gas hydrates (natural gas trapped in water ice structures). Pipeline and LNG transportation dominate the international trade of natural gas whereas pipelines dominate the domestic transport. In 2008 the international trade of natural gas consisted of 877 bcm by pipeline and 243 bcm by LNG [2]. In spite of the considerable energy required for the liquefaction process, LNG transport is cheaper for larger distances thanks to the 600-time smaller volume to be handled in comparison with natural gas in gaseous phase.

■ **Liquefied Natural Gas (LNG) –** The LNG chain is illustrated in Figure 3. Natural gas is first liquefied and then loaded and shipped to the receiving terminals where it is unloaded, re-gasified and distributed by pipelines to end-users, which include private customers, householders, office buildings, industry and power plants. Due to the large investment in liquefaction plants, shipping fleets, regasification terminals, and the energy involved in the process, LNG is the technology of choice only for large quantities of natural gas over large open-sea distances.

Tab. 4 – Average oil pipeline costs of projects proposed in the United States [13]

1000 US$ per km	2008	2009
Materials	650	815
Labour	835	879
Miscellaneous	520	471
ROW & damages	96	151
Total	**2101**	**2316**

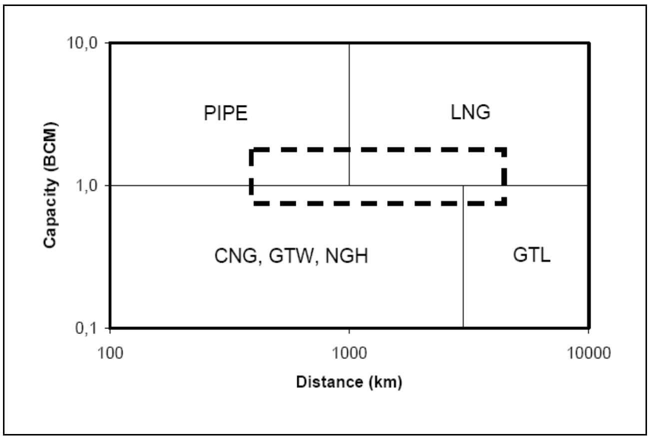

Figure 2 – Capacity-Distance Diagram for Natural Gas Transportation Technologies [17]

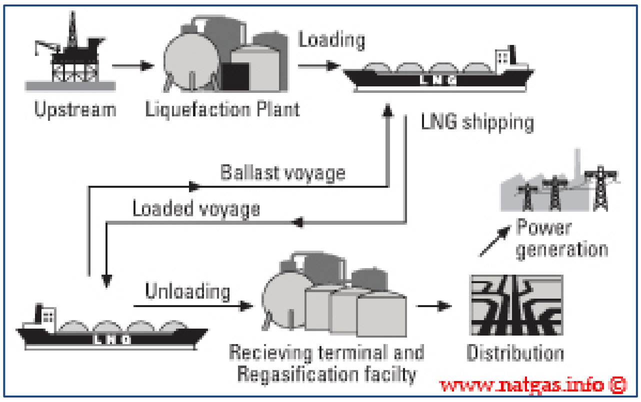

Figure 3 – The LNG chain

Liquefaction Plants – The first step of the liquefaction process is the removal of natural gas impurities (S, CO_2, H_2O, O_2) and the recovery of natural gas liquids (NGL, i.e. heavy gaseous hydrocarbons like ethane, propane, butane) that are often mixed with methane in natural gas resources. Natural gas is then cooled and liquefied at -162°C using a refrigerant cycle. This process is energy

Please send comments to Pernille.Seljom@ife.no, Author, and to
Giorgio.Simbolotti@enea.it and Giancarlo Tosato (gct@etsap.org), Project Co-ordinators

intensive and the power to the refrigerant cycle is usually provided by natural gas fired in gas turbines. The efficiency of the process mainly depends on turbines and heat exchangers efficiency. The natural gas needed for the refrigerant cycle is approximately 15% of the natural gas input (11% in future liquefaction plants) [18].

The most expensive component in the LNG value chain is the liquefaction plant, which cost has decreased significantly during the past decades due to technology improvements and increasing size. A typical cost breakdown for the LNG chain includes 15-20% for exploration and production, 30-45% for liquefaction, 10-30% for shipping and 15- 25% for distribution [19], with actual values depending on technology choices, transportation distances and production scale. The typical investment cost of a LNG plant per unit of capacity is given in Table 5 as US dollars per million British Thermal Units of LNG per year ($/MMBtu-y). Table 5 also includes the cost of LNG storage capacities and presents the cost evolution over time. Future costs are estimated to be around $ 2.9 per MMBtu-y [20]. A typical lifetime of a LNG plant is 25 years, and the construction time is 4 years. The operation cost (excluding fuel) is in the order of €7800 per ton LNG) [21].

Shipping Fleets – After the liquefaction, the LNG is shipped by LNG tankers. While modern oil tankers are mostly been equipped with diesel propulsion systems, LNG fleets are mainly equipped with steam-turbine systems fuelled with heavy fuel oil (HFO). This is because the steam propulsion systems can cheaply and easily use the boil-off gas (BOG i.e. evaporated LNG losses). The steam propulsion technology has, however, lower fuel efficiencies and higher CO_2 emissions than diesel engines. Recent technology developments have made diesel propulsion suitable for LNG carriers and it is expected that in the future an increasing number of LNG ships will be equipped with diesel propulsion systems. Among the LNG propulsion systems on order in 2005 for vessel capacities above 150,000 m^3, 27% were based on HFO-fired steam-turbines, 24% on low-speed diesel, and 39% on dual fuel/electric-power systems [22]. The low-speed diesel engine includes a re-gasification plant to return the BOG to the cargo. The main advantage of this system is the reduced LNG losses. The first vessel of this type was ordered in February 2004 [22]. Another option is based on dual fuel electric engines that are able to run either in gas mode or in diesel mode. The engine has lower fuel consumption than steam turbines. The first vessel of this type was ordered in February 2002 [22].

From 1965 to 1975 almost all fleets were under 100,000 m^3 capacity while from 1975 onward the fleets with capacities above 100,000 m^3 have gained a dominant role, with standard LNG capacity from 125,000 m^3 to 155,000 m^3 [23]. Among fleets delivered in 2009, 8 were above 250,000 m^3, 6 between 200,000 and 250,000 m^3, and 28 fleets between 100,000 and 200,000 m^3 [23].

Table 5 – LNG plant investment cost over time [21], US$ (2005) per MMBtu-y

1988	1993	1998	2001	2003
10.6	9.2	5.0	4.0	3.8

Table 6 – Price of a new 150,000 m^3 LNG ships, [6]

Year	1985	1990	2000	2005	2006	2007	2008
US$ 10^6	200	225	165	205	220	220	245

The number of vessels has increased exponentially from 2002 onward reaching over 50 LNG fleets in 2008 [24]. The average lifetime of a commercial vessel is 25 years. Diesel engines have a lifetime significantly longer than steam turbine propulsion. Low-speed diesel engine has a lifetime of up to 40 years [5]. Shipping accounts for between 10% and 30% of the delivered value of LNG (depending on distance between resources and markets), compared to less than 10% for oil. This is basically due to the relatively high LNG ship manufactory costs [25]. Table 6 shows the price for a new built 150,000 m^3 LNG ship from 1985 to 2008. In such LNG carriers, diesel engines have an additional cost of $1-2 million compared to steam turbine propulsion [26]. The operating costs for LNG fleets with steam and dual fuel diesel propulsion are shown in Table 7 for loaded and ballast conditions. The steam turbine propulsion offers the advantage of almost no operating costs while the dual fuel electric option involves maintenance and system oil costs that are higher for loaded conditions compared to ballast conditions. The cylinder oil (lubricant for dual fuel engine) cost is independent on the operating conditions. Table 8 shows the fuel consumption and corresponding CO_2 emissions for a 150,000 m^3 fleet with steam and dual fuel propulsion. For loaded conditions, the CO_2 emissions are 33% less for diesel propulsion compared to steam propulsion. A typical speed for a LNG fleet is 20 knot (10.3 m/s). Loading and unloading processes take typically 24 h [5].

Re-gasification Plants – The cost of the re-gasification plant depends significantly on the site and is highly influenced by the type and capacity of the storage tank, which accounts for between 33% and 50% of the total cost [27]. The thermal insulation of the storage tanks is usually insufficient to avoid a significant evaporation (boil off) of natural gas. Even with a very good insulation, a continuous removal of a small amount of boil-off gas is required to maintain the required temperature. The extracted gas is often compressed and fed to the natural gas network. The typical capital cost of a re-gasification plant is estimated at $ 75 million per ton LNG for greenfield projects (with no constraint imposed by prior work) and $ 45 million per ton LNG for expansion projects [28]. The operating cost amounts to around 4% of the capital cost per year. The plant availability is about 340 days per year), with average process losses of 2.5% [28].

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Giorgio.Simbolotti@enea.it and Giancarlo Tosato (gct@etsap.org), Project Co-ordinators

■ **Pipeline Transport –** Many of the current onshore natural gas pipelines are made of X70 grades steel material and work at an operating pressure under 75 bar. Using higher grade steel (X80 and X100) enables higher operating pressures and the transportation of higher volumes of gas, with reduced pumping energy. The Europipe II offshore pipeline from Norway to Germany which was built in 1996, is the first pipeline using X-80 grade steel [29]. Figure 4 shows the pipeline transportation cost for a 1000-km pipeline depending on capacity and steel grade. The transportation cost for such a distance can be reduced by 20% using X-100 instead of X-70. For 20 bcm per year and 1000-km distance the pipeline transportation cost is $0.47/MMBtu using X-70 and $ 0.8/MMBTu with X-100. On the other hand, high pressure can result in formation of natural gas hydrates that are solid gas molecules surrounded by a lattice of water molecules. Hydrates originate from water and natural gas (usually methane) at high pressures and low temperatures, and their dissociation involves rather a slow process. In natural gas pipelines, hydrates formation is highly undesirable as it can result in ice-like plugs and prevent a continuous and steady flow. The flow of pressurised natural gas through pipelines involves pressure drop due to friction of the gas against the pipeline wall. To maintain the required gas pressure and flow, gas compression stations are installed along onshore pipelines every 65 to 160 km [30]. The energy required for compression can be provided by the natural gas itself or by an external energy source (electricity). The energy needed for compression (pumping power) for a 1000-km pipeline corresponds to about 1.8% of the energy transported in Europe and 2.7 % per 1000 km in the Russian Federation [32]. Natural gas compressors are important components of the pipelines. In 2008-2009, the average cost for onshore compression projects was $1484 per kW [13]. As far as natural gas leakage rate (from pipelines) is concerned, highest values are reported for Russian pipelines, with estimated rate of 1.4% per 6000 km [32]. A typical lifetime of a gas pipeline is between 30 and 50 years [8]. In Norway there are seven natural gas export pipelines with a total length of 4954 km, including the 1200-km Langeled pipeline which started operation in October 2007 [8]. In 2007, the total pipeline natural gas export totalled 86.7 bcm, with an operation cost of 4101 thousand NOK [31].

■ **Gas Storage Facilities –** The worldwide underground gas storage (UGS) capacity amounts to about 352 bcm in some 630 facilities [33]. According to the UGS data bank, the United States has the largest share (31%) of storage capacity, Russia follows with 27%, Asia Pacific with only 1% while Africa and Middle East have no underground storage capacity. UGS facilities consist basically of depleted oil and gas fields (83%), salt caverns (12%) and aquifers [33]. Base-load storage in depleted gas reservoirs is used to meet the variable seasonal demand for natural gas whereas salt caverns are mostly used to meet peak load demand [35]. Similarly to oil, natural gas can also be stored on board LNG fleets. When the LNG price is temporary low fleets are tanked up waiting for short-time price increase.

Table 7 – Operating cost for loaded and ballast conditions (with no fuel cost) for steam turbine and dual fuel electric propulsion, US$/h [5]

Maintenance	Steam Turbine	Dual fuel electric
Loaded	0	38.6
Ballast	0	35.9
System Oil		
Loaded	0	7.3
Ballast	0	6.6
Cylinder Oil		
Loaded	0	35.1
Ballast	0	35.1

Table 8 – Fuel consumption and CO_2 emissions (kg/km) for steam turbine and diesel dual fuel propulsion for a 150,000 m^3 fleet [5]

Loaded conditions	Steam Turbine	Dual fuel electric
CO_2 emissions	702	467
HFO consumption	433	69
Diesel consumption	0	129
Nat. Gas consumption	269	269
Ballast conditions		
CO_2 emissions	746	422
HFO consumption	611	43
Diesel consumption	0	245
Nat. gas consumption	134	134

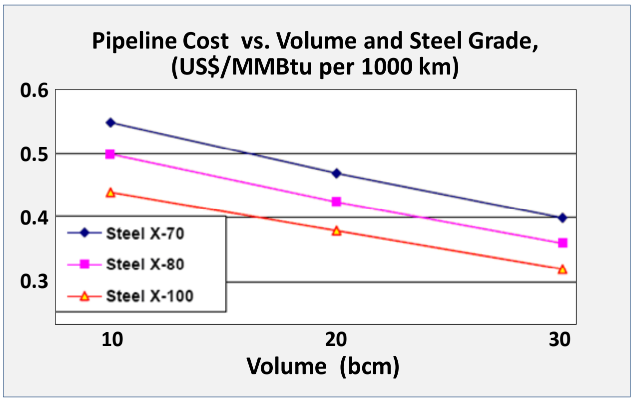

Fig. 4 – Pipeline transportation cost for a 1000 km pipeline as a function of volume and steel grade [29]

POTENTIAL AND BARRIERS – Oil and natural gas are dominant components of today's energy system and are expected to remain so for decades to come. The future of oil and gas logistics is therefore strongly linked to the expansion of the oil and gas market and to the increasing energy security problems. Emerging economies like China and India are likely to expand their oil and gas logistics

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following their growing energy needs. However, considerable uncertainty exists regarding the impact of future climate policies. The recent focus on reducing greenhouse gas (GHG) emissions may also have an impact on oil and gas logistics. For example, oil tankers and LNG carriers may be fuelled by alternative low-carbon fuels such as biodiesel. Similarly – assuming a significant penetration of carbon capture and storage (CCS) technologies – LNG fleets could transport LNG to consuming markets and CO_2 to suitable storage sites. Moreover, GHG emission restrictions can result in the need of CO_2 capture from the LNG liquefaction process. It is worth to note that low-carbon fuels such as biofuels and hydrogen may be even more demanding than oil and gas as far as logistics is concerned.

From an environmental and economic perspective, an important aspect relates to today's significant losses due to venting and flaring of natural gas occurring when natural gas is produced in association with oil and there is neither infrastructure nor market to transport or sell natural gas. Investments in natural gas infrastructure can result in an increased natural gas production capacity and a decrease of polluting natural gas flaring and venting.

Table 9 – Summary Table – Key Data and Figures for Oil and Gas Logistics

Oil Logistics (typical figures)	
Diesel Tankers for Oil Transport	
Tons of oil carried per Dead Weight Ton (DWT)	6.7 ton per DWT
Lifetime, (av. age of a decommissioned tanker), 2009	29 years
Average age of the current oil tankers, 2009	17.6 years
Average deliverable size (2008)	77 000 DWT
Fuel consumption, gram per ton-km	2.2 for 75,000–120,000 DWT; 2.3 for 120,000–200,000 DWT; 3.8 for DWT > 200,000
CO_2 , gram per ton-km	6.6 for 75,000 – 120,000 DWT; 4.1 for 120,000 – 200,000 DWT; 3.8 for DWT > 200,000
Price of a new built oil tanker, US$ million (2008)	US$ 48 million for 45,000 DWT; US$ 76 million for 110,000 DWT; US$ 151 million for 300,000 DWT
Oil Pipelines	
Oil flow speed	1 – 6 m/s
Average cost per km	2008: US$ 2 101 000 per km, 2009: US$ 2 316 000 per km
Technical lifetime	25 - 40 years
Pump station onshore	Every 32 to 160 meter
Energy requirement pump station	About 0.5 % of the energy transported
Natural Gas Logistics (typical figures)	
LNG Liquefaction Plants	
Natural gas losses, percentage of input	15 %, future plants 11 %
Lifetime	25 y
Construction time	4 y
Investment costs, USD(2005)	US$ (2005) 3.8 - 2.9/ MMBtu
Operating cost, excluding fuel cost	US$ 10,500 per ton LNG (converted from Euro at US$ 1.35/€)
LNG Fleets	
Lifetime, yr	Steam Turbine (HFO): 25; Slow speed diesel: 40
Cost of new built 150,000 m^3 fleet, US$ 2008	245 million
Maintenance cost per hour of operation, US$/h	Steam Turbine (HFO): NA Slow Speed Diesel: Loaded conditions: 81; Ballast conditions: 78
HFO consumption (150,000 m^3 fleet) kg/km	Steam Turbine: Loaded conditions: 433; Ballast conditions: 611 Slow Speed Diesel: Loaded conditions: 69; Ballast conditions: 43
Natural gas consumption (150,000 m^3 fleet) kg/km	Steam Turbine: Loaded conditions: 269; Ballast conditions: 134 Slow Speed Diesel: Loaded conditions: 269; Ballast conditions:134
Diesel consumption, (150,000 m^3 fleet) kg/km	Slow Speed Diesel: Loaded conditions: 29; Ballast conditions: 245
CO_2 emissions, (150,000 m^3 fleet) kg/km	Steam Turbine Loaded conditions: 702; Ballast conditions 746 Slow Speed Diesel Loaded conditions: 467; Ballast conditions 422
LNG Regasification Plants	
Investment cost per ton of LNG, US$	Greenfield Projects US$ 75/t LNG; Expansion projects US$ 45/t LNG
Operating cost	4 % of the capital cost per year
Process losses	2.5 %
Availability	340 days per year
Natural gas- pipeline	
Technical lifetime	30 – 50 years
Average cost per km, US$	US$ 194 – 226*10^6
Energy requirement compressor station	About 1.8 – 2.7 % of the energy transported

Please send comments to Pernille.Seljom@ife.no, Author, and to
Giorgio.Simbolotti@enea.it and Giancarlo Tosato (gct@etsap.org), Project Co-ordinators

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Please send comments to Pernille.Seljom@ife.no, Author, and to
Giorgio.Simbolotti@enea.it and Giancarlo Tosato (gct@etsap.org), Project Co-ordinators