
Petrochemical plant on Jurong Island, Singapore

Oil tanker in the Strait of Johor

Oil tanker breaking in Chittagong, Bangladesh

Pipeline on Jurong Island

Architecture of Territory
ETH Zurich
FCL Future Cities Laboratory

Hinterland
Singapore, Indonesia, Malaysia
Project 1, part 2

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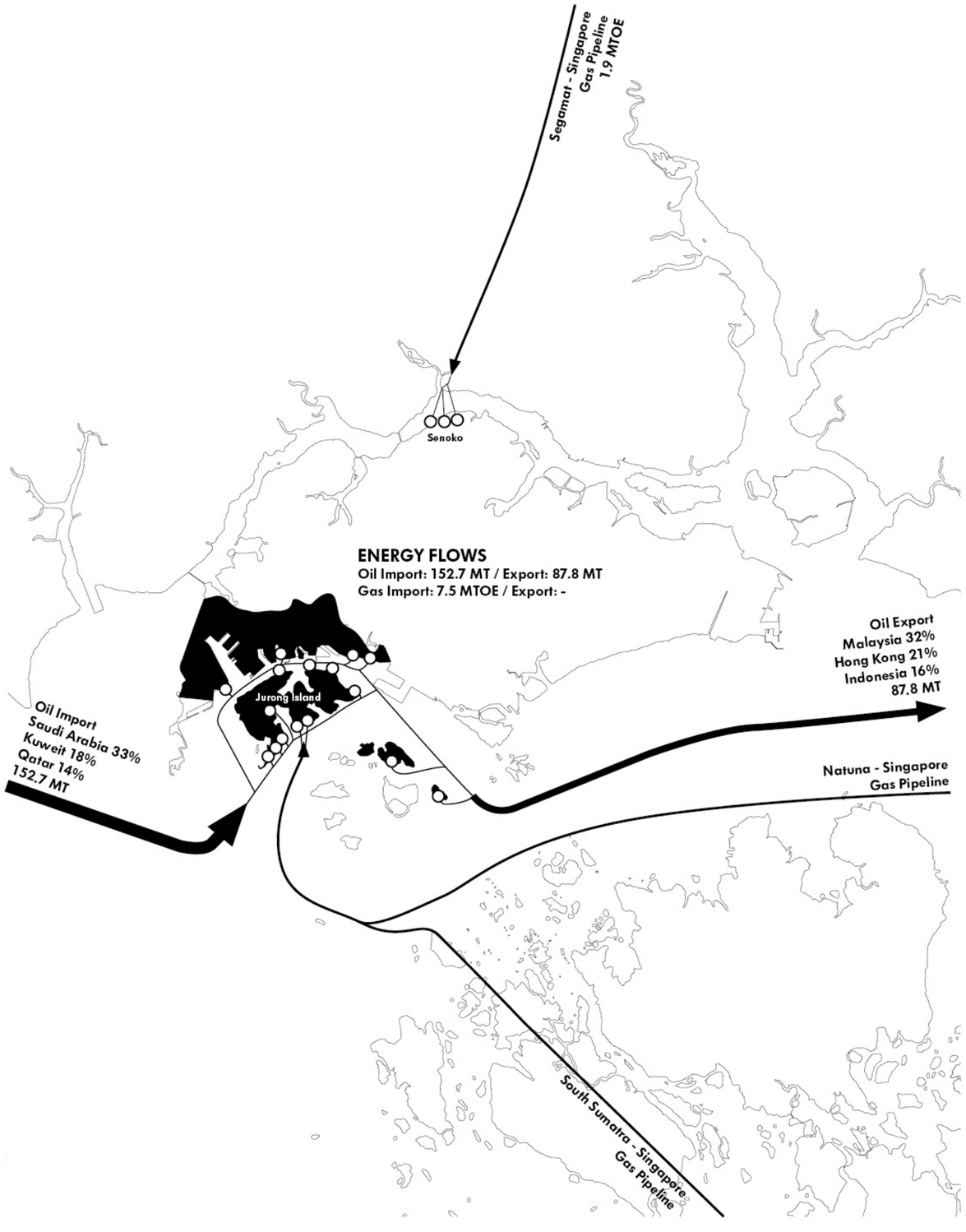
THE EXTENDED STRAIT

Singapore's Oil Hub

by
Martin Garcia
Magnus Nickl



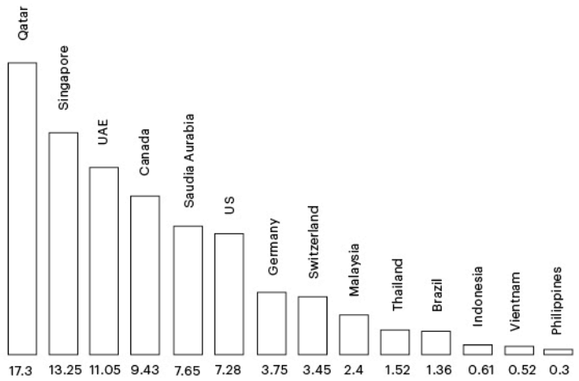
This work investigates ways by which energy sources shape the space of the global city of Singapore. High electricity demand, the strategic location as a petroleum hub and a highly specialized ship building industry serving the demands of modern oil explorations are major topics that will be discussed. The oil industry, which is prominently located on Singapore's Jurong Island represents a major case study showing the importance of this industry. More importantly, petroleum products are used by many other industries in the chemical sector as a raw material creating a network, which is visible within the urban fabric.

Dependent Island

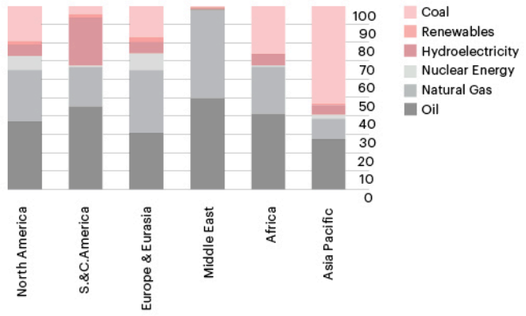
As Singapore does not have renewable energy sources, it relies intensively on imports. To improve this situation, renewable sources like solar power, wind energy and others could be a solution. However, the spatial limitations of the island restrict the extent to which these partial solutions could contribute to Singapore's consumption.

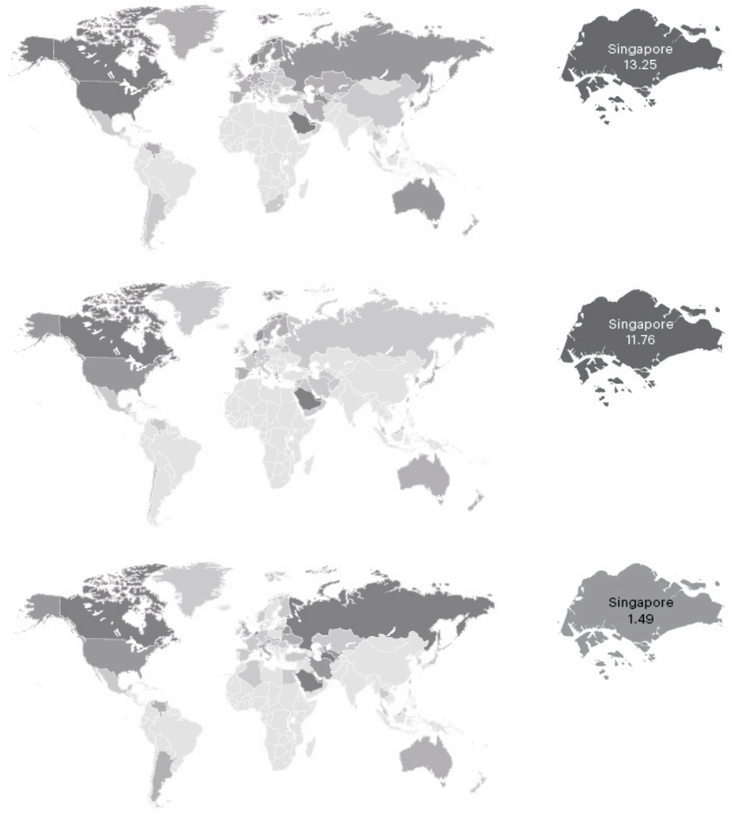
Singapore at night

Total Energy Consumption per Capita (oil tonnes equivalent per year)



Regional Consumption Pattern, 2011





* Based on gross generation from renewable sources including wind, geothermal, solar, biomass and waste, and not accounting for cross-border electricity supply. Converted on the basis of thermal equivalence assuming 38% conversion efficiency in a modern thermal power station.

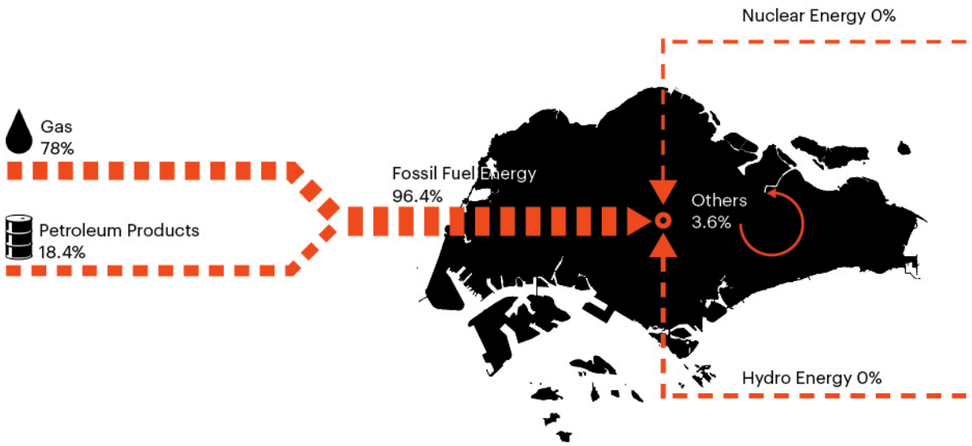
Gas-Powered Island

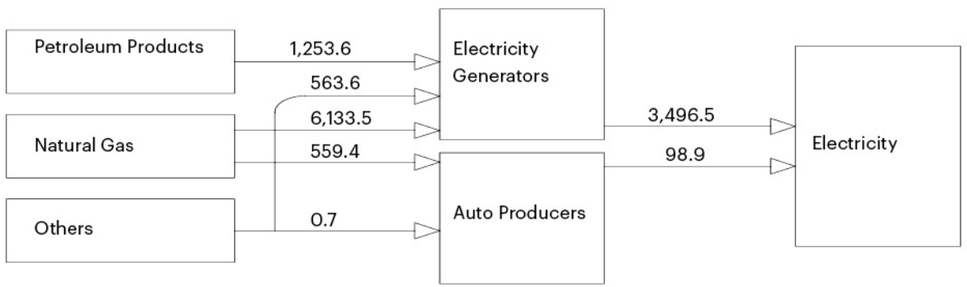
Singapore's energy demand has risen dramatically since its independence in 1965. Energy played a key role for the nation's ambition to join the ranks of 'developed countries'. All of Singapore's electricity was generated through the burning of fuel until recently. Singapore changed its supply system and added gas as a source of electricity due to increasing prices and environmental issues. This gas is imported from Indonesia and Malaysia.

Until today, Singapore sources of electricity are hardly diversified; a situation similar to that of Switzerland. The Swiss rely mostly on hydropower and nuclear power for its electricity.

As prices of natural gas are relatively high compared to coal, Singapore is investigating the possibility of building a coal-fired plant for the production of electricity.

The renewable proportion of Singaporean produced electricity is generated through several incineration plants where household and commercial waste is turned into energy.





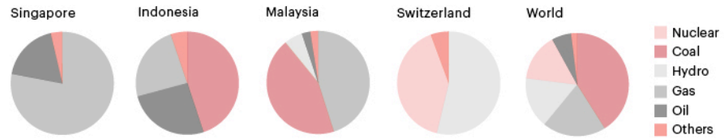
Electricity Generation Singapore

Singapore has one of the least diversified energy sources worldwide.

*Auto Producers are defined as companies whose main business is not electricity generation and the electricity produced is mainly for the companies' own use.

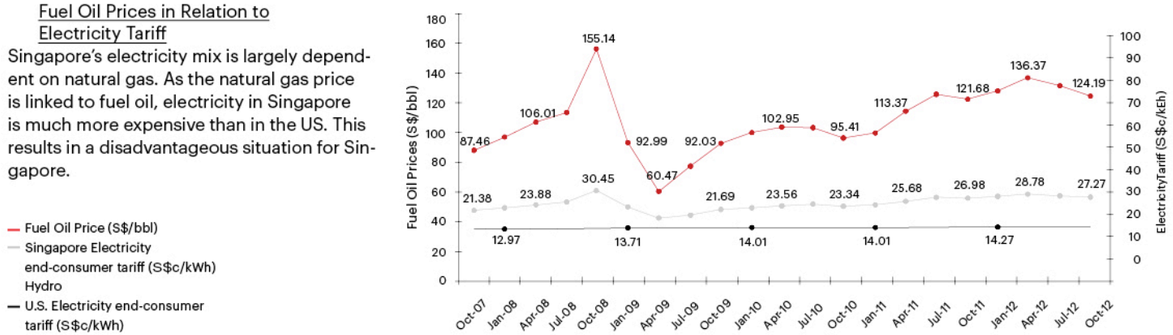
View on HDB housing by night from the Future Cities Laboratory

Comparison of Electricity Generation by Energy Source

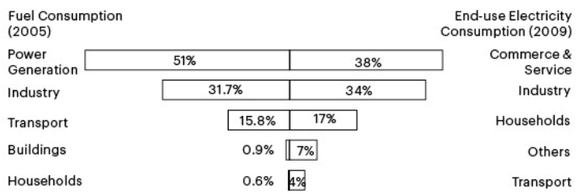


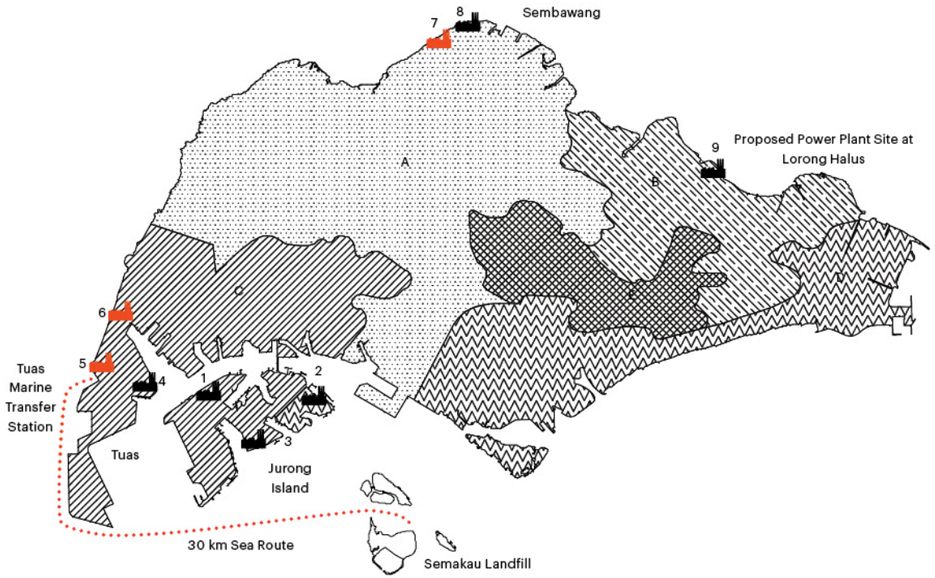
Fuel Oil Prices in Relation to Electricity Tariff

Singapore's electricity mix is largely dependent on natural gas. As the natural gas price is linked to fuel oil, electricity in Singapore is much more expensive than in the US. This results in a disadvantageous situation for Singapore.



Fuel Consumption Compared to Electricity Consumption



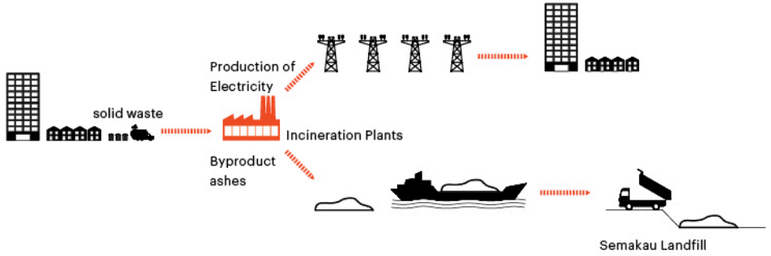


Transmission Planning Zones

Zone A - North-West Block
Zone B - North-East Block
Zone C - South-West Block
Zone D - South-East Block
Zone E - Central Block

Power Plants
Incineration Plants

1. Keppel Merlimau Cogen
2. PowerSeraya
3. SembCorp Power
4. Tuas Power Generation
5. Tuas South Incineration Plant
6. Tuas Incineration Plant
7. Senoko Incineration
8. Senoko Energy



Solid Waste Management in Singapore

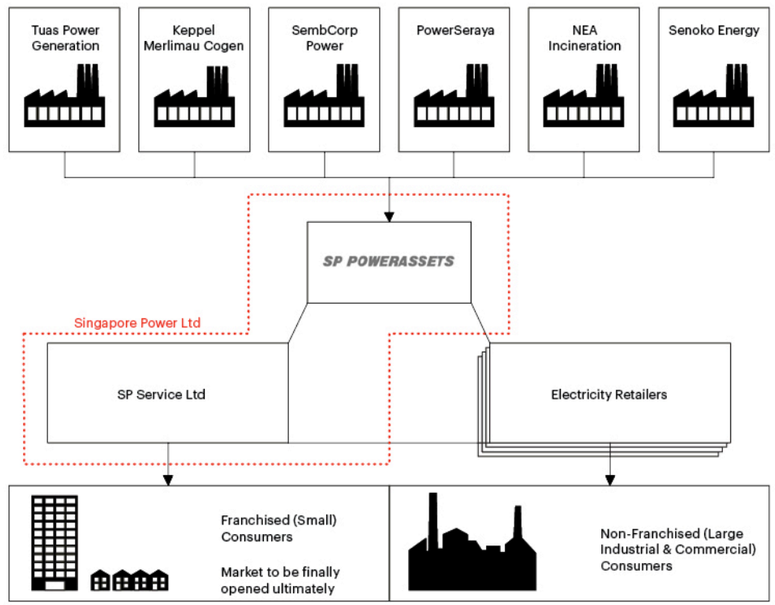
The byproduct of the incineration plants is used to fill-up Semakau island.

Waste (byproduct of the incineration plants) is unloaded from the ships at the landfill's transfer building. Lorries then transport the waste to landfill cells where it is discharged and compacted.


2000 2003 2010

Semakau Landfill

Commenced operation	2009
Incineration ash	1'400 t/day
Non-incinerable waste	600 t/day
Capacity	63'000'000 m³
Area	350 ha
Cost	610'000'000 S$
Expected Lifespan	25-45 years



Milestones in the Singapore electricity market

1995 OCTOBER
Corporatisatuin of PUB's gas and electricity undertakings. Formation of Singapore Power.

1998 APRIL
Singapore Electricity Pool commenced operation.

1999 SEPTEMBER
Government review of electricity industry

2000 MARCH
Government decision on further deregulation.

2001 APRIL
Energy Market Authority formed.

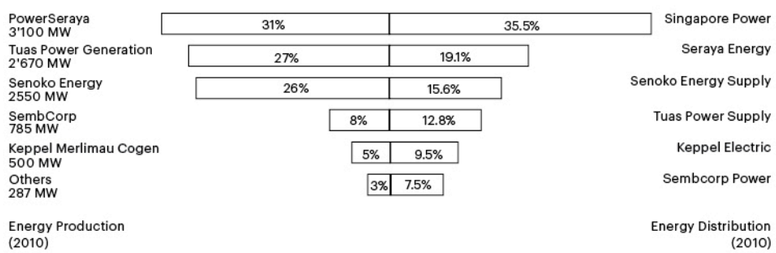
2001 JULY
2MW Consumers become contestable.

2003 JANUARY
The National Electricity Market of Singapore (NEMS) commencement.

2003 JUNE
Commencement of "Phase 1"Retial Market Liberalisation

2003 DECEMBER
Commencement of "Phase 2"Retial Market Liberalisation

2004 JANUARY
Vesting Contract &Interruptible Load scheme introduce in the electrical market.



Energy Reserves

The ASEAN countries (Indonesia, Malaysia, Philippines, Singapore, Thailand, Brunei, Burma, Cambodia, Laos, and Vietnam) possess a fair amount of oil and gas reserves, especially in Brunei, Malaysia and Indonesia.

The coal industry is most active in Vietnam, Thailand and Indonesia. Renewable energy sources are already present or could be developed in Brunei, Laos and Cambodia due to geographic circumstances and large rivers. Other renewable sources are present, though most of them are underdeveloped due to the lack of funding and political backing.

Singapore does not own any natural resources except biomass obtained through municipal waste. Nevertheless, many Singaporean companies are involved in energy related enterprises all over Asia where they secure the country's needs in these matters.

Proved Energy Reserves, 2008

SINGAPORE
Biomass
Municipal solid waste 3994 TJ/yr

INDONESIA
Coal 5'529 Million Tonnes
Crude Oil 497 Million Tonnes
Natural Gas 3'186 Billion Cubic Meter
Hydropower 2'147 TWh/yr
Biomass 70'953 TJ/yr
Geothermal Energy:
Electricity generation 8'213 GWh
Direct use 43 TJ
Wind energy 2 GWh

THAILAND
Coal 1'239 Million Tonnes
Crude Oil 50 Million Tonnes
Shale Oil 916 Million Tonnes
Natural Gas 340 Billion Cubic Meter
Hydropower 18 TWh/yr
Biomass 2'438 TJ/yr
Solar Energy 34 MWp
Geothermal Energy:
Electricity generation 1GWh
Direct use 79 TJ
Wind energy 2 GWh

VIETNAM
Coal 150 Million Tonnes
Crude Oil 626 Million Tonnes
Natural Gas 217 Billion Cubic Meter
Hydropower 300 TWh/yr
Geothermal Energy:
Direct use 92 TJ
Wind energy 3 GWh

MALAYSIA
Coal 4 Million Tonnes
Crude Oil 701 Million Tonnes
Natural Gas 2'330 Billion Cubic Meter
Hydropower 230 TWh/yr
Solar Energy 8.8 MWp

PHILIPPINES
Coal 316 Million Tonnes
Crude Oil 15 Million Tonnes
Natural Gas 93 Billion Cubic Meter
Hydropower 47 TWh/yr
Wind energy 3 GWh

BRUNEI
Crude Oil 160 Million Tonnes
Natural Gas 350 Billion Cubic Meter

LAOS
Coal 503 Million Tonnes
Hydropower 233 TWh/yr

MYANMAR
Coal 2 Million Tonnes
Crude Oil 7 Million Tonnes
Shale Oil 286 Million Tonnes
Natural Gas 590 Billion Cubic Meter
Hydropower 348 TWh/yr

CAMBODIA
Hydropower 88 TWh/yr


1.


2.


3.


4.


5.


6.

1.
Offshore oil field, Brunei

2.
Gas field, Natuna,
Indonesia

3.
Coal mining, East
Kalimantan Indonesia

4.
Sudirman (Mrica),Central
Java, Indonesia

5.
Puetro Galera wind farm,
Philippines

6.
Geothermal Infrastructure,
West Java, Indoensia

Singapore's Gas Demand

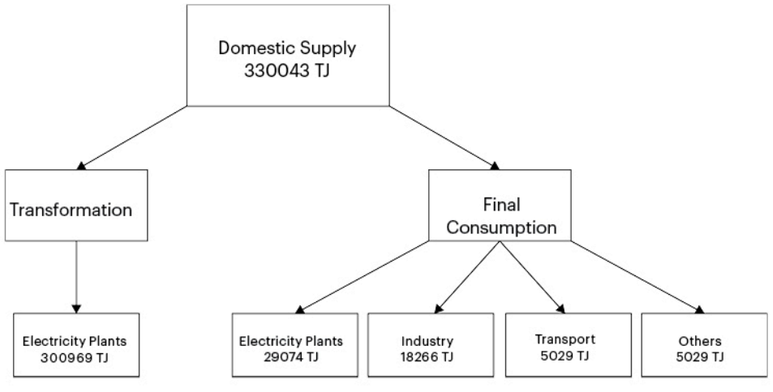
Gas used mainly for the generation on electricity plays a key role in many ASEAN countries, especially in Singapore and Brunei, where this is the primary source of electric energy.

In addition, gas is sufficiently available in most countries in Southeast Asia. However, there will be challenges in the future as the demand grows.

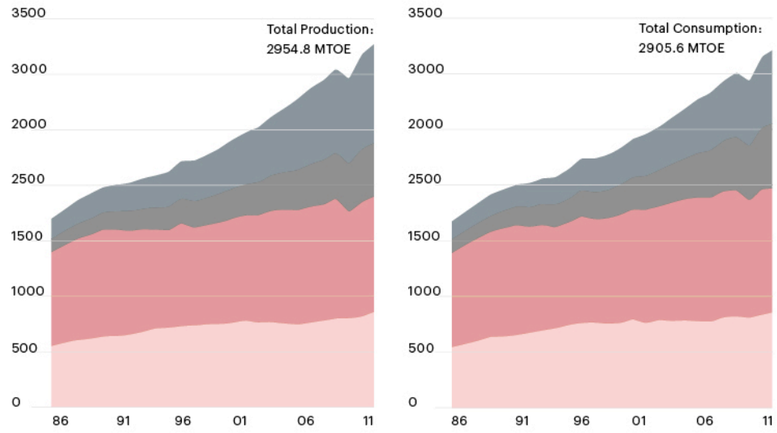
"Increasing energy demand in the region is mainly driven by a rapid level of urbanization and industrialization. The region has one of the fastest urbanization trends in the world. It is predicted that, by the year 2025, more than 50 percent of the region's population will reside in urban areas, as compared with 39 percent in 2000." (Energy and environment in the ASEAN: Challenges and opportunities; Shankar, Mann, Salehfar).

Singapore will face challenges in the future to diversify its electricity generation further as the reliance on gas is not sustainable. Furthermore, as Singapore's gas's resources all arrive via pipelines coming form Indonesia and Malaysia, there is a need to reduce the dependence on these countries by diversifying sources of energy imports.

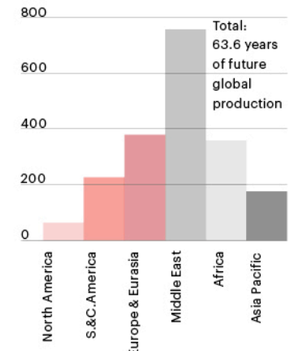
Distribution of Gas within Singapore, 2009



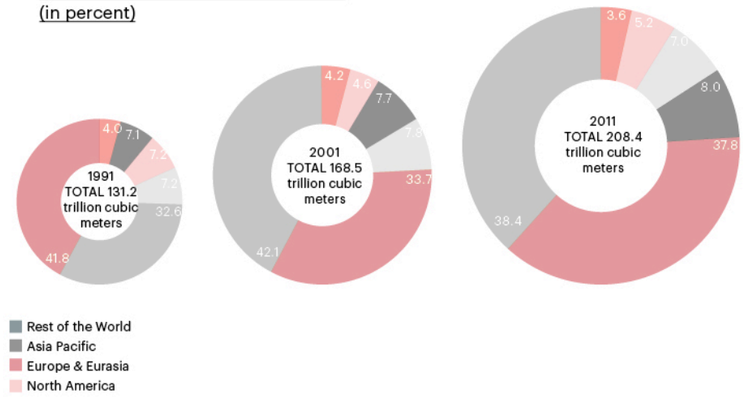
Production and Consumption by Region, 2011 (mtoe)



Resereves to Production Ratio, 2011 (years)



Distribution of Proved Reserves, 2011 (in percent)



1922 BEGIN AMERICAN PRICE RECORD
Beginning of the American wellhead price record by the U.S. Energy Information Administration.

Wellhead price:
The price less transportation costs charged by the producer for petroleum or natural gas.

1925 FIRST LONG-DISTANCE ALL-WELDED STEEL GAS PIPELINE
The first long-distance all-welded steel gas pipeline was laid by Magnolia Gas of Dallas. The line, from northern Louisiana to Beaumont, Texas, was 217 miles in length and comprises 14-, 16- and 18-inches diameter pipes.

1939 FIRST GAS-POWERED TURBINE TO GENERATE ELECTRICITY
The first gas-powered turbine to generate electricity for public use is operated at a power station in Switzerland.

1947 NEW TYPE OF CAST IRON
A new type of cast iron, which is twice as strong and three times as resistant to shock, is introduced in Britain by Harold Hartley.

1951 NATURAL GAS PRODUCED FROM COAL
For the first time in the Western world, natural gas is produced from coal, while it is still underground in the coal seam, at a colliery at Newman Spinney, England.

TRANS-CONTINENTAL GAS PIPELINE
Trans-Continental Gas Pipeline completed an 1840 mile long and 30-in diameter gas pipeline from the vast reserves on the Texas-Louisiana Gulf Coast to the high demand areas around Philadelphia, New Jersey and New York. It worked at a pressure of 800 psi maintained by 19 compressor stations. It was of welded steel construction throughout.

1959 LNG
LNG is produced for the first time on an industrial scale in Los Angeles. It will be transported to Britain for the first by the vessel Methane Pioneer.

1989 AMERICAN GAS INDEX
The American Gas index Fund was introduced.

HENRY HUB
The Henry hub is a distribution hub on the natural gas pipeline system in Erath, Louisiana, owned by Sabine Pipe Line LLC. Due to its importance, it lends its name to the pricing point for natural gas futures contracts traded on the New York Mercantile Exchange (NYMEX) and the OTC swaps traded on IntercontinentalExchange (ICE).

1990 TRADE OF NATURAL GAS
On April 3rd, trading on natural gas futures began at the New York Mercantile Exchange (NYMEX).

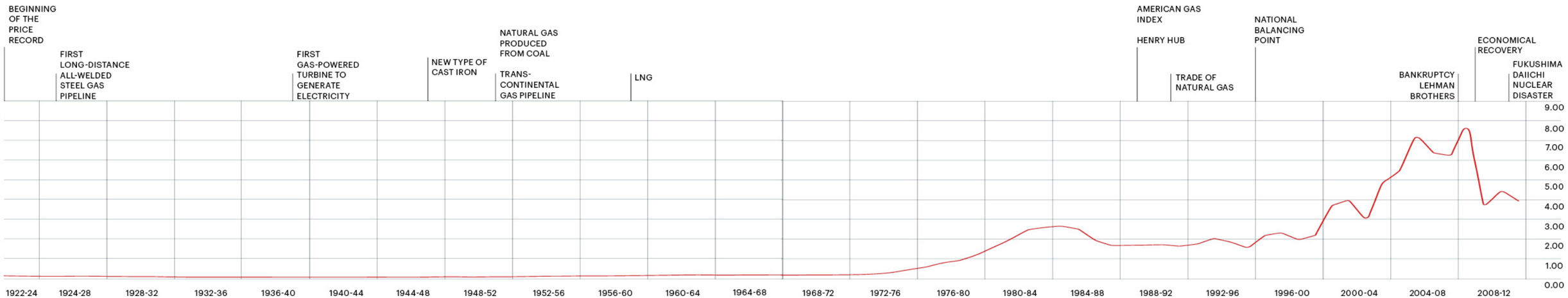
1996 NATIONAL BALANCING POINT
The National Balancing Point, commonly referred to as the NBP, is a virtual trading location for the sale and purchase and exchange of UK natural gas. It is the most liquid gas trading point in Europe. It is similar in concept to the Henry Hub in the United States - but differs in that it is not an actual physical location.

2008 BANKRUPTCY LEHMAN BROTHERS
Bankruptcy of Lehman Brothers in September 2008. In the following months, many other banks had to be rescued by government bailouts. Lehman Brother's bankruptcy marked the beginning of a global economic downturn.

2010 ECONOMICAL RECOVERY
American economy recovers slowly, production increased.

2011 FUKUSHIMA DAIICHI NUCLEAR DISASTER
The Fukushima Daiichi nuclear disaster was a series of equipment failures, nuclear meltdowns, and releases of radioactive materials at the Fukushima I Nuclear Power Plant, following the Tōhoku earthquake and tsunami on March 11, 2011. It is the largest nuclear disaster since the Chernobyl disaster of 1986.
In the following months after the accident in Japan, the German government decided to shut down its nuclear power plants by 2022.

Development of US Gas Wellhead Price (Dollars per Thousand Cubic Feet)



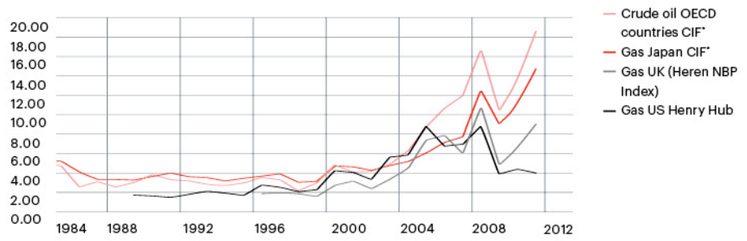
Gas Japan CIF*
The situation in Japan is similar to that in many Asian countries, where there is only a limited spot market. Prevailing prices reported in the graph are averages of all supplies and largely reflect long-term contracts for natural gas in terms of their linkages to crude oil. Japanese natural gas prices have been rising over the past year, even before the catastrophe of Fukushima.

Gas UK (Heren NBP Index)
Northwestern Europe has also developed strong spot markets, starting in the United Kingdom and now in Belgium, the Netherlands, and Germany. Spot prices at the United Kingdom's National Balancing Point (NBP) generally track other northwestern European pricing points. Spot prices in northwest Europe are influenced by the limited number of suppliers and a relative lack of local production. Key suppliers (Russia and Qatar) supply much of their gas under long-term contracts, which is not directly reflected in the spot market, and gas deliveries from Norway can vary.

Gas US Henry Hub
North American natural gas markets are highly competitive, with many buyers and sellers. They have seen considerable production growth in recent years; according to EIA, US dry natural gas production rose 20 percent between 2005 and 2010. Henry Hub spot prices are the reference prices for North America and have averaged about $4.17 per million British thermal units since January 2009. Prices at Henry Hub have been modest by global standards since the financial crisis of 2008-09.

American: "Hey, it's cheaper and you get bigger portions!"
Singaporean: "Groaning"

Development of Gas Trading Price (US Dollars per Million British Pound)



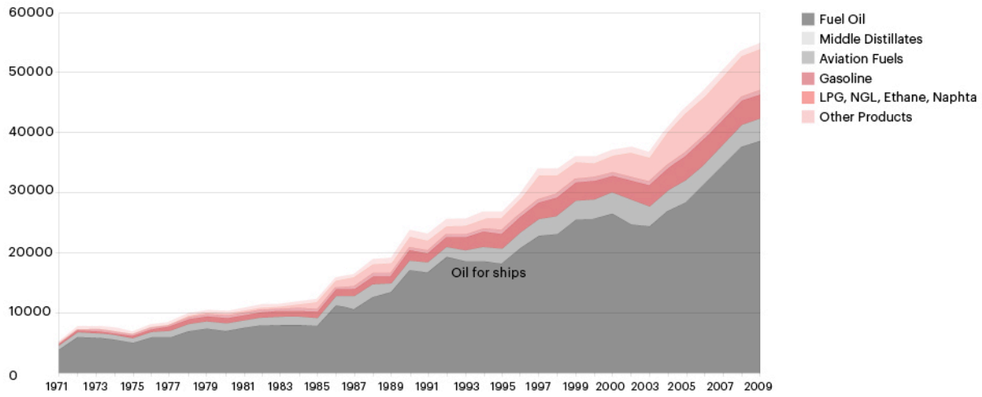
Singapore's Oil Demand

The situation regarding oil demand in Singapore is different than with gas. Singapore harbor is an important gas station for ships.

"Although Singapore does not produce any oil, it is one of the top bunkering (ship refuelling) ports in the world. In 2010, about 43 million tonnes of bunkers were lifted in Singapore. This is enough to fill over 17,000 Olympic-sized pools." (MPA Singapore)

In addition, the four refineries located in Singapore produce important raw materials, distributed all over the world. The incoming raw oil is therefore transformed into products with a much higher value. As there is no pipeline, all the oil arrives into Singapore by ships and leaves the same way.

Consumption of Oil Products in Singapore, 2011



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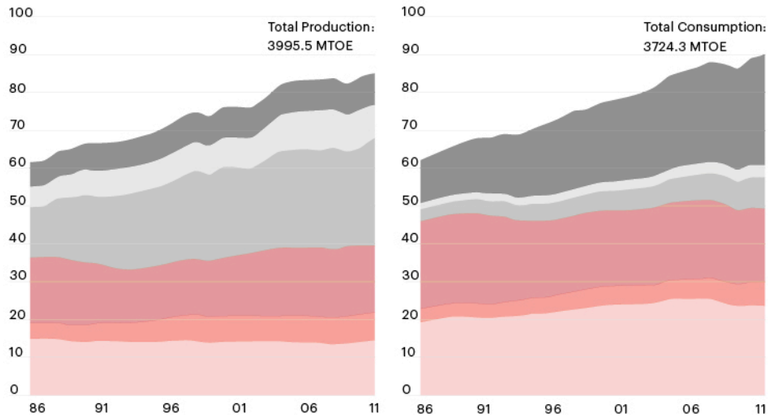
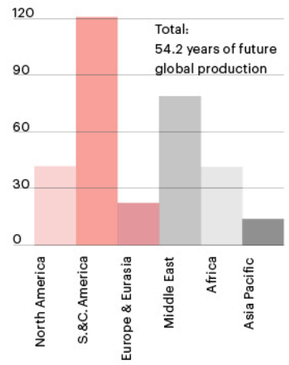


Reserves to Production Ratio, 2011 (years)



Distribution of Proved Reserves, 2011 (in percent)

Despite very little oil reserves of their own, the emerging economies in Asia Pacific consume large amounts of oil.

There is a need to import oil from the Middle East to Asia. This fact puts Singapore into a strategic position as a distributer of oil and oil-related products.

PENNSYLVANIAN OIL BOOM
The Pennsylvanian oil rush was a "boom" in petroleum production, which occurred in northwestern Pennsylvania from 1859 to about 1870. It was the first oil boom in the United States.

RUSSIAN OIL BOOM
Meanwhile, the Russian oil industry was not organized competitive as it was a state-run monopoly. The policies, however, changed in 1870s, and a private competitive industry emerged leading to explosive entre-preneurship and oil drilling based on American discoveries instead of hand-dug oil. The first wells were drilled in 1871-72, and by 1873 many producers and refiners (more than 20) had sprung up; but many were still inefficient and techno-logically backward by 1873.

SUMATRA OIL PRODUCTION AND THE FOUNDING OF SHELL
The discovery of commercial quantities of crude oil in Sumatra just over 100 years ago led directly to the formation of Royal-Dutch Petroleum.

FEARS OF SHORTAGE IN US
The vital role of oil in a modern industrial economy had vividly been brought home to the American people by World War I. Immediately thereafter, the US developed a deep-seated fear of oil shortages.

EAST TEXAS FIELD DISCOVERED
On October 5, 1930, Columbus Marion (Dad) Joiners Daisy Bradford No. 3 well hit oil at 1,078 m below ground surface. This well is located near the southeastern boundary of the oil field. Shortly after the Daisy Bradford find, and after another two smaller wells were drilled near the original hole, another new well, this one on the Crim family farm about nine miles (14 km) north of the Bradford farm, reached oil, producing a gusher with a spectacular initial daily flow of 22,000

POST-WAR RECONSTRUCTION
The war increased the demand for oil dramatically and increased the awarenes of how dependent a modern society is on oil.

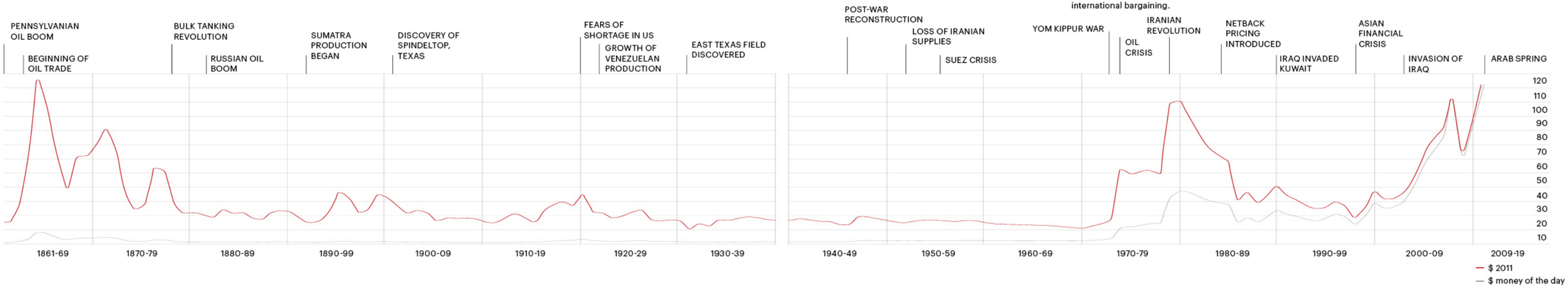
SUEZ CRISIS
The Suez Crisis erupted in July 1956, when Nasser, denied economic assistance by the United States and Britain, retaliated by nationalizing the Suez Canal Company. Nasser seized the British- and French-owned firm to demonstrate his independence from the European colonial powers, to avenge the Anglo-U.S. denial of economic aid, and to garner the profits the company earned in his country.

OIL CRISIS
The 1973 oil crisis started in October, when the members of the Organization of Arab Petroleum Exporting Countries or the OAPEC proclaimed an oil embargo.
Prior to the embargo, the geo-political competition between the Soviet Union and the United States, in combination with low oil prices that hindered the necessity and feasibility for the West to seek alternative energy sources, presented the Arab States with financial security, moderate economic growth, and disproportionate international bargaining.

NETBACK PRICING INTRODUCED
A pricing assessment or pricing formula based on the effective price to the producer or seller at a specific location or defined point.

ASIAN FINANCIAL CRISIS
The Asian financial crisis was a period of financial crisis that gripped much of Asia beginning in July 1997, and raised fears of a worldwide economic meltdown due to financial contagion.
As a result the demand of oil was decreased.

ARAB SPRING
The Arab Spring is a revolutionary wave of demonstrations, protests, and civil-wars occurring in the Arab world.



Development of Oil Price

BEGINNING OF OIL TRADE
America exports petroleum for the first time when the Elizabeth Watts departs Philadelphia's docks bound for London with a cargo of 901 barrels of Pennsylvanian oil and 428 barrels of refined kerosene.

BULK TANKING REVOLUTION
To overcome the high handling cost and transportation difficulties, Ludwig Nobel conceived the idea of shipping the oil in bulk tankers (instead of shipped wooden barrels) launching a major revolution in oil transport. The first successful bulk tanker, Zoroaster, was put in service on the Caspian in 1878.

DISCOVERY OF SPINDELTOP, TEXAS
On January 10, 1901, a well at Spindletop struck oil ("came in"). The new oil field soon produced more than 100,000 barrels (16,000 m3) of oil per day. Gulf Oil and Texaco, now part of Chevron Corporation, were formed to develop production at Spindletop.

GROWTH OF VENEZUELAN PRODUCTION
After about twenty years from the installment of the first oil drill (1910), Venezuela had become the largest oil exporter in the world and the second largest oil producer, after the United States. Exportation of oil boomed from 1.9% to 91.2% between 1920 and 1935.

LOSS OF IRANIAN SUPPLIES
Under the nationalist government of Mossadegh, the Iranian Leadership decided to put control over the irnanian oil into the hands of the government. This resulted in an armed conflict between Iran and the U.S. and Great Britain.

YOM KIPPUR WAR
During the Yom Kippur War, the accessibility of the Suez canal was not given. This resulted in longer transport routes and costs.

IRANIAN REVOLUTION
The oil boom of the 1970s produced "alarming" increase in inflation and waste and an "accelerating gap" between the rich and poor, the city and the country.

IRAQ INVADED KUWAIT
In 1990, Iraq accused Kuwait of stealing Iraqi petroleum through slant drilling, although some Iraqi sources indicated Saddam Hussein's decision to attack Kuwait was made only a few months before the actual invasion.

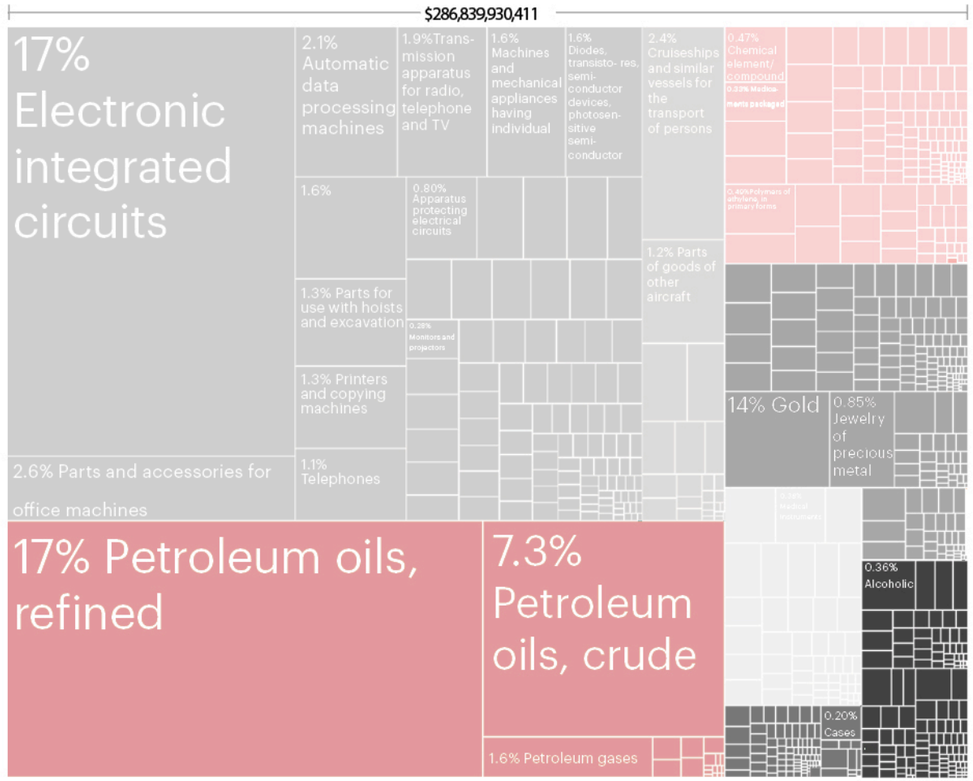
INVASION OF IRAQ
Securing American Influence over oil resources.

Minerals and Chemicals as Pillars of the Economy

Besides machinery and electrical products, minerals are a major imported product in Singapore. This is due to the high demand by ships, as the Singapore harbor is a bunkering center, the strong presence of refineries and allied industries and the demand for chemical products, which are generated from crude oil within Asia.

Singapore has been a location for oil storage since the beginning of the 20th century. In the 1960s, refineries opened up in Singapore due to its strategic location, the proximity to major markets and the political stability.

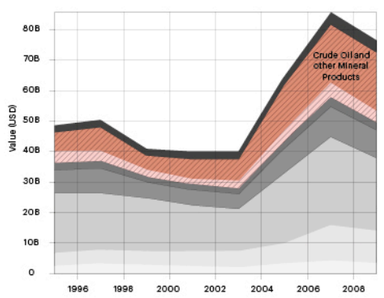
In recent years, the chemical companies in Singapore have increased in number and size and are expected to increase even further resulting in a growing demand for minerals. This development is, nevertheless, threatened by high electricity prices.



Net Import Singapore, 2009

Import of mineral products mainly for the transformation into other, more refined, products for the chemcal industry.

- Mineral Products
- Chemicals & Allied Industries; Plastics/Rubber
- Agricultural Products; Animal & Animal Products; Foodstuffs
- Textiles; Footwear & Headgear; Raw hides, Skins, Leathers, Furs
- Wood & Wood Products; Metals; Stone/Glass
- Machinery & Electrical
- Transportation
- Others

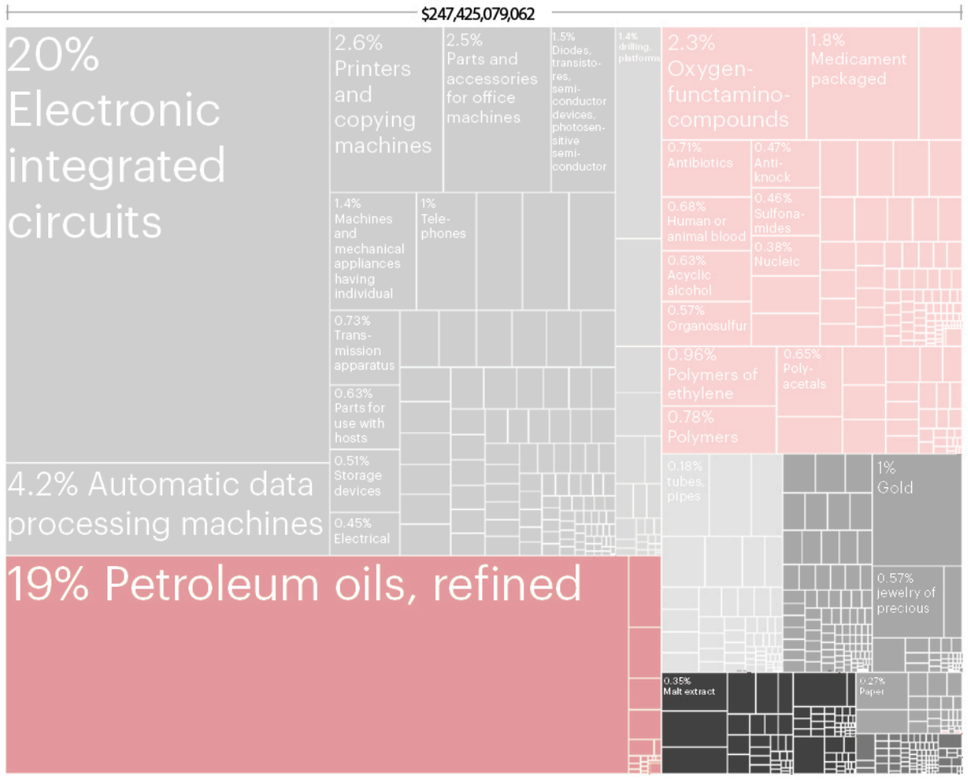


INDONESIA

13.65%	Petroleum oils, refined
2.79%	Aircraft, spacecraft & launch vehicles
2.69%	Petroleum oils, crude
2.04%	Parts and accessories of the motor vehicles
1.83%	Automatic data processing machines

MALAYSIA

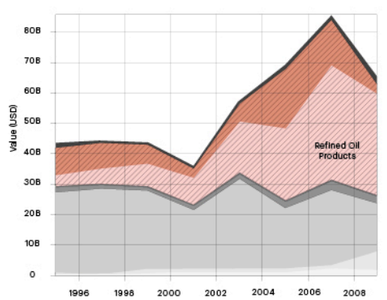
15.05%	Electronic integrated circuits
5.84%	Petroleum oils, refined
2.93%	Petroleum oils, crude
2.88%	Parts and accessories for office machines
2.00%	Automatic data processing machines



Net Export Singapore, 2009

Singapore is increasingly becoming a centered on the chemical industry in Asia. With high demand in the emerging regions like China, but also from South Korea and Japan, this sector is expected to grow even further.

It is attracting foreign investment because of political stability, the strategic location of its harbour between the Middle East and Asia and lastly, because of its superior infrastructures. In addition, companies enjoy tax incentives as well as receiving support by the economic development board.



INDONESIA

10.16%	Coal, briquettes
7.60%	Petroleum gases
6.62%	Palm oil, crude
5.77%	Petroleum oils, crude
4.39%	Natural rubber

MALAYSIA

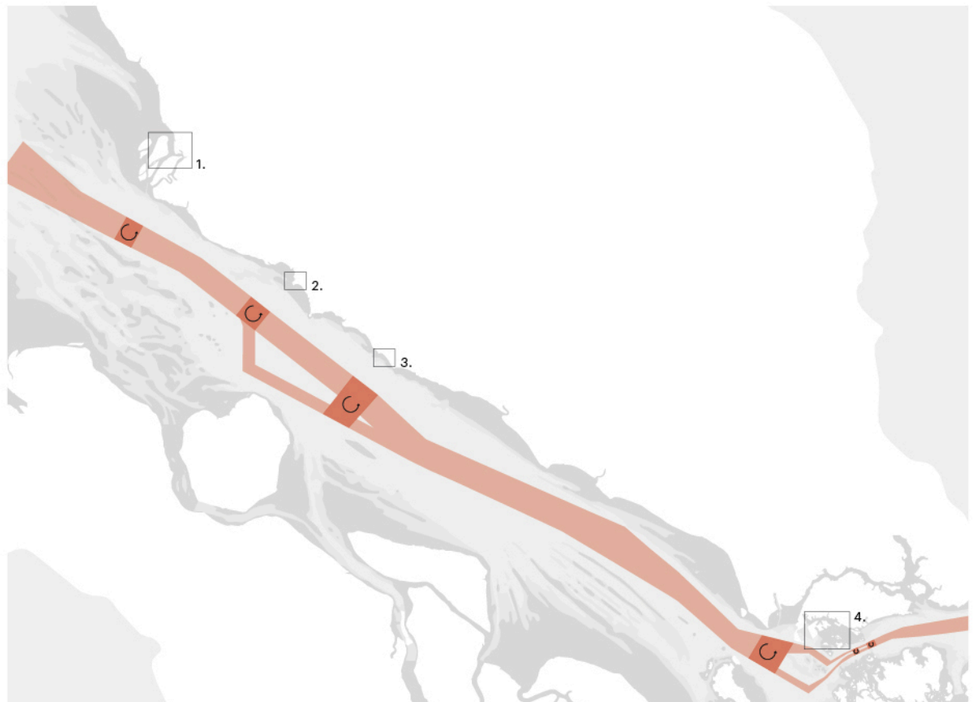
13.80%	Electronic integrated circuits
5.81%	Petroleum oils, refined
5.57%	Petroleum gases
5.48%	Palm oil, crude
5.32%	Parts and accessories for office machines

Liquid Hub

The Liquid Hub of Singapore incorporates the harbor and its facilities, Jurong Island especially, and the surrounding region of Johor Municipality in Indonesia and the Islands of Bintan, Batam and Karimun in Indonesia.
As Singapore is on of the three major oil trading hubs in the world, many companies are keen to have a certain volume of oil stored in the region to be able to react fast to market changes. Therefore, oil storage plays a vital role.

Space limitations in Singapore are forcing more and more storage companies to move away from the island-state and to set up in the surrounding area, creating a truly tri-national hub.

Jurong island skyline



Competition or Complementation

There are only few oil facilities in the Strait of Malacca. The globally important terminals are in Malaysia. The Port of Singapore is still the most important location for bunkering as well as for the petrochemical industries. It is a very discussed issue if the fast growing oil and petrochemical sector in the region is going to result in stronger competition or if there will be a complementation to the point where a supranational hub is congregated.

Strait of Malacca

1. 2. 3. 4.

1. Port Klang

Port Klang is devided mainly in two ports, each one with its own operator. These are called the North Port and the West Port.

Both have oil tank facilities of considerable dimensions. Port Klang is the biggest oil storage harbour in the Strait of Malacca.

2. Port Dickson

Port Dickson is one of the locations of Royal Dutch Shell in Southeast Asia and ExxonMobil, each of them running a refinery at this location.

3. Malacca Oil Storage Terminal

Very near Malacca in Sungai Udang petronas erected a refinery taking a large part of the terrain. Through one major jetty the tankers that brings the crude oil and takes the refining products can dock perfectly even if the depth are quite small.

4. Jurong Island in Singapore

Jurong Island of Singapore is the biggest oil and petrochemical hub in the region and is the preffered location for bunkering of both tankers and cargo vessels because a lot of their main operative actions take place in Singapore.

History of the Oil Hub

The growth of the port's petroleum trade has been spectacular. In the mid 1930s, a traveller returning after a 25 year leave exclaimed, "the numerous islands with which the entrance to Singapore is studded... an indication of the new Singapore. Large patches of hard yellow soil disfigured by huge oil tanks replaced the green spaces of yesteryear.

Oil did not enter Singapore physically except for the island's own use. Since the product was not owned by Singaporean residents, there was no petroleum market in Singapore.

The oil companies used it as a place where petroleum produced in Netherlands India and British Borneo could be collected, blended and distributed. In contrast to Singapore's importance as a merchant and fi-nancier in other commerce for petroleum, its principal trade function were handling, storage and shipment. These activities generated a relatively low number of employment opportunities. Petroleum had its greatest effect on economic development through volume and the large demand for ship repair facilities.

The petroleum trade consisted of three main products, namely kerosene, liquid fuel (fuel oil) and motor spirit (petrol, gasoline).

At the beginning of the century the main constituent of the petroleum trade was kerosene, used primarily as an illuminant by the poorer sections of the population.

But the phenomenal expansion in petroleum exports during the inter-war period resulted almost entirely from the new products of liquid fuel and motor spirit. Liquid fuel was required chiefly for the bunkering of oil-fired ships and to a lesser extent to run industrial machinery, while motor spirit was needed for automobiles.

The story of Singapore's petroleum trade was - and remained - the use which multinational oil companies found for the port in their worldwide operations. Apart from some kerosene imported from the west coast of the United States, petroleum distribution via Singapore was in the hands of two subsidiaries serving three oil majors by 1939: The Asiatic Petroleum Company, established by Royal Dutch Shell, and the Standard Vacuum Company associated with Standard Oil of New Jersey and Standard Oil of New York.

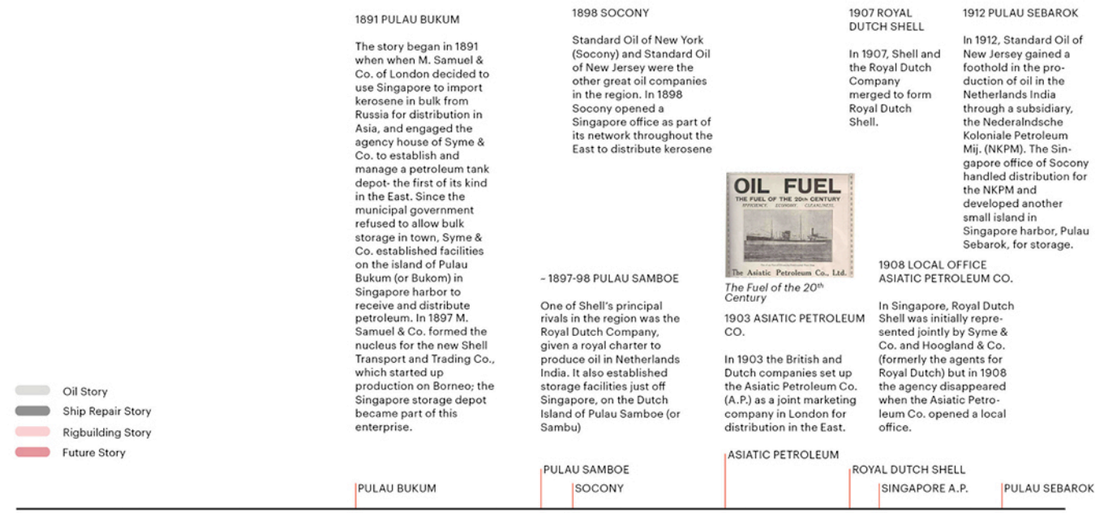
Oil companies were drawn to Singapore because of its geographical advantages - both local and international – and freedom from regulations. Offshore islands afforded a deep-water anchorage adjacent to Singapore harbor, while at the same time allowing safe storage of large quantities of petroleum.

The export of petroleum did not give rise to a merchant class in Singapore, nor did it make it an international petroleum market. The Straits Settlement Commission observed that "Singapore is not a market for the oil, there are no middleman's or dealer's profits involved and oil is merely distributed from here for the sake of convenience."

During the inter war period, unlike the period after 1959, there was no question of government intervention through tax concessions, infrastructure provisions or joint ventures to try to increase the role of oil companies in Singapore or linkages arising from the petroleum trade.

The important linkage of dry dock facilities, which oil tankers created in Singapore, is normally associated with a terminal port, where the longer stay of vessels affords the most economically viable place to obtain repairs.

In largely supporting the dry docks, tanker repair contributed to Singapore's economic development in two important respects. One was to add substantially to Singapore's attractiveness as a port. Second, the dry docks helped Singapore to develop a major engineering industry. The docks were judged "one of the most modern ship-repairing establishments in the East" by an "expert and highly critical" witness: "I do not think there is a place in the world in which you can get to work as solid or as sound or as good a job as you can get in Singapore.



1921 OIL BUNKERING

By 1921 the port had a "large oil-bunkering business... providing facilities for the berthage of large ocean-going vessels at Pulau Bukom and Pulau Samboe", and made the port largest British station for the storage and sale of oil bunkers in the East.

Singapore Harbour

1926 OIL BUNKERING AT THE WHARVES

In 1926 Singapore's convenience for oil-fired ships was further increased when the Asiatic Petroleum Co. began to supply oil bunkers at the wharves. The Company erected storage tanks and a central pumping station at the northern end of the wharves on land leased to it by the Singapore Harbour Board. Pipelines connected the tanks with most of the wharves, allowing the simultaneous transfer of fuel and cargo.

1930s LOST ADVANTAGE

By the 1930s Singapore had lost much of its advantage as an early leader in the provision of oil bunkers: other ports had obtained good bunkering facilities, and the trade in bunkers had become competitive because ships could go further without re- fuelling. In

1942 LOWERING OF UNION JACK

"When the Union Jack was lowered on Fort Canning, in Singapore, on that Sunday morning it marked the sudden and dramatic end of an epoch in our Colonial Empire (Letter to The Times, 24. Feb. 1942)

1914-18 SUPPLYING ALLIED VESSELS

The sale of oil bunkers developed by the Asiatic Petroleum Co. made Singapore a pioneer in their provision and and helped to attract the new oil burning vessels there, During World War 1 the Company gained experience in the bunkering trade through supplying Allied vessels.

1931 PULAU BINTANG

In 1931 the NKPM shifted most of the international distribution of petroleum which had been undertaken from Pulau Sebarok to the nearby Dutch island of Pulau Bintang. After 1931 Pulau Sebarok became almost exclusively a centre for distribution to British Malaya.

1939 VENT FOR SURPLUS

Before World War 2, Singapore grew as an integral of a "vent for surplus" region centred on Malaya and, even more, Netherlands India (Indonesia). Singapore as a port, market and financier provided the essential services component in the venting process which underlay rapid regional growth.

1945 RECOVERY

It was largely the pre-World War 2 economy and society with which Singapore started the 1950s: World War 2 and the Japanese occupation had made surprisingly little difference in a strictly economic sense.

ALLIED VESSELS | OIL BUNKERING | OIL BUNKERING AT THE WHARVES | PULAU BINTANG | LOST ADVANTAGE | VENT FOR SURPLUS | LOWERING OF UNION JACK | RECOVERY

World War I | Bunkering Port 1918-1930 | Years of Decline 1930-1940 | World War II

1920 | 1930 | 1940

Interaction Oil Storage/Ship Repair 1914-1930 | Competition and Decline 1930-1956

1920s TANKERS FLEET

Lager fleet of oil tankers based in Singapore

1930s SLUMP DEMAND

In the 1930s slump demand for ship repair contracted sharply, and dry dock gross revenue fell

SHIP REPAIR | OIL TANKERS | SINGAPORE NAVAL BASE | ASIATIC | DECLINE | GRAVING DOCK | RECOVERY

1914-18 SHIP REPAIR

Singapore did benefit from an increased demand for ship repairs arising from World War 1.

1920s OIL TANKERS

By the time the demand for ship repair arising from World War 1 began to subside, the upsurge in the petroleum trade multiplied the number of oil tankers based in Singapore. In this, Singapore was fortunate that tankers "are always expensive in upkeep" and "require reconstructing after 12 years, and again when 20 to 22 years old."

Floating Dock

1928 SINGAPORE NAVAL BASE

Between 1880 and 1900 7. The Singapore Naval Base was established on the north side of the island. Here, in 1928, the Admiralty installed a floating dock of 857 feet brought from England.

1930 ASIATIC PETROLEUM CO.

Until 1930 most oil tankers of the Asiatic Petroleum Co. docked at Singapore.

1933 DECLINE

By 1933 many Asiatic Petroleum Co. tankers were repaired outside Singapore.

Graving Dock

1938 GRAVING DOCK

In 1938, the Admiralty completed a large graving dock at the Singapore Naval Base.

1938-39 RECOVERY

In 1938/39 the dry dock business, probably with increased repair of oil tankers, reached an annual average of 3.2 million.

Oil Tanker in the 1950s

1950s EXPANDED PETROLIUM EXPORTS

Petroleum exports expanded substantially during the 1950s, and by mid-decade were four times greater in volume than in 1937/38. The Royal Dutch Shell group maintained the Far East headquarters of its tanker fleet at Singapore.

1957-58 SINGAPORE INDUSTRIAL PROMOTION BOARD

In 1957 the Singapore Industrial Promotion Board was established to attract new enterprises to Singapore and encourage the expansion of existing firms.

Caltex gets ready for retail trade

Straits Times, 24 November 1959

1959 CALTEX

In 1959, Caltex began marketing operations in Singapore.

1961 1ST REFINERY AT PULAU BUKOM

Royal Dutch Shell opened the country's first refinery in 1961 on the island of Pulau Bukom. Singapore's geographical location and the worldwide trend among international oil companies to locate refineries near rapidly growing markets were the major reasons determined

1965 SEPARATION

After its separation from the Federation of Malaysia in 1965, Singapore adopted an export-oriented industrialization program to stimulate industrial growth.

Singapore Refining Company (SRC), located on Pulau Merlimau

1977 PETROCHEMICAL CORPORATION OF SINGAPORE

23 Japanese companies and the Singapore government established a 50-50 joint venture, the Petrochemical Corporation of Singapore. The Singapore government offered Pulau Ayer Merbau, as a site for the construction of the petrochemical complex.

1979 SECOND INDUSTRIAL REVOLUTION

After nearly two decades of strong growth based on a liberal policy of attracting all kinds of foreign investments, the „revolution" was aimed at raising the value-added content of the country's economic activity.

PETROLIUM EXPORTS | INDUSTRIAL PROMOTION BOARD | CALTEX | PULAU BUKOM | SEPARATION | JOINT VENTURE | SECOND INDUSTRIAL REVOLUTION

Governmental Action 1945-1961 | Initial Phase | Export Oriented Industrialization 1965-1979 | Transformation

1950 | 1960 | 1970 | 1980

Competition and Decline | Transformation | Path to Global Leadership 1963-1983

Boom in Rigbuilding 1969-1981

QUEEN'S DOCK | JURONG SHIPYARD | RIGBUILDING | VLCC | PALMSTAR ORCHID

View of Clifford Pier, the Inner Roads and the Breakwater in the 1950s

1956 QUEEN'S DOCK

Queen's Dock, completed in 1956, brought the total number of dry docks to six.

Jurong Shipyard, 1969

1963 JURONG SHIPYARD

The first commercial shipyard, Jurong Shipyard, was set up as a joint venture with IHI Japan in 1963. Today, Jurong Shipyard is a wholly owned subsidiary of Sembcorp Marine Ltd.

JW McLean

1969 RIGBUILDING

Singapore was launched into rigbuilding by the fledging Far East Shipbuilding Industries Ltd. The company completed the first jack-up, JW McLean, in 1969.

1972 VLCC

The first Very Large Crude Carrier (VLCC), ST Bulford, drydocked at Jurong Shipyard, propelling Singapore into the supertanker league.

Palmstar Orchid

1976 PALMSTAR ORCHID

Singapore delivered its first and largest oil tanker, the 91,000-dwt Palmstar Orchid, in 1976.

1984 PETROCHEMICAL COMPLEX I

After more than a decade of planning and preparation, Singapore's and Southeast Asia's first petrochemical complex (PCS I) finally came on-stream on Pulau Ayer Merbau in February 1984. The establishment of PCS I provided a key link to the integrated process among the subsectors of the chemical industry.

1980s CHEMICAL ISLAND COMPLEX

Committed to nurturing Singapore as a regional chemical hub, the government has invested S$7.2 billion to build a chemical island complex. This infrastructural project involves combining seven southern offshore islands of Singapore into a single landmass, known as the Jurong Island Chemical Complex.

1991 JURONG ISLAND PROJECT

In 1991, JTC Corporation (formerly Jurong Town Corporation) was appointed the agent of the Jurong Island project. JTC planned and coordinated with various government agencies in providing the necessary infrastructure and services to the island.

1994 PETROCHEMICAL COMPLEX II

In March 1994, the partners of PCS I to announce a S$3.4 billion investment to build PCS II. As related and interdependent activities, these diverse petrochemical investments have contributed to the cluster-development strategy.

1997 COMPLEX II

The Complex II was started up in the 2nd quarter of 1997.

Jurong Island Reclamation

2000 OPENING OF JURONG ISLAND

Jurong Island was officially opened on October 14, 2000 by then Prime Minister Goh Chok Tong.

COMPLEX I
CHEMICAL ISLAND
JURONG ISLAND
CLUSTER
COMPLEX II
OPENING JURONG ISLAND

Transformation | Petrochemical Complex 1984-1995 | Jurong Island 1995-2009

1980 1990 2000

Restructuring 1983-1997 | New Technologies 1997-2009

Collapse 1981-1989 | A New Beginning

DOWNTURN
GLOBAL LEADERSHIP
NEW WAYS
REHABILITATION
RESTRUCTURING
FLOATING POWERPLANT

1981 DOWNTURN

Over 300 rigs were built between 1980 and 1982 in response to global concerns over future oil supply. But when the downturn came, it was so severe that some rigbuilders never recovered. Worldwide orders trickled to 27 in 1984. Starved of new orders, Marathon Le Tourneau and Robin Shipbuilders decided to close.

Semi-Submersible Drilling Rig, Ocean Monarch

1983 GLOBAL LEADERSHIP

Singapore became the largest shiprepair centre in the world in terms of capacity with an aggregate deadweight of 2.82 million tonnes.

1986 NEW WAYS

As new projects were rare, FELS began work on a harsh environment jack-up which can drill in water depths of 90 to 105 metres. The Monarch was the first one to be built.

1989 REHABILITATION

Only specialised units are in demand, for deep-sea or shallow-draft operation. Rigbuilders have had to redefine their roles.

1997 RESTRUCTURING

Restructuring within marine industry saw the first major merger between industry majors, Sembawang Shipyard and Jurong Shipyard.

Sultana del Este

2001 FLOATING POWERPLANT

Jurong Shipyard delivered Sultana Del Este, the world's largest floating power plant to Wartsila NSD of Finland.

(UNKNOWN) SINOPEC

China's Sinopec, has started work to build Southeast Asia's largest oil storage terminal at the Batam free trade zone.

Jurong Island Completion

2009 COMPLETATION OF JURONG ISLAND

From the 9.91 km² land area of the original seven islets, as of completion of the land reclamation on September 25, 2009, Jurong Island currently has a total land area of 30 km².

Pengerang Terminal

2015 PENGERANG OIL TERMINAL

By January 2015, a joint venture between the Dutch oil and chemicals provider Vopak and the Malaysian terminal operator Dialog, plans to finished the first phase of the Pengerang oil terminal at a cost of $620 million.

UNKNOWN TANJUNG PIAI

In Tanjung Piai on the most southern point of the west Malaysia Benalec Sdn Bhd is planning to reclaim 3'485 acres. This reclaimed area is meant to be the ground for the Tanjung Piai Integrated Petroleum and Petrochemical Hub.

COMPLETATION
SINOPEC
PENGERANG
TANJUNG PIAI

Current Extensions | The Future Triangle 2014-2040

2010 2020 2030 2040

NEW WAYS

Roll-on/Roll-off

2009 NEW WAYS

Singapore Technologies Marine delivered the first newbuild Roll-on/Roll-off vessel for transportation of large aircraft components, City of Hamburg.

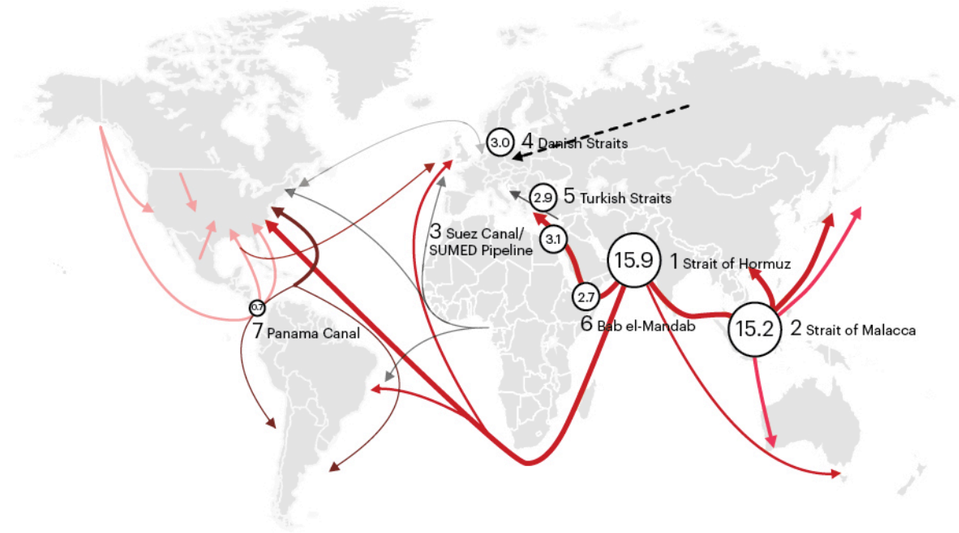
Panoramic View of Singapore, 1863
Panoramic View of Singapore, 2012

Oil: An Imported Industry

Singapore does not have any own oil reserves; there fore, the island state relies completely on imports. Due to the geographic location of the world's oil reserves, most of the imports have their origin in the Middle East.

The oil ships have to pass the Strait of Hormuz on their way to Singapore; the biggest chokepoint for oil trade – and the Strait of Malacca, the second largest.

As oil demand in countries of Asia is increasing, the importance of Singapore as the "gate" to this chokepoint increases.



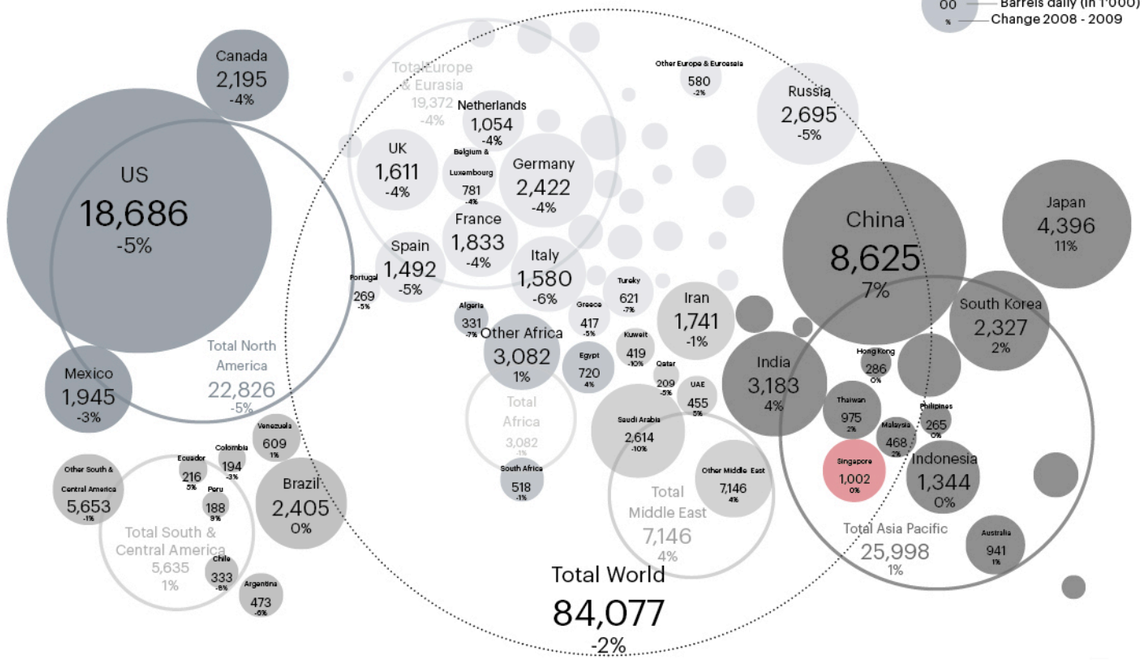
Transport of Crude Oil and Petroleum Products

- Latin America
- Middle East
- Pacific Asia
- North America
- Africa
- Western Europe
- Former Soviet Union
- Pipeline
- Volume of Crude Oil and Petroleum Products transported through World Chokepoints, 2010 (in million barrels per day)[5]

Different Modes of Global Oil Tranport

	Pipelines	Marine	Rail	Truck
Volumes	Large	Very large	Small	Small
Materials	CrudeProducts	Crude/Products	Products	Products
Scale	2 ML+	10 ML+	100 kL	50-60 kL
Unit costs	Very low	Low	High	Very high
Capital costs	High	Medium	Low	Very low
Access	Very limited	Very limited	Limited	High
Responsiveness	1-4 weeks	7 days	2-1 days	4-12 hours

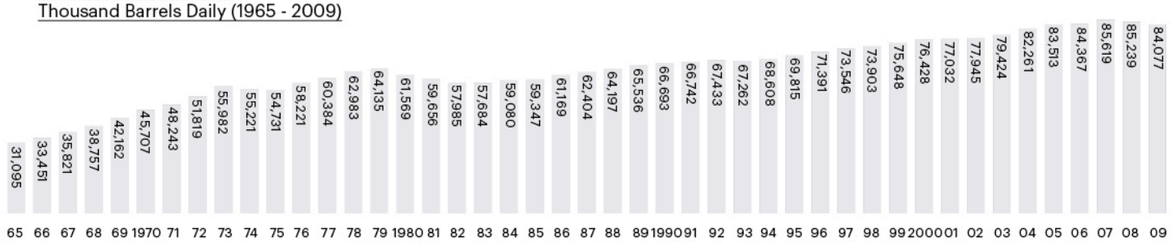
Oil Consumption Around the World, 2009



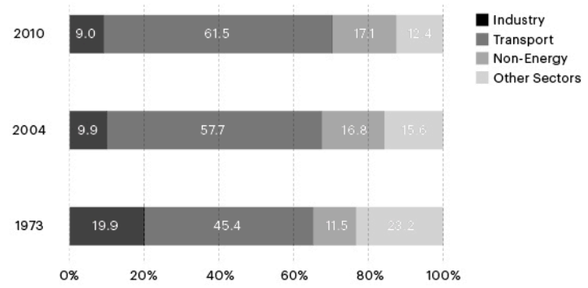
Daily Oil Consumption, 2009

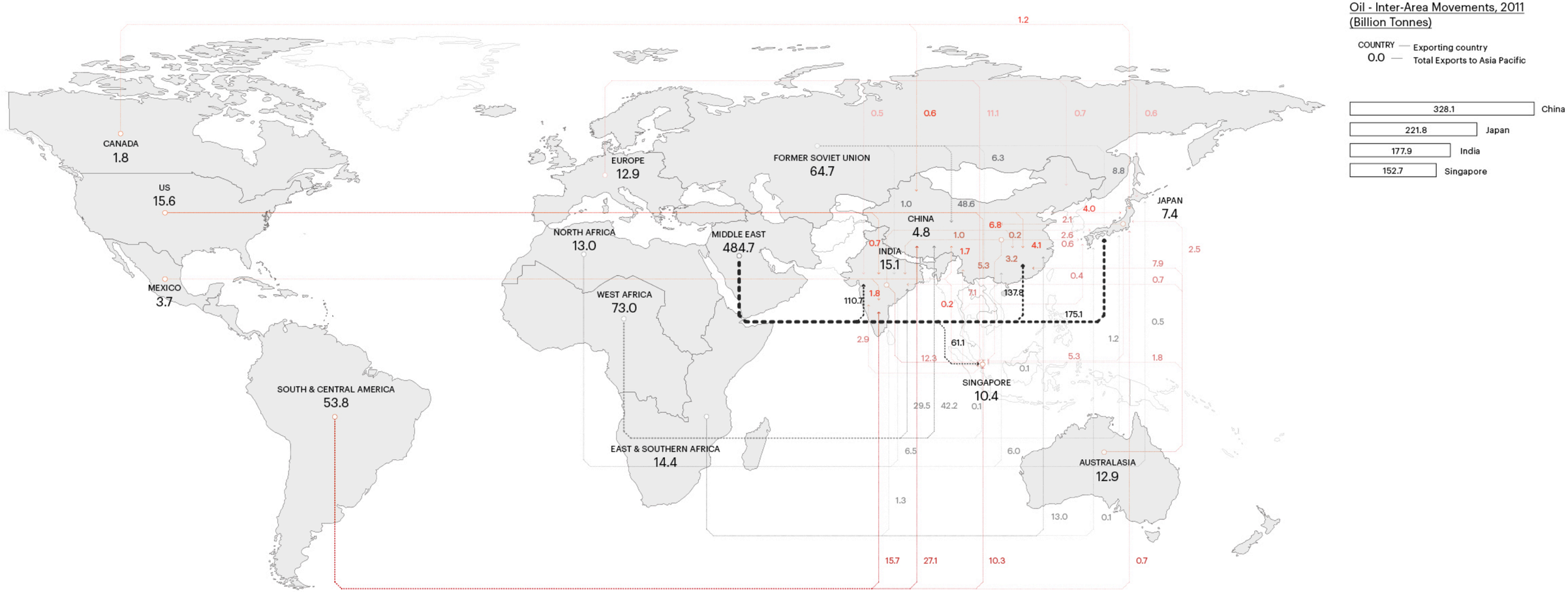
Country
00 — Barrels daily (in 1'000)
% — Change 2008 - 2009

World Oil Consumption
Thousand Barrels Daily (1965 - 2009)



World Oil Energy Consumption by Sector (1973-2010)





Oil - Inter-Area Movements, 2011
(Billion Tonnes)

COUNTRY — Exporting country
0.0 — Total Exports to Asia Pacific

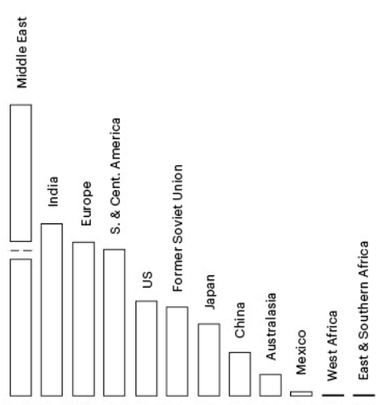
328.1	China
221.8	Japan
177.9	India
152.7	Singapore

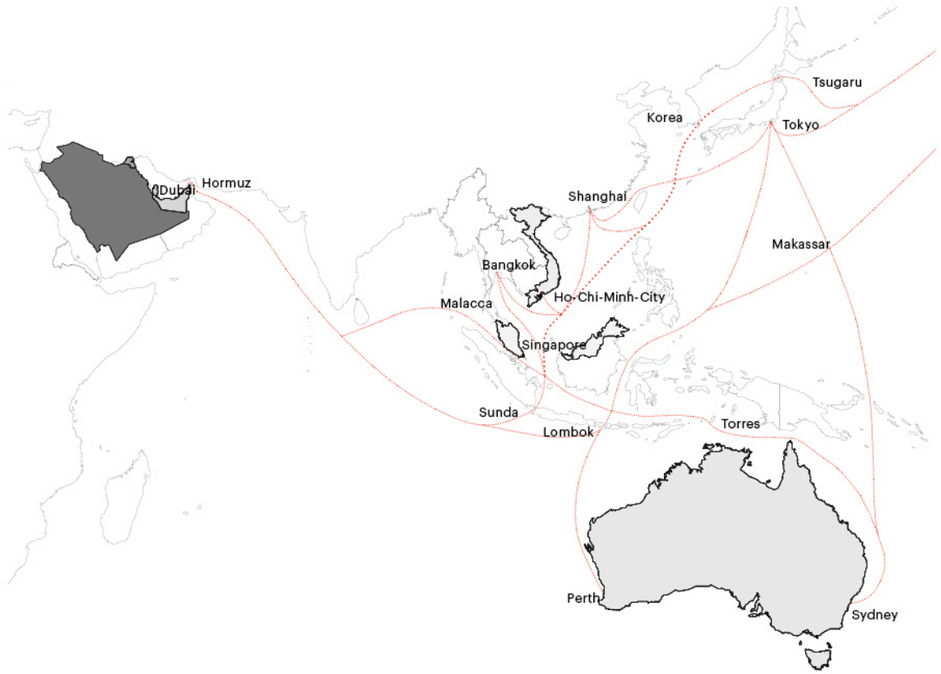
Worldwide Oil Imports to Asia

The largest oil exporters are the Middle East, the former Soviet Union and West Africa.

Singapore receives a total of 152.7 billion tones of oil per year, which makes it the fourth largest importer of oil in Asia. Singapore's imports are largely diversified, making it more independent than in the gas sector. The island state receives the largest portion of its oil imports from the Middle East, followed by India, Europe and South and Central America.

Singapore's Oil Importers, 2011
(Billion tonnes)





Singapore's Oil Import

Singapore's Oil Export

Oil Facilities

1. Tanjung Bin Terminal
2. Tanjung Piai Terminal (Future)
3. Idemitsu Petrochemical Complex
4. Titan Terminal
5. Pasir Gudang Terminals (Vopak & Felda)
6. Tanjung Langsat Terminals
7. RAPID Terminal (Future)
8. Jurong ExxonMobil Refinery
9. Penjuru Vopak Terminal
10. Penjuru Chevron Terminal
11. Jurong Island
12. Pulau Bukom
13. Pulau Sebarok
14. Pulau Karimun Oiltanking Terminal (Future)
15. Pulau Sambu Pertamina Terminal
16. Pulau Janda Berias Sinopec Terminal (Future)
17. Batam Pelabuhan CPO Terminal
18. Bintan Tanjung Uban Terminal

Oil Anchorage Zones

19. Tanjung Pelepas Petroleum Anchorage
20. Tuas Petroleum Holding
21. Very Large Crude Carrier
22. Sudong Bunkering
23. Western Petroleum
24. Eastern Petroleum
25. Eastern Bunkering
26. Johor Petroleum
27. Karimun Offloading Zone to Improve Accessibility of VLCC Vessels into Singapore

○ "Gates to the City": Pilot Boarding Point
● Offloading Points: Jetties

Oiltanker

Singapore receives all of its mineral products by ship. The harbor and its accessibility therefore plays a crucial role.

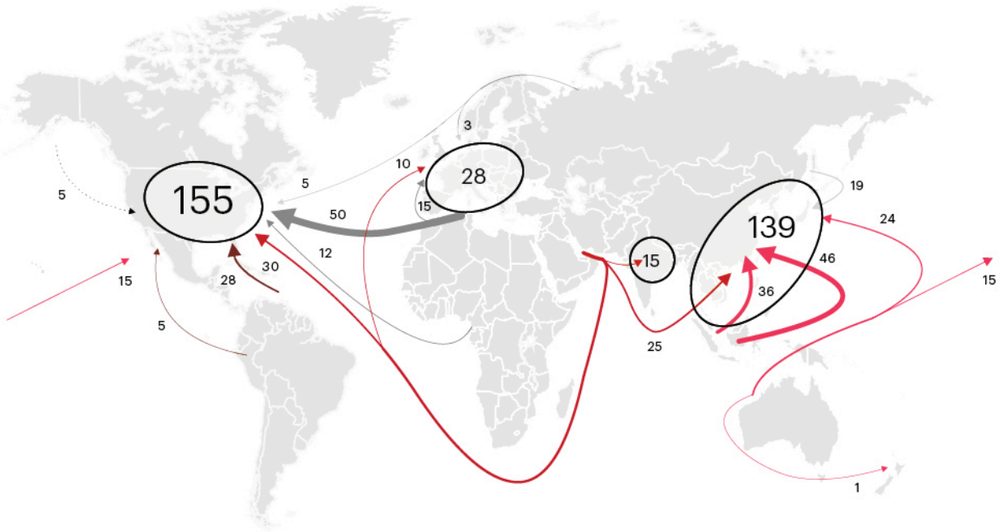
Gas: A Regional Network

In comparison to Singapore's oil import, the import situation of natural gas is different. Instead of a global oil chain, the gas import structure is based on a regional network.

Neighboring countries like Malaysia or Indonesia are providing the gas security for Singapore so far. Due to growing demand in the home countries, Singapore could face a serious shortage of supplies in the near future. Therefore new gas import options like LNG are currently under construction, securing Singapore's independence in future times.

The new Singaporean LNG terminal is located on Jurong Island and will be operational by the beginning of 2013, opening a new field of markets for growing energy demand. This could benefit companies, which rely heavily on electricity, especially in the chemical industry.

In addition, trading opportunities could develop trough the storage of LNG within Singapore, reinforcing Singa-pore's position as a global hub for liquid energy.



World LNG Trade (2015)
Total Sales = 337mt
(13% of global gas consumption)

Dependence on Gas for Energy Consumption in Southeast Asia

Brunei and Singapore are both largely dependent countries on natural gas for electricity generation.

Other than Singapore, Brunei has major gas reserves and is energitically self-sufficient. The same is true with other ASEAN countries.

The independence of Singapore is a certain risk for economic development, due to the tendency towards electricity prices, because of these circumstances.

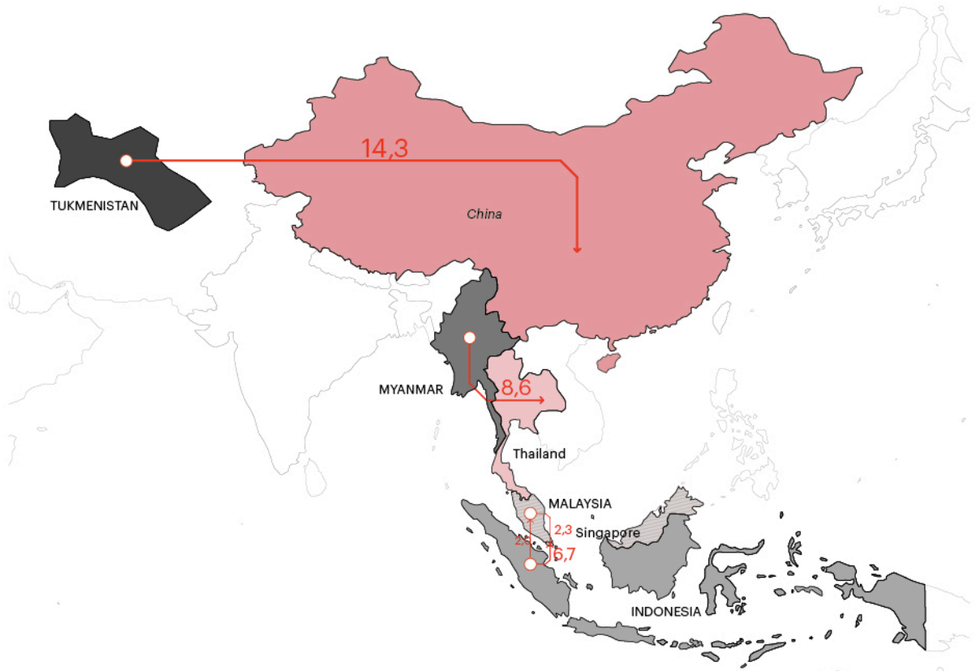
The opening of Singapore towards a larger LNG market is a first step, though alternatives like coal or renewables sources should be kept in mind.

ASEAN Pipeline Network

As Singapore relies entirely on piped natural gas, it wants to diversify its sources of gas by building a new LNG terminal, which will be operational by 2013.

Even though Indonesia and Malaysia were the second and third largest LNG exporters last year, these countries are now looking to import LNG as a result of their decreasing productivity and increasing demands.

Pipeline Trade Movements to Asia Pacific



Trade Movements by Pipeline

China is the largest recipient of piped natural gas in Asia. Singapore follows at second place, receiving 6.7 billion cubic meters from Indonesia and 2.3 billion cubic meters from Malaysia.

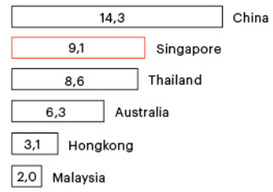
The problem concerning pipeline trade is the high dependence on other countries, not providing any alternatives in case of conflict.

The advantage of pipelines on the other hand is the constant flow of gas, which enables a precise production, so that storage can be reduced to a minimum.

The alternative to piped natural gas is LNG, which requires costly liquefaction and regasification as well as large storage facilities as the incoming flow of gas is constantly changing.

The drive for Singapore in reducing its dependence is understandable, but it has to prove to be economical feasible.

Total Imports (Billion Cubic Meters)



Total 9,1 Billion Cubic Meters imported to Singapore

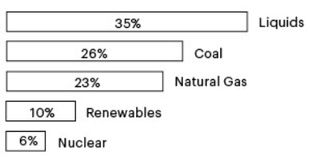
Global Primary Energy Demand

Global demand for energy has risen inexorably in the last 150 years along with industrial development and population growth. Hunger for energy is predicted to continue to rise by at least 50% by 2030, as developing countries like China and India seek to fuel their rapid economic growth. The lion's share of global energy (about 84% at present) is supplied by coal, oil and gas - the fossil fuels." (BBC News) Singapore relies almost entirely on these fuels for its primary energy demand. Today, around 88 percent of the energy consumed comes from oil products, 11 percent comes from gas and an small portion from renewable sources.

Primary Energy Consumption, 2011 (million tones oil equivalent)

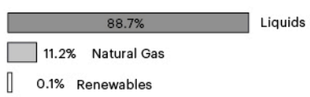
Emerging economies in Asia Pacific consume large amounts of oil. However, oil reserves in this part of the globe are relatively small. Oil imports from the Middle East is therefore necessary to meet the demand of local Asian Pacific markets. Singapore occupies a strategic position in this network as it operates as a distributer of oil and oil-related services.

World Market Energy Use, 2010



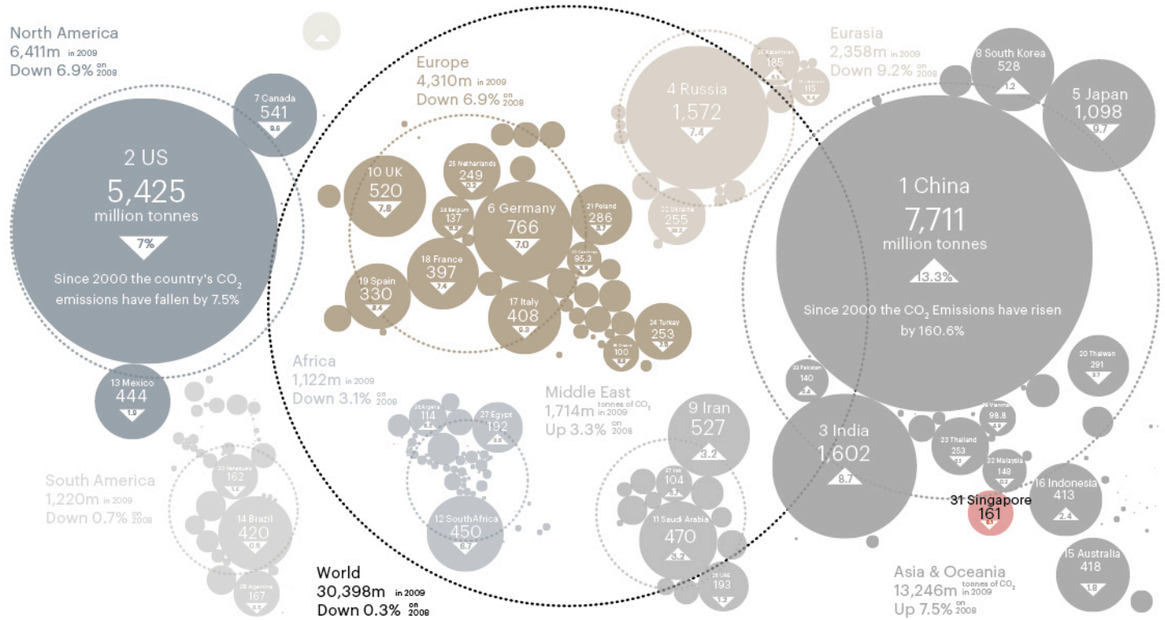
TOTAL 12274.6 MTOE
million tonnes oil equivalent

Singapore Energy Use, 2011

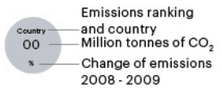


TOTAL 70.44 MTOE
million tonnes oil equivalent

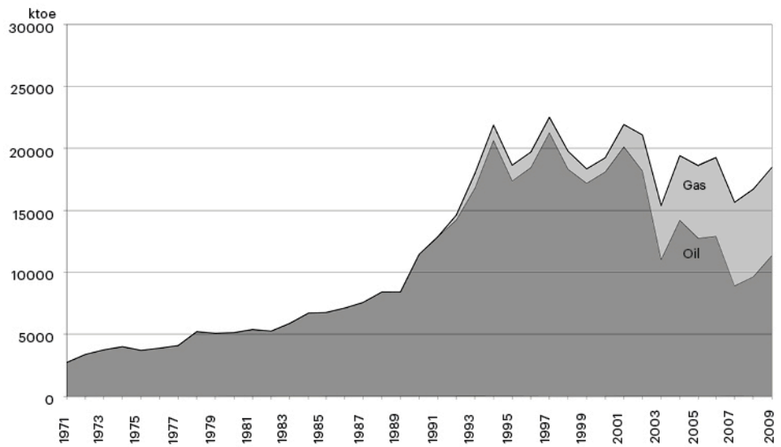
An Atlas of Pollution: the World in Carbon Dioxide Emissions



Emissions, 2009



Total primary Energy Supply, Singapore, 2009 (ktoe)



South-East Asia Pipelines Map 2011

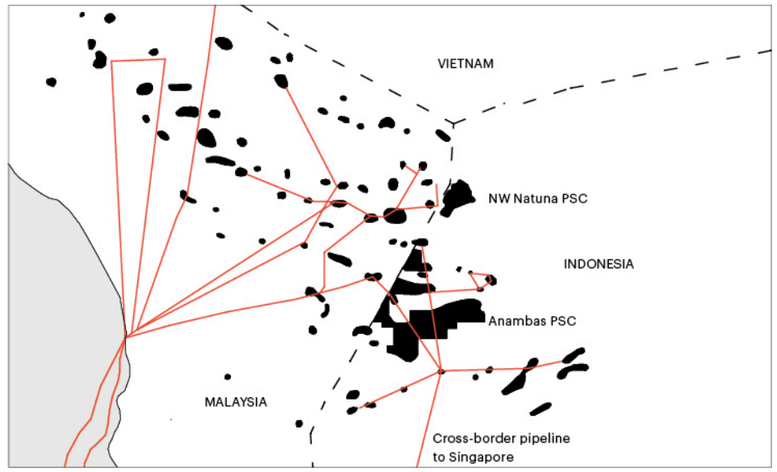
GXX Gas Pipeline

Natuna Gas Field

"Natuna gas field is in the Greater Sarawak Basin about 1,100km (700 miles) north of Jakarta and 225km (140 miles) northeast of the Natuna Islands, Indonesia's northernmost territory in the South China sea.

Discovered in 1970 by Italy's Agip, the field is the biggest in Southeast Asia with an estimated 46 trillion cubic feet (tcf) of recoverable reserves, but has been developed only recently.

The 640km Natuna transportation system is one of the world's longest subsea gas pipelines, delivering to Singapore."



Zoom-in
Natuna Gas Field

Cross-Border Pipelines

- Indonesia - Singapore

G41 W. Natuna Sea fields - Singapore

- Malaysia - Philippines

G44 Bintulu - Manila

- Malaysia - Singapore

G52 Segamat - Singapore

- Myanmar - Thailand

G68 Yadana field -Ratchaburi

G79 Yadana field -Ratchaburi

- Thailand - Malaysia

G45 Thailand-Malaysia

Brunei

G23 Offshore fields - Lumut

Indonesia

G37 Muaraenim fields - Palembang

G39 Rantau- Belawan

G40 Talang Akar fields - Palembang

Malaysia

G46 Kerteh - Kuala Lumpur

G47 Kuala Lumpur - Melaka

G48 Penang - Kota Baharu

G49 Sarawak offshore fields - Bntulu

G50 Sarawak offshore fields - Lutong

G51 Sarawak offshore fields - Labuan Island

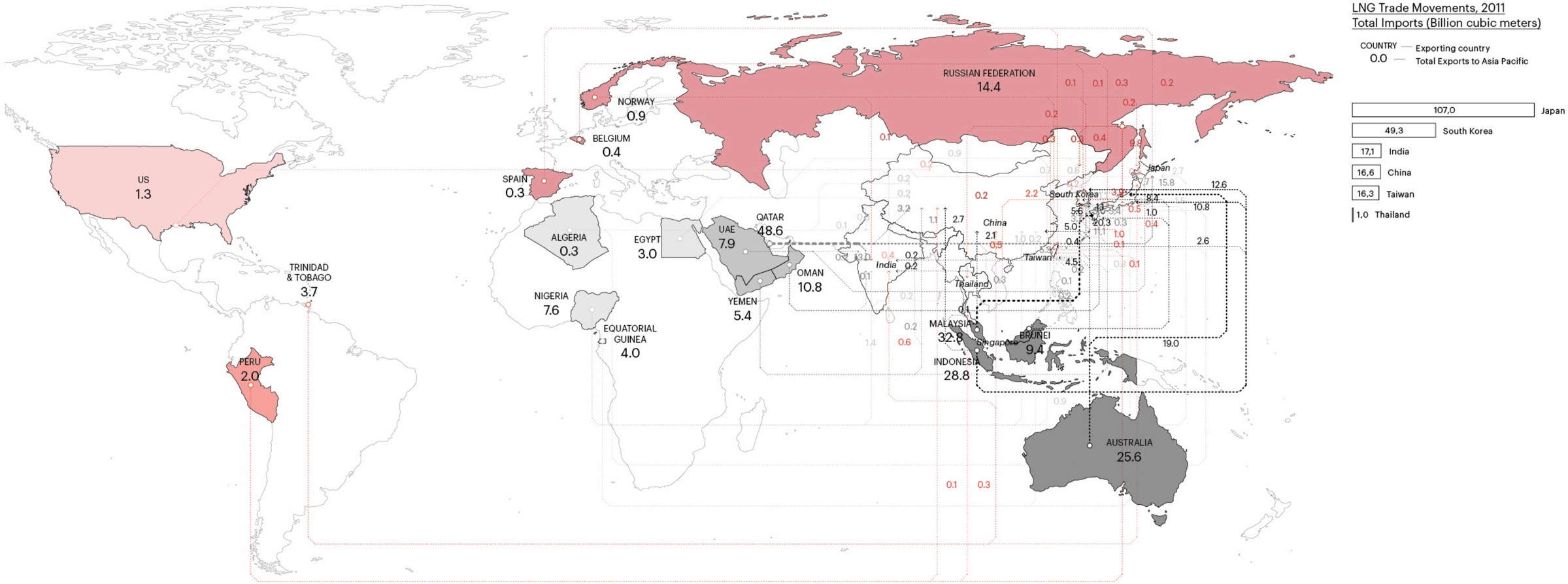
G53 W. Malaysia offshore fields - Kerteh

Thailand

G64 Erawan - Khanom GSP/PP

G65 Gulf of Thailand - Map Ta Phut GSP

G66 Link from G65 - Ratchaburi



LNG Trade Movements, 2011
Total Imports (Billion cubic meters)

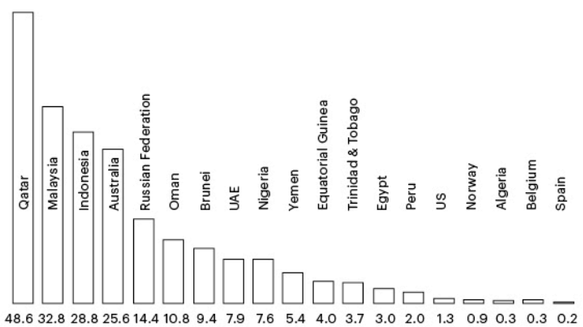
COUNTRY — Exporting country
0.0 — Total Exports to Asia Pacific

107,0 Japan
49,3 South Korea
17,1 India
16,6 China
16,3 Taiwan
1,0 Thailand

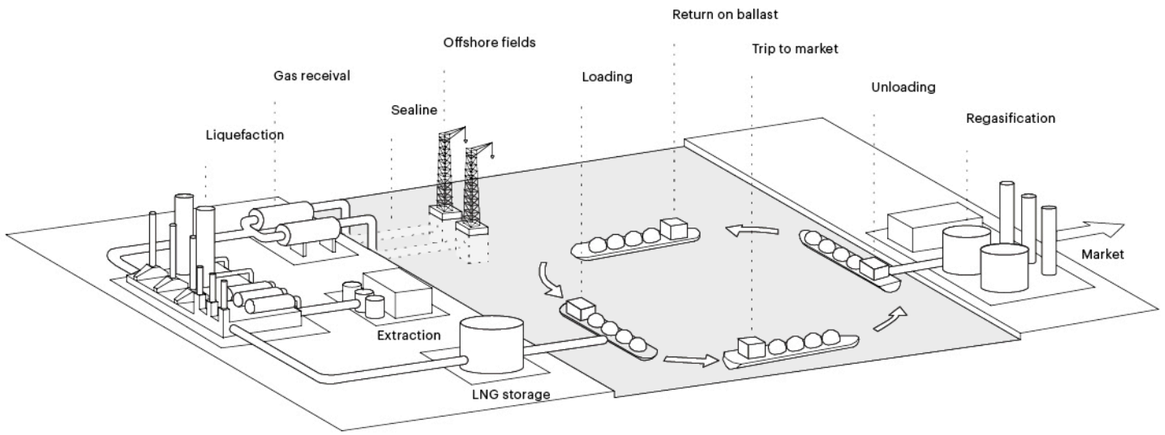
Liquified Natural Gas (LNG) Trade

"The cost of transporting natural gas per unit of energy to distant markets is much higher compared to oil because of its volume–pressure behavior, and currently usually occurs by pipeline on-land, or, increasingly, via liquefied natural gas (LNG) for overseas."(Review of Ways to Transport Natural Gas Energy from Countries which do not need the Gas for Domestic Use; Thomas, Dawe; Energy; Elsevier; 2003)
"The biggest obstacle for the LNG trade, which allows the transport of gas over long distances is that, many importing countries do not have the capital to build the huge storage and regeneration facilities." (Review of Ways to Transport Natural Gas Energy from Countries which do not need the Gas for Domestic Use; Thomas, Dawe; Energy; Elsevier; 2003)

LNG Trade Movements 2011
Total Exports to Asia Pacific
(Billion Cubic Meters)



The LNG Value Chain

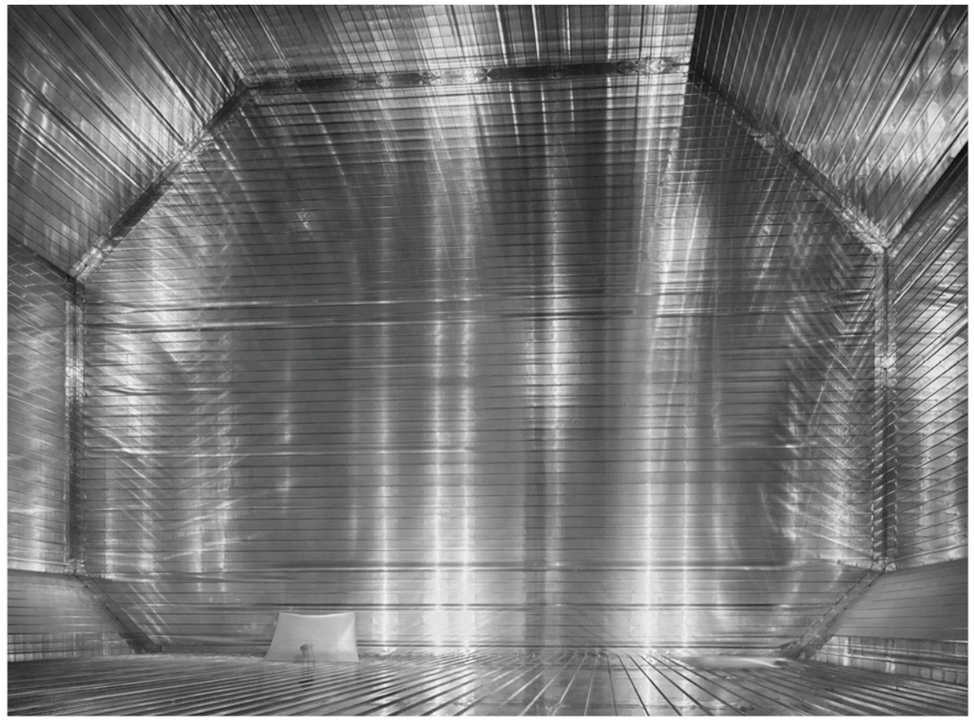


Singapore's Future: LNG

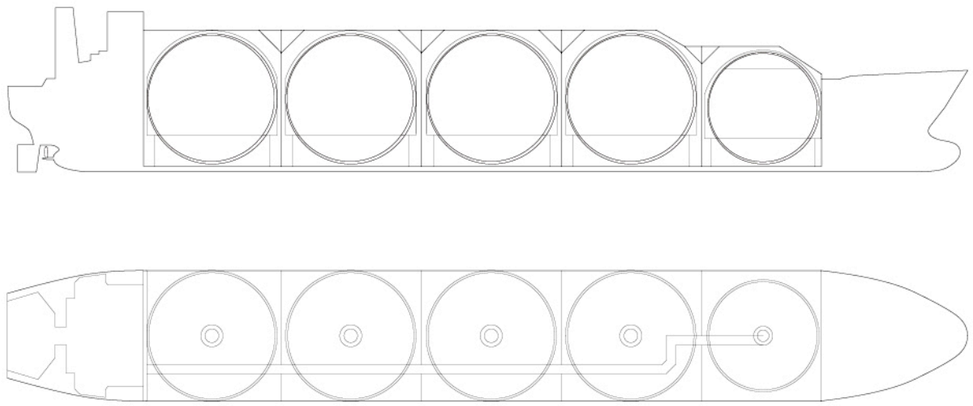
"Singapore's new liquefied natural gas (LNG) terminal will be able to handle sufficient imports of the fuel to cover all of the country's power needs, even if piped gas supply contracts with Malaysia and Indonesia are not renewed.

Supply will come under pressure because of growing domestic gas demand in Malaysia and Indonesia. What we will do is ensure sufficient capacity to import LNG to meet all of our gas demand," said Chee Hong Tat, the chief executive of Singapore's Energy Market Authority.

Singapore officials have previously said the new terminal was designed to supplement piped gas.



LNG carrier from inside



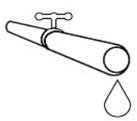
Gas Facilities

1. LNG Terminal Singapore (2013)

Gas Anchorage Zones

2. Tanjung Pelepas Explosives
3. LNG/LPG/Chemical Gas Carriers
4. Sudong Explosive
5. Eastern Special Purpose
6. Eastern Special Purpose

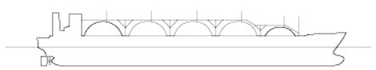
○ "Gates to the City": Pilot Boarding Point
● Offloading Points: Jetties



Natural Gas by Pipeline

Advantage for Singapore:
Constant flow of gas, Fixed prices

Disadvantage:
Reliance on Indonesia and Malaysia



LNG Carrier

Advantage for Singapore:
Global market, probably lower prices due to competition

Disadvantage:
High investment costs, unsteady flow

1.
ATB Tanjung Bin

2.
Pulau Sambu

3.
Karimun

4.
Juront Island area

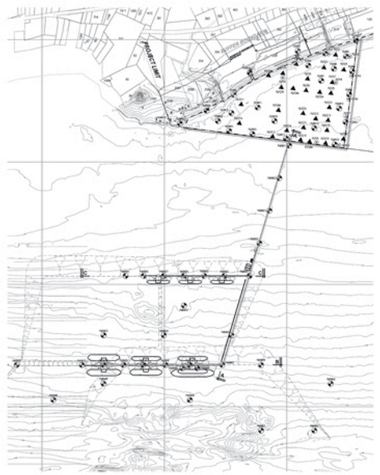
5.
Plan for RAPID LNG
Terminal, Penggeran

6.
Pasir Gudang

7.
Tanjung Langsat

1.

2.



5.

3.

4.

6.

7.

Oil Facilities

1. Tanjung Bin Terminal
2. Tanjung Piai Terminal (Future)
3. Idemitsu Petrochemical Complex
4. Titan Terminal
5. Pasir Gudang Terminals (Vopak & Felda)
6. Tanjung Langsat Terminals
7. RAPID Terminal (Future)
8. Jurong ExxonMobil Refinery
9. Penjuru Vopak Terminal
10. Penjuru Chevron Terminal
11. Jurong Island
12. Pulau Bukom
13. Pulau Sebarok
14. Pulau Karimun Oiltanking Terminal (Future)
15. Pulau Sambu Pertamina Terminal
16. Pulau Janda Berias Sinopec Terminal (Future)
17. Batam Pelabuhan CPO Terminal
18. Bintan Tanjung Uban Terminal

Oil Anchorage Zones

19. Tanjung Pelepas Petroleum Anchorage
20. Tuas Petroleum Holding
21. Very Large Crude Carrier
22. Sudong Bunkering
23. Western Petroleum
24. Eastern Petroleum
25. Eastern Bunkering
26. Johor Petroleum
27. Karimun Offloading Zone to Improve Accessibility of VLCC Vessels into Singapore

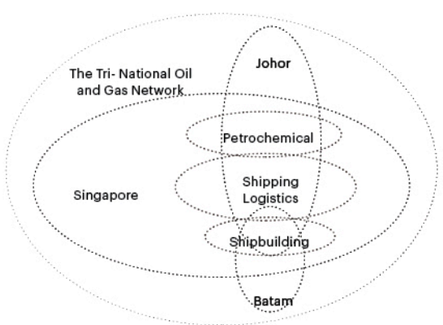
Gas Anchorage Zones

21. LNG/LPG/Chemical Gas Carriers
24. Sudong Explosive
27. Eastern Special Purpose
28. Eastern Special Purpose

Gas Facilities

32. LNG Terminal Singapore

○ "Gates to the City": Pilot Boarding Point
● Offloading Points: Jetties



Chemical Island

If Singapore is the petrochemical center of the region, then Jurong Island could be called the petrochemical heart of Singapore. Often referred as Houston of the East, Singapore's Jurong Island is already often taken as a model of how to organize a petrochemical sector densely and efficiently. The whole petrochemical industry in Singapore can be considered as a maritime enclave with an intended separation from the mainland. These two islands artificially created to hold this specific sector are highly organized and have special regulations. If the mainland was not so dependent on them It could be said that Jurong Island and Pulau Bukom are not really part of Singapore.

View to Jurong Island from the Vopak jetty in Singapore mainland

Land Reclamation Process

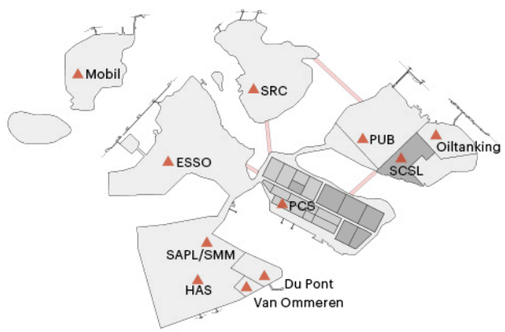
- Former Islands
- First Joining
- Second Joining
- Island Expansion

The Construction of Jurong Island

Until the 1960s the former islands of Pulau Seraya, Merlimau, Ayer Merbau and Ayer Chawan contained small fishermen kampungs. Whith the arrival of the Singapore Refining Company, Esso and Mobil to Pulau Merlimau, Ayer Chawan and Pesek, the environment of these former islands would rapidly change.

The fast industrialization of Singapore and the government pushing the petrochemical sector resulted in a growing lack of industrial land. From this came the idea of joining the 7 islands into an immense new island. With the formation of the JTC Corporation, a main institution was formed for the management of the island.

100% 121% 159% 286%



Initial Uses

- Company
- Pipe Bridges
- Existing Land
- Complex I
- Complex II

1.

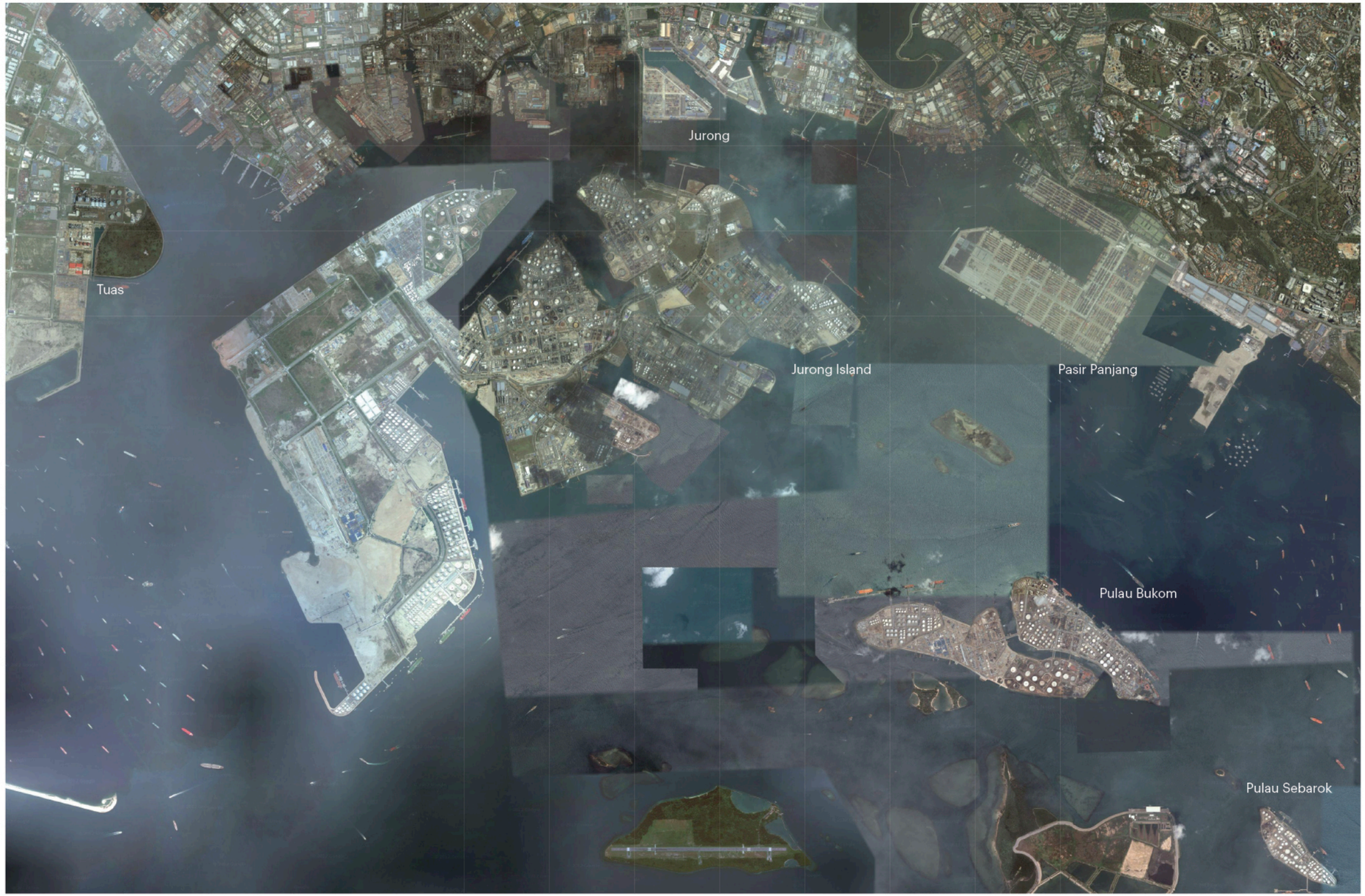
2.

3.

1. View from Taman Jurong to Pulau Seraya

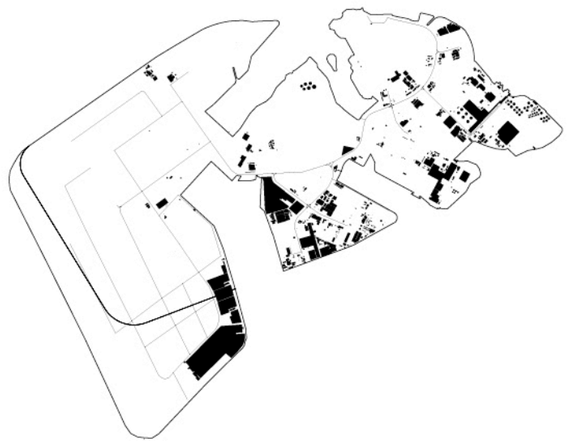
2. Natural coastline of Taman Jurong

3. Urbanized coastline of Taman Jurong



Center of Petrochemical Industries

Jurong Island is right in front of the Pasir Panjang Container Terminal. As visible on the satellite image, Jurong Island and Pulau Bukom gather all the facilities which are meant for primary petrochemical production. The ongoing reclamation on the south eastern part will offer even more space for this sector.



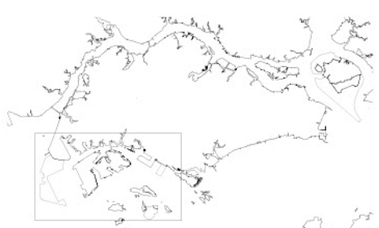
Data provided by URA

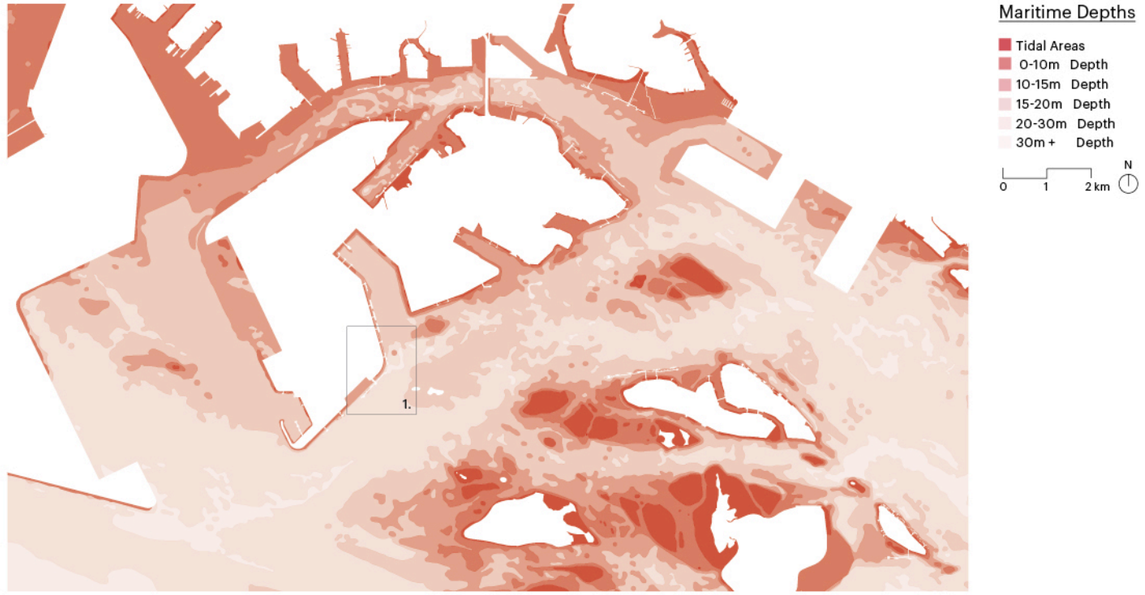
Reconstructing the Map

The first step in mapping Jurong Island would be to acquire maps with the footprint and the street network. But in the case of Jurong Island, such information remain scarce. The corresponding data with the exact in information are categorized as sensitive since the events of 9/11. In order to understand the island better we used satellite pictures of different sources and years to reconstruct maps of the built structure of Jurong island and specially to get information of the characteristics of petrochemical plants.

Built Structures

There are two important types of built structures on Jurong Island. The main typologies are the oil tanks and the chemical plants. Most of the structures are visibly connected by pipes of several sizes and give an impression of being one giant structure. These typologies are also visible on the Pulau Bukom and Pulau Sebarok islands.





Maritime Depths

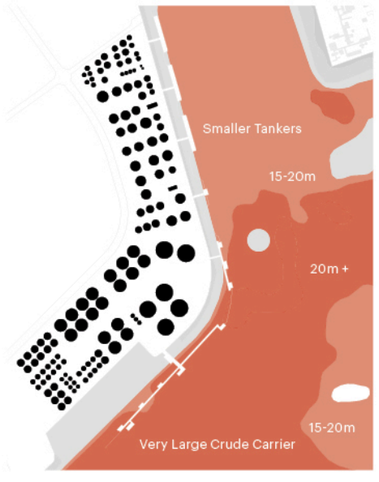
Tidal Areas
0-10m Depth
10-15m Depth
15-20m Depth
20-30m Depth
30m + Depth

0 1 2 km N

Maritime Accessibility

The natural conditions of the maritime territory of Singapore are one of the main reasons for the success of its port. The depths allow vessels of the Malaccamax class (very large crude carriers) to be served at the Port of Singapore.

The new reclamations, for example in Tuas, allow an even greater access to deep water zones in the land area granting more berths for large vessels.



Maritime Zones

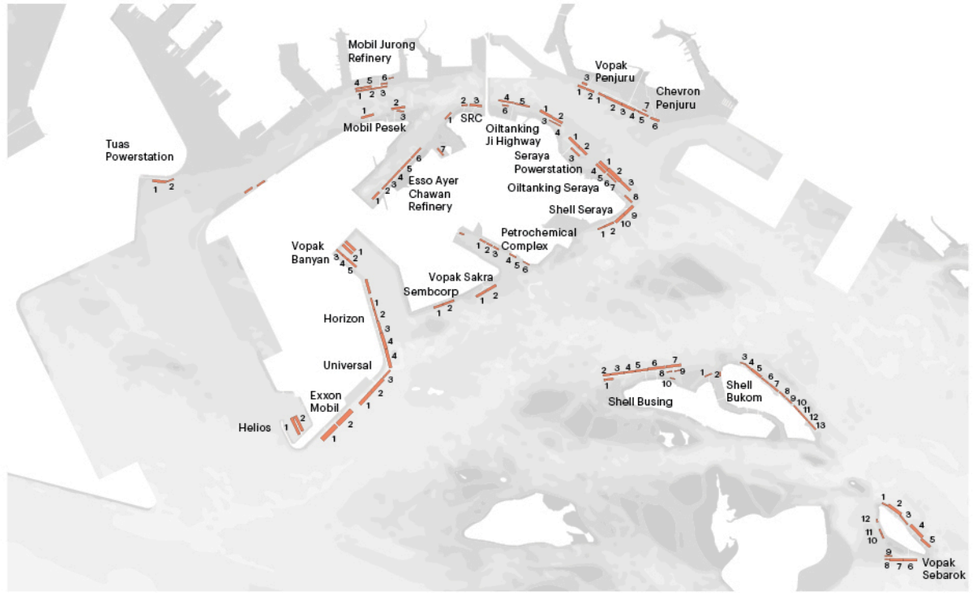
Pilot Boarding Point
Shipways
General Anchorages
Military Anchorages
Petroleum Anchorages
Bunkering
Special Purposes

0 1 2 km N

Maritime Service Zones

The space around Jurong Island is not void. It is a highly organised space, which is mainly used for transiting and anchoring. To enter the Port of Singapore a vessel coming from the strait has to stop at a pilot boarding point. Once the pilot arrives, the vessel is under the control and supervision of the Maritime Port Authority of Singapore and guided by the port master. Because the Port of Singapore is so busy, there are several different anchorage zones for different sizes of vessels and different loads.

Zonings of Jurong & Tuas



Jetties
Berth Areas
0 1 2 km N

Jetties & Berths

Jetties are needed to transfer crude oil and oil products from a vessel to a terminal and vice-versa. Every storage and refining company needs jetties to get their crude oil, while value adding downstream companies can acquire their feedstock from the refineries and the terminals. A Jetty provides a pipeline connection between the tanks of the vessel and the terminal tanks. The engine of the terminal is used to pump the oil to the ship, while to get oil from the ship the engine of the ship is used. The depths of the berths are the most crucial quality of a jetty because they define exactly what ships can dock to the jetty and what specific amount of load they are permitted to carry.

Depths

Tuas Powerstation
Berth 1 - 13.0m
Berth 2 - 10.3m

Mobil Jurong Refinery
Berth 1 - 13.9m
Berth 2 - 12.9m
Berth 3 - 13.0m
Berth 4 - 12.3m
Berth 5 - 11.8m
Berth 6 - 8.6m

Mobil Pesek
Berth 1 - 14.7m
Berth 2 - 14.6m
Berth 3 - 9.0m

Esso A. Chawan Refinery
Berth 1 - 13.6m
Berth 2 - 8.5m
Berth 3 - 12.6m
Berth 4 - 12.6m
Berth 5 - 15.5m
Berth 6 - 15.2m
Berth 7 - 10.0m

SRC
Berth 1 - 10.7m
Berth 2 - 11.4m
Berth 3 - 12.4m
Berth 4 - 15.3m
Berth 5 - 15.5m
Berth 6 - 10.6m

Vopak Penjuru Terminal
Berth 1 - 14.1m
Berth 2 - 13.7m
Berth 3 - 12.0m

Chevron Penjuru Terminal
Berth 1 - 13.3m
Berth 2 - 13.9m
Berth 3 - 14.3m
Berth 4 - 11.8m
Berth 5 - 12.1m
Berth 6 - 10.3m
Berth 7 - 2.9m

Seraya Powerstation
Berth 1 - 16.3m
Berth 2 - 15.2m
Berth 3 - 15.4m

Oiltanking Seraya Terminal
Berth 1 - 14.3m
Berth 2 - 14.5m
Berth 3 - 16.1m
Berth 4 - 12.3m
Berth 5 - 12.8m
Berth 6 - 14.5m
Berth 7 - 14.6m
Berth 8 - 12.4m
Berth 9 - 14.8m
Berth 10 - 13.9m

Shell Seraya Chemical
Berth 1 - 15.2m
Berth 2 - 15.7m

S. Petrochemical Complex
Berth 1 - 12.0m
Berth 2 - 12.1m
Berth 3 - 10.0m
Berth 4 - 6.8m
Berth 5 - 1.8m
Berth 6 - 3.0m

Vopak Sakra Terminal
Berth 1 - 13.0m
Berth 2 - 12.3m

Sembcorp Industries
Berth 1 - 13.2m

Chevron Oronite
Berth 1 - 14.5m

Vopak Banyan Terminal
Berth 1 - 16.5m
Berth 2 - 16.8m
Berth 3 - 11.5m
Berth 4 - 15.8m
Berth 5 - 15.2m

Horizon Terminal
Berth 1 - 16.5m
Berth 2 - 16.5m
Berth 3 - 16.5m
Berth 4 - 16.8m

Universal Terminal
Berth 1 - 23.7m
Berth 2 - 23.5m
Berth 3 - 22.8m
Berth 4 - 17.7m
Berth 5 - 23.4m
Berth 6 - 17.3m
Berth 7 - 18.7m
Berth 8 - 10.6m
Berth 9 - 10.8m
Berth 10 - 10.8m

ExxonMobil
Berth 1 - 24.5m
Berth 2 - 23.5m

Helios Terminal
Berth 1 - 18.3m
Berth 2 - 18.5m

Shell Busing
Berth 1 - 15.9m
Berth 2 - 17.5m
Berth 3 - 17.1m
Berth 4 - 15.3m
Berth 5 - 14.7m
Berth 6 - 16.9m
Berth 7 - 17.0m
Berth 8 - 14.7m
Berth 9 - 13.5m
Berth 10 - 8.5m

Shell Bukom
Berth 1 - 11.2m
Berth 2 - 5.7m
Berth 3 - 13.2m
Berth 4 - 13.0m
Berth 5 - 16.2m
Berth 6 - 13.5m
Berth 7 - 15.6m
Berth 8 - 12.9m
Berth 9 - 11.8m
Berth 10 - 11.3m
Berth 11 - 11.3m
Berth 12 - 12.3m
Berth 13 - 15.8m

Vopak Sebarok
Berth 1 - 9.6m
Berth 2 - 17.1m
Berth 3 - 10.3m
Berth 4 - 16.9m
Berth 5 - 12.9m
Berth 6 - 17.7m
Berth 7 - 17.0m
Berth 8 - 17.0m
Berth 9 - 11.7m
Berth 10 - 11.2m
Berth 11 - 12.1m
Berth 12 - 5.5m

Oil Storage Companies
Companies
Underground Storages
0 1 2 km N

Storage

The storage of oil and its products require a relatively large amount of space compared to the other functions of the Island. In order to save the surface space of Jurong Island for the more specialized processes, JTC Corporation is currently building an underground crude storage facility (Jurong Rock Cavern) with a capacity of 2'940'000 cbm.

Vopak (1.+2.)
TOTAL CAPACITY: 3'048'297 cbm
Banyan: 1'261'319 cbm
Sebarok: 1'260'958 cbm
Sakra: 288'070 cbm
Penjuru: 237'950 cbm

Universal (3.)
TOTAL CAPACITY: 2'300'000 cbm

Oiltanking (4.)
TOTAL CAPACITY: 1'815'072 cbm
Seraya: 717,500 cbm
Ji highway: 649,572 cbm
Helios: 448'000 cbm

Horizon (5.)
TOTAL CAPACITY: 1'237'400 cbm

Chevron (6.)
TOTAL CAPACITY: 238'480 cbm


1.


2.


3.


4.


5.

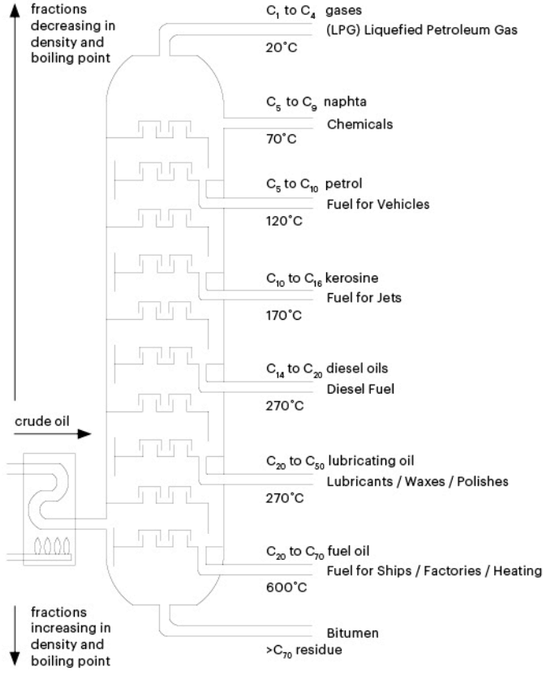

6.

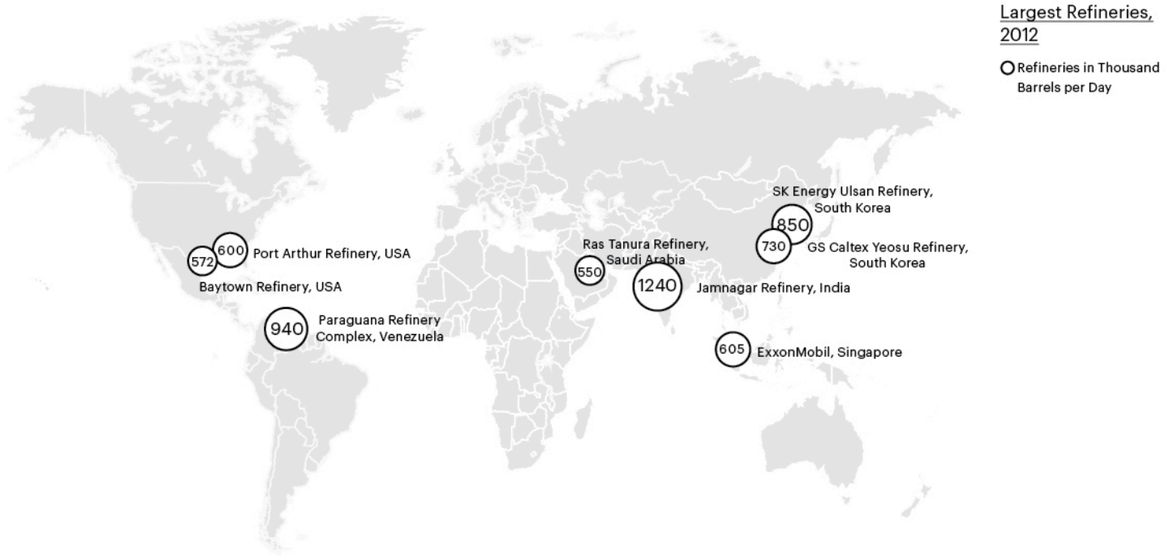
Refineries

Crude oil reveals its real qualities when it is divided in its components. This process is called refining and the main instrument for understanding this procedure is the refining column.

Each product of this process has own qualities, but for the petrochemical sector three refining products are relevant. Liquefied petroleum gas, naphtha and gasoil are the main components that continue their way on Jurong Island for example from ExxonMobil to the Petrochemical Corporation of Singapore (PCS).

1. Refining





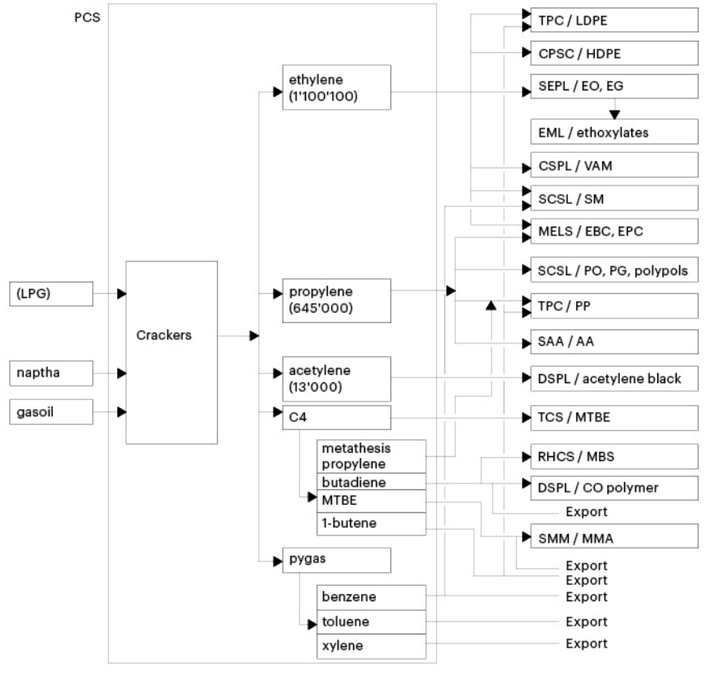
Petrochemicals and Products

The main purpose of PCS is to provide the downstream companies high quality ethylene, propylene, acetylene, butadiene etc. It functions as the upstream company of the petrochemical complex on Pulau Ayer Merbau and coordinates all the supporting activities for the downstream companies.

The downstream companies take these products and produce monomers or further products but already with much higher value than the crude oil that came to Singapore by tankers. These other downstream companies complement and compete with each other. There are cases where the same two companies are competitors in one field and have supply contracts on the other side. In any case most of the products leave Singapore again by a tanker.

2. Cracking

3. Value Adding



Gas Network

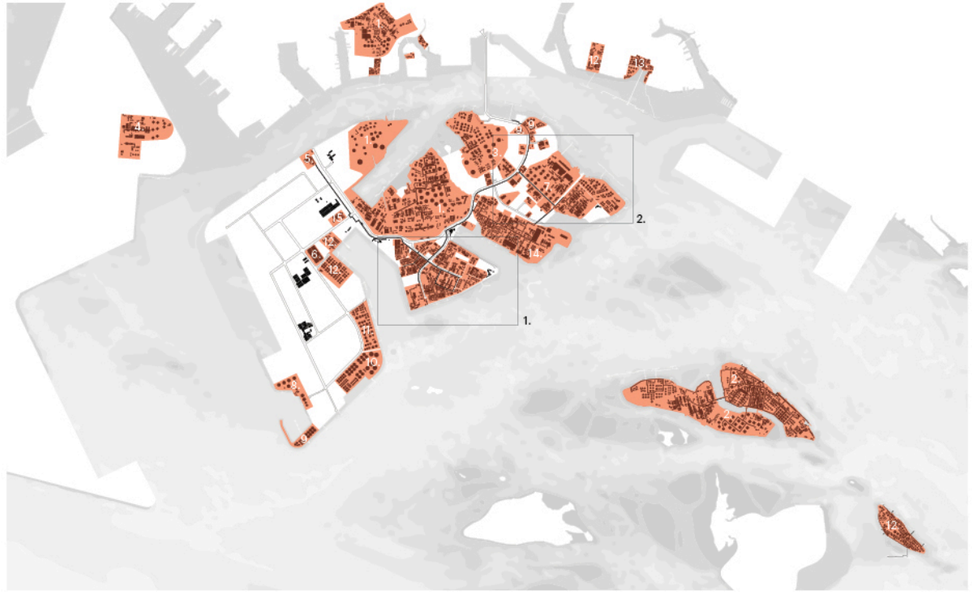
Jurong Island together with Senoko are the main influx point of natural gas in Singapore. Because of the presence of the pipelines at this entry point of gas, there are also some Powerstations in the area.

When the submarine pipelines arrive to Jurong, the gas is transformed from high pressure to low pressure. The gas is transferred through the main pipe rack of Jurong Island to its destinations. Many companies on Jurong Island have their own power generators.

Sembcorp is the operator of the main pipe rack called the service corridor.

Left:
Main pipe rack surrounding a plot

Right:
Main pipe rack along the main street.



Companies

The JTC Corporation is putting a lot of effort to conceal the precise location of the individiual companies on Jurong Island. The sites of the major companies such as refineries, storage companies and the historically relevant companies are known generally. But there are a lot of the small downstream plants and supporting companies which are difficult to identify without the help of JTC Corporation.

Pulau Bukom and Pulau Sebarok are managed by Shell and Vopak respectively.

1. ExxonMobil
2. Shell
3. SRC
4. Tuas Power
5. Keppel Energy
6. Sembcorp
7. Seraya Energy
8. SLNG
9. Oiltanking
10. Universal
11. Horizon
12. Vopak
13. Chevron
14. PCS
15. BASF
16. Linde Gas
17. Akzo
18. Continental
19. Rotary
20. Huntsman
21. Denka
22. Eastman
23. Perstop
24. Sumitomo
25. Kuray
26. Invista
27. Asahi Kasei
28. Chem. Indust.
29. Air Products
30. Lucite
31. Celanese
32. TPS
33. MPS

Security Aspects
Check Point
Watch Tower
Prohibition Zones
0 1 2 km
N

Security Aspects

Since 9/11, Jurong Island is closed to the public. As the petrochemical sector became more important for Singapore, its facilities are being secured very strictly.

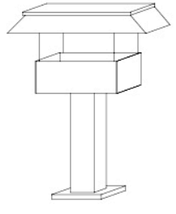
The maritime Prohibition Zone surrounding the island grants a separation space between the shipway and the land. This zone is secured by the Singaporean Coast Guard and watchtowers manned by a private security company.

The air space is controlled by the Singapore Air force that patrols over Jurong Island, which can change depending on the amount of risk. The use of jets for this task is more common. Sometimes there is an interval of less than 10 minutes between each jet, which means either that there is an exercise or that a special event is happening in Singapore. But even if the jets' primary task would be to guard an event, it will always fly over Jurong Island.

1.

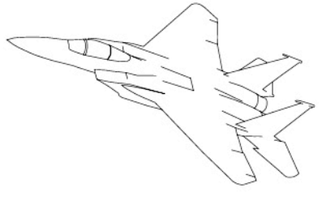
2.

3.



4.

5.



6.

1. Checkpoint at Jurong Island Connection

2. Checkpoint at Jurong Island Connection Satellite Image

3. The Helios Terminal surveiled by a watch tower and a patrol boat

4. Watch Tower

5. Patrol Boat

6. RSAF (Repubic of Singapore Airforce)

Urban Uses
- Visitor Center (1)
  - Food Centre
  - Shop
  - Medical Service
- Dormitories (2,3,4)
- Main Street Network

0 1 2 km N

Urban Uses

Since Jurong Island is a highly privatized and strongly secured area, there are not many urban uses present. But because there is an amount of 30'000 workers coming in on every day, there are a few uses which seem very obvious and others which are quite surprising. The expected facilities like a food court, shop or medical service are all combined in the visitor centre. Most of the companies don't have their own canteens and have to order their food from outside of Jurong Island.

More informal uses like resting space during work breaks are found next to every bigger construction site in Jurong Island.

The most unexpected facility in Jurong Island as well as in Pulau Bukom are the dormitories for some of these workers. The dormitories on Jurong Island are quite far from the petrochemical plants while in Pulau Bukom they are right next to the facility.

1.

2.

3.

1. & 2.
Workers resting in front of tanks under construction

3.
Dormitories near oil storage facilities

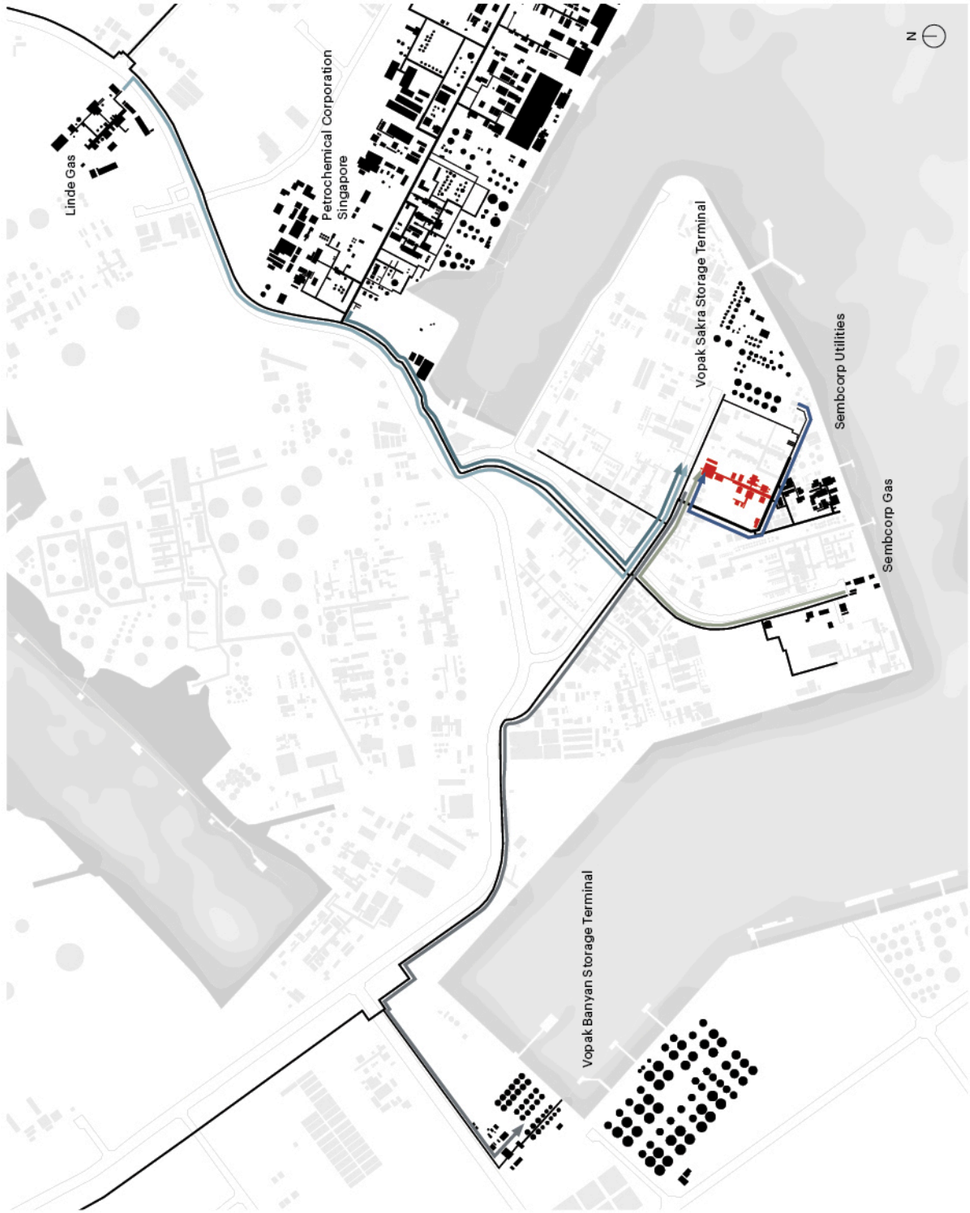
MMA Refining Column

Lucite International Alpha 1 MMA Plant

Lucite International is company specializing in the design, development and manufacture of acrylic-based products.

2009 Lucite was acquired by Mitsubishi Rayon Co Ltd and have strengthened the position as the world's largest supplier of Methyl Methacrylate (MMA), which is the essential building substance for all acrylics.

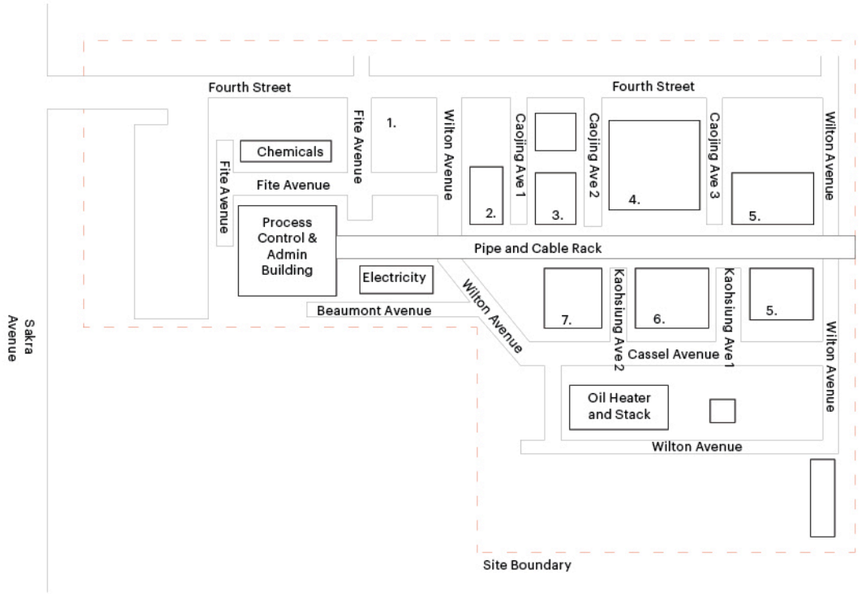
On Jurong Island, Lucite is using a new kind of MMA production with their Alpha 1 MMA Plant.



Connectivity of Lucite

- Lucite International
- Connected Companies
- Natural Gas
- Carbon Monoxite
- Ethylene
- Methanol
- Methyl Methacrylate

0 150 300 m



MMA Production Process

The feedstock for the production of MMA consists mainly of ethylene, methanol and carbonmonoxite. In a first step the two intermediate products MeP and formaldehyde have to be created. Together they will react to crude MMA. With heat the MMA is refined and finally stored in the Vopak Banyan Terminal.

Left:
Sembcorp Pipeline

Right:
Lucite's Pipe Rack

Internal Pipeline Corridor

The different reactors are all connected together by a pipe rack, which conducts the feedstock and the product, but also natural gas for the energy demand of the plant and nitrogen for fire outbreaks and explosions.

1. Check Point
2. Jurong Island Visitor Center
3. Watch Tower
4. Prohibition Zone
5. Street Network
6. Service Corridor

Services Provided in Jurong Island

If a company wants to rent a plot in Jurong Island, it will get 30-days rental with certain services included in the price.

The aspects that Jurong Island provides are specially the security, the pipeline service corridor and a street network based on the needs of each subsector. Of course the visitor centre contains food facilities.

1.
Incoming Pipes

2.
MEP Reactor

3.
Storage Tank Area

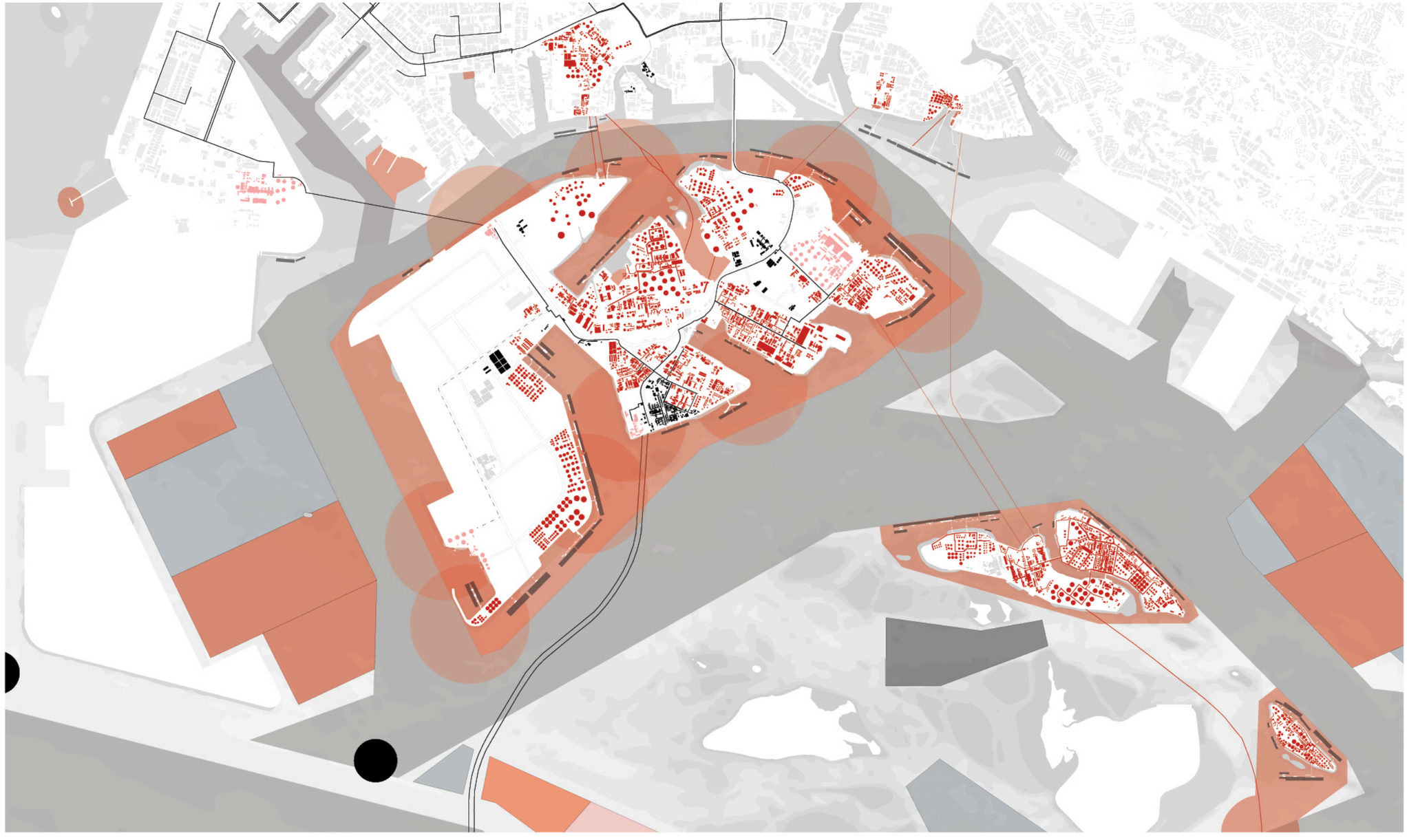
4.
Left: Formaldehyde Reactor, Right: MMA ROG

1.

2.

3.

4.



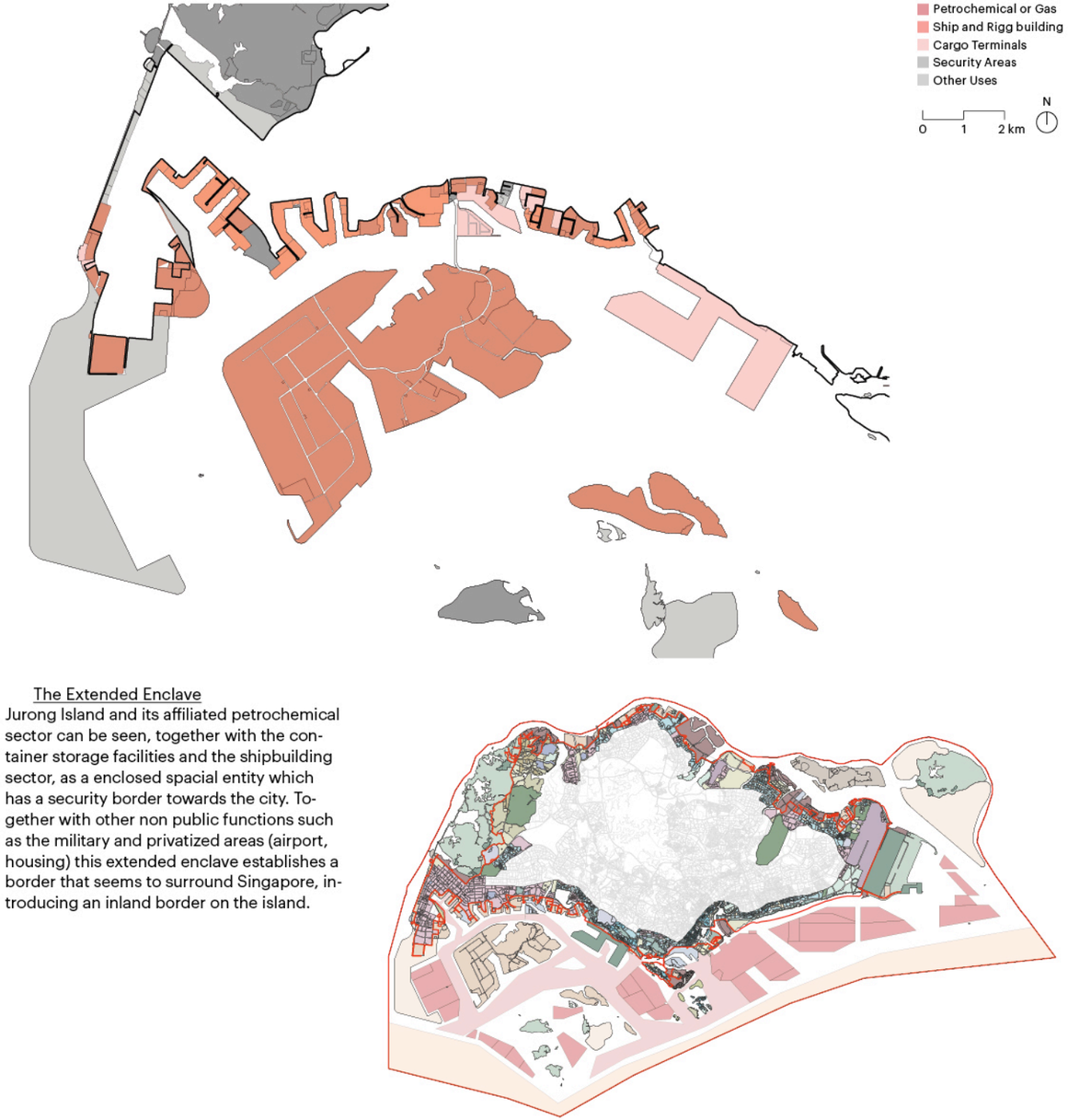
Combined Layers of Infrastructures

By overlaying the main organisational aspects of Jurong Island, one can see how small the footprint of the gas facilities is compared to the oil and petrochemical sector. Nevertheless the gas remains crucial for running the plants. So the strict separation of functions like we did it on the layers remains questionable.

Petrochemopolis

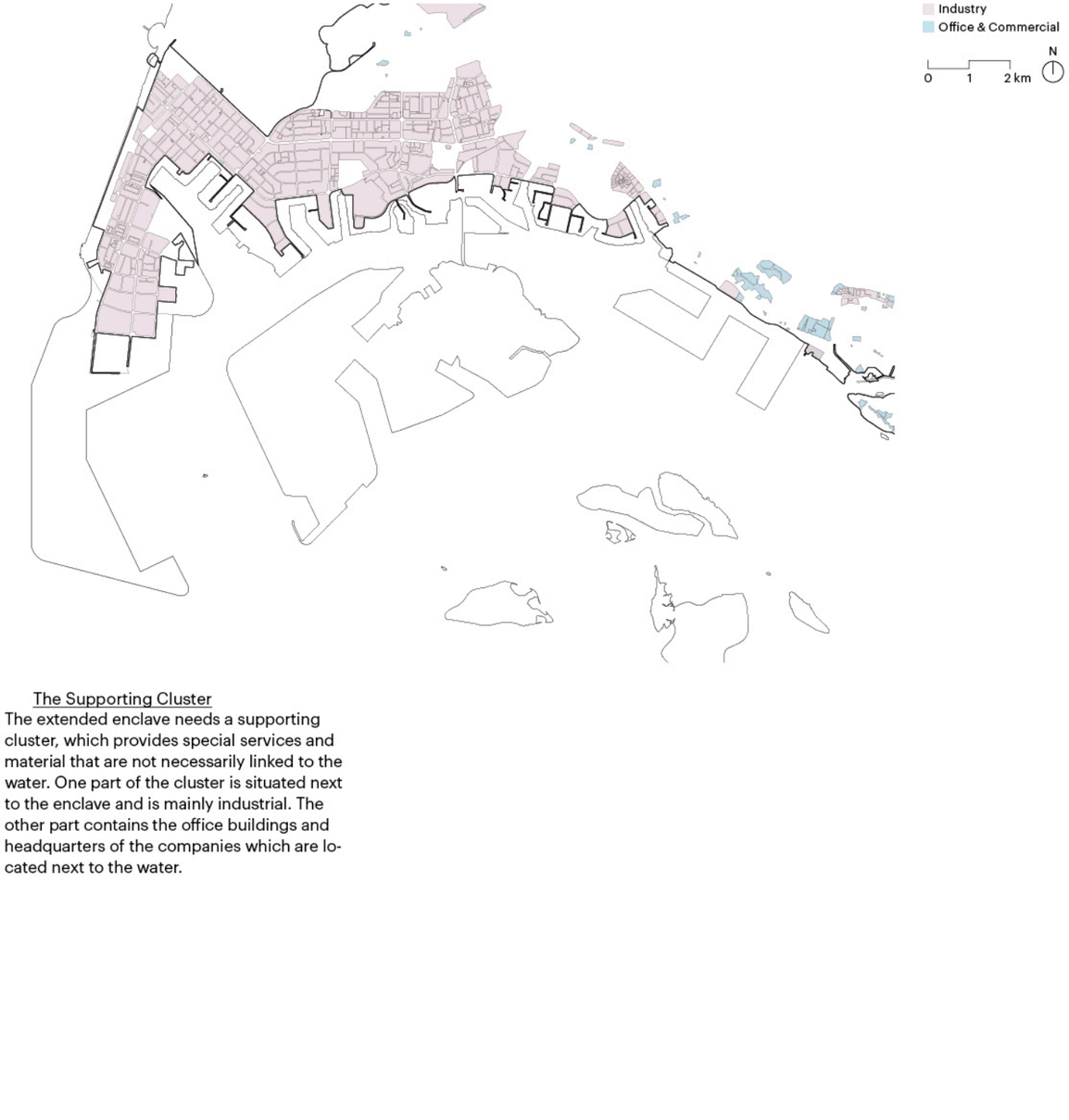
As we having analysed Jurong Island thoroughly in the previous chapter, we will now focus on the whole islands-state. How is the interconnectivity between the facilities located on Jurong Island and the processing industry, support companies, logistics providers and headquarters located on the main island organized? How is this connectivity expressed spacialy within the city fabric?

ExxonMobil Jurong
Refinery and Surroundings



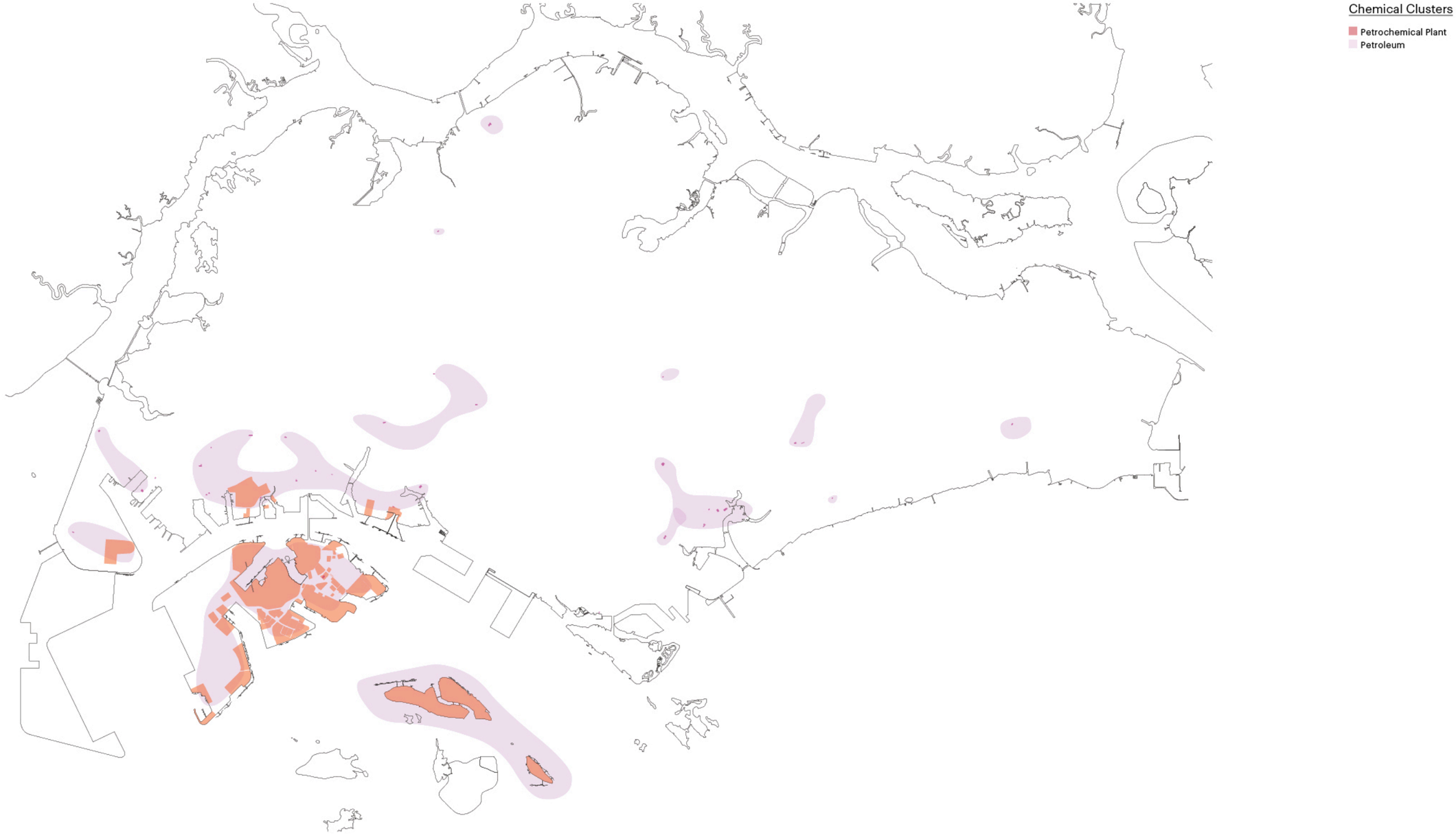
The Extended Enclave

Jurong Island and its affiliated petrochemical sector can be seen, together with the container storage facilities and the shipbuilding sector, as a enclosed spacial entity which has a security border towards the city. Together with other non public functions such as the military and privatized areas (airport, housing) this extended enclave establishes a border that seems to surround Singapore, introducing an inland border on the island.



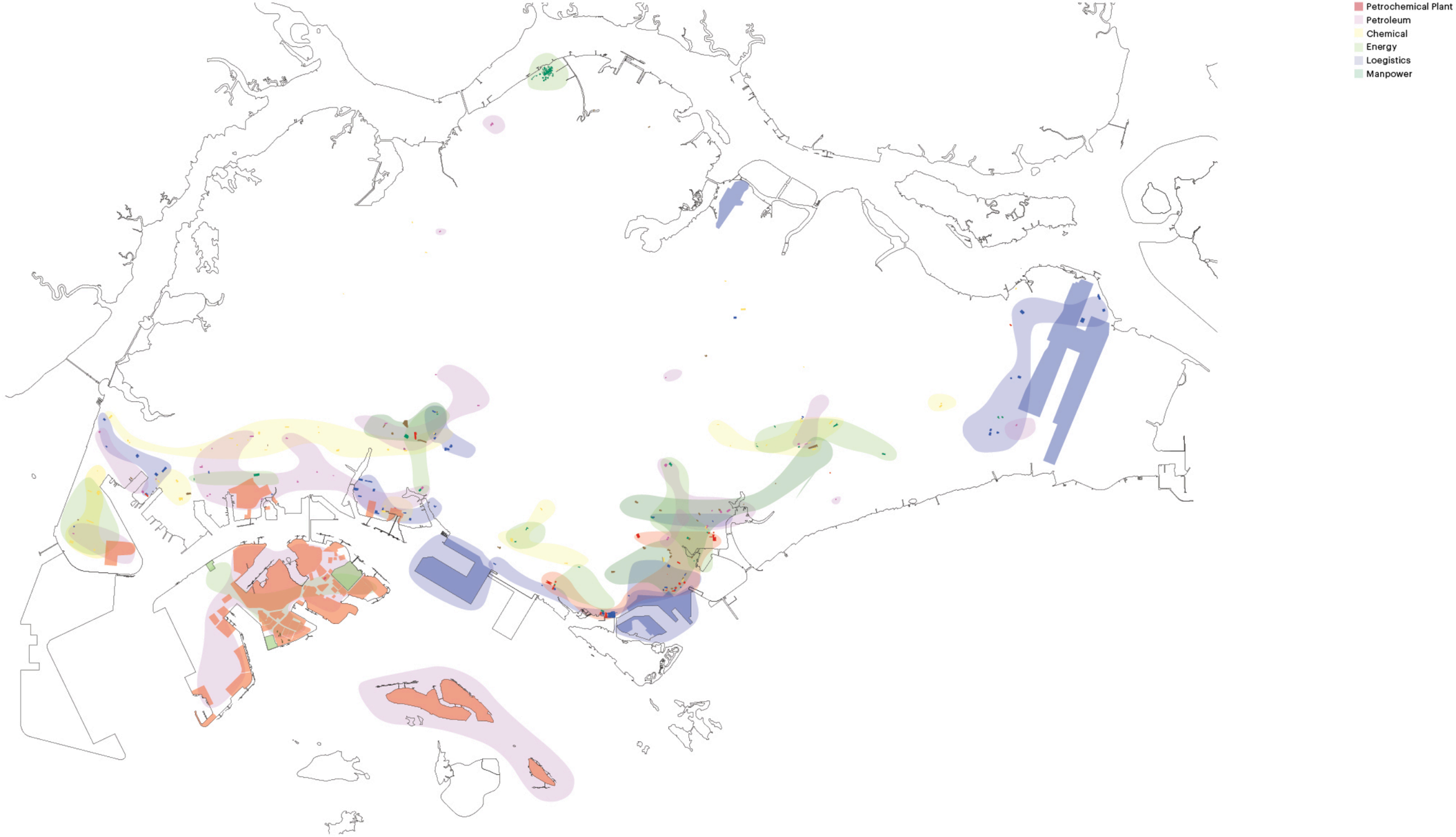
The Supporting Cluster

The extended enclave needs a supporting cluster, which provides special services and material that are not necessarily linked to the water. One part of the cluster is situated next to the enclave and is mainly industrial. The other part contains the office buildings and headquarters of the companies which are located next to the water.



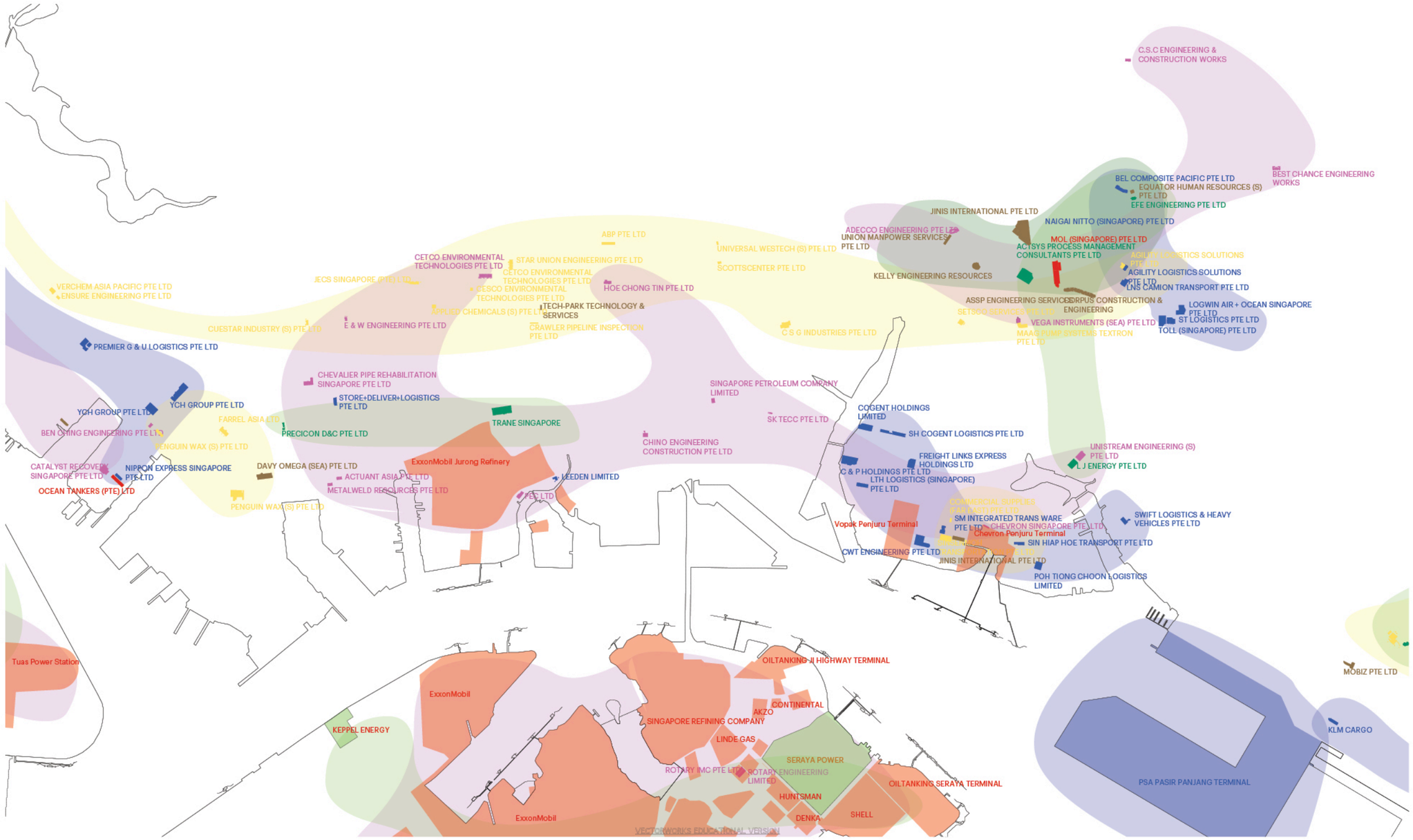
Petroleum Cluster

The concentration of this cluster lies in the Jurong area and specially in Jurong Island, while its headquarters are within the financial center.



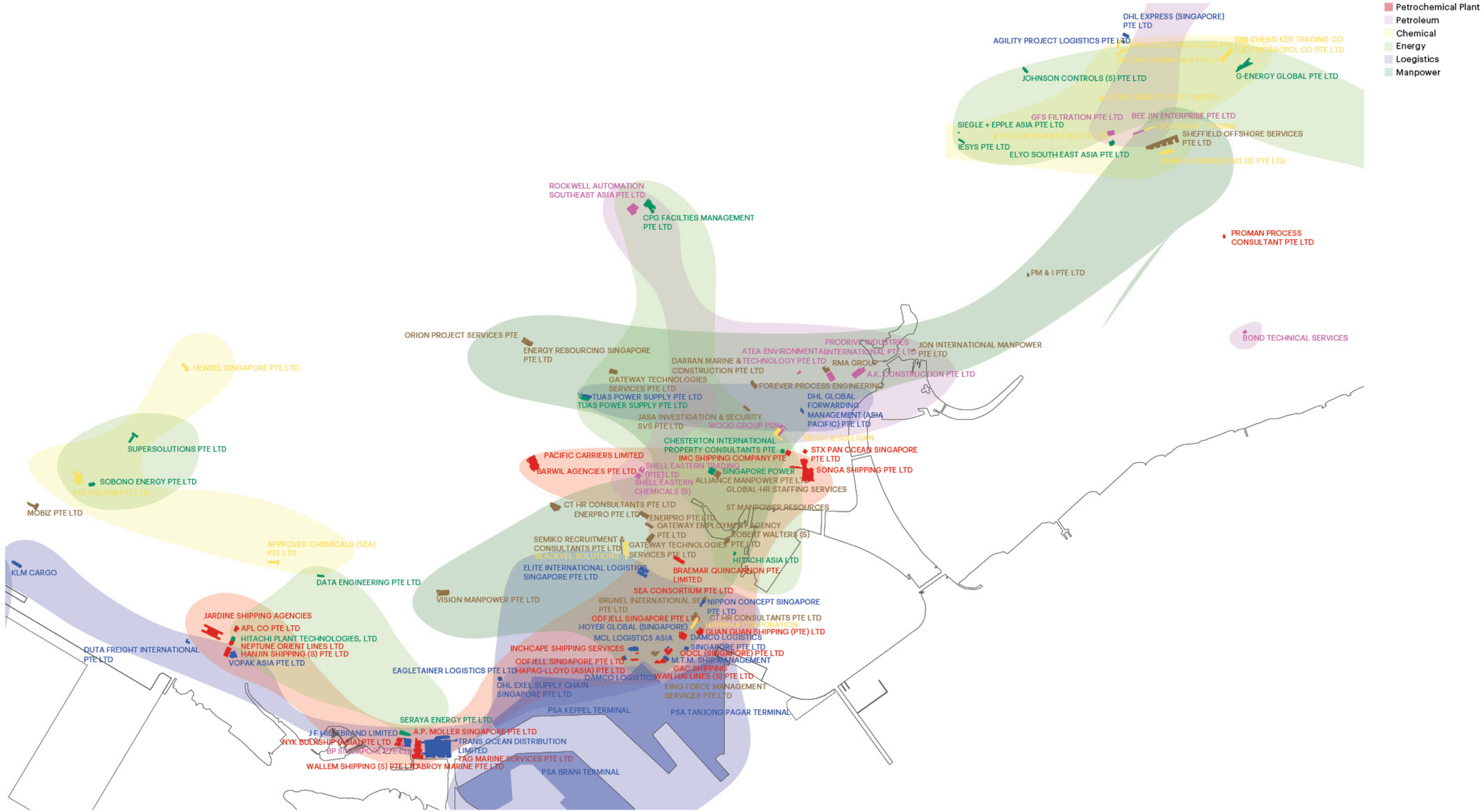
Chemical Clusters

These clusters are formed by the subclusters of petroleum, chemical, energy, logistics and manpower. It is defined as a highly interconnected conglomeration of companies.



The Cluster in Jurong Industrial Estate

This cluster is influenced mainly by Jurong Island, the shipyards and the logistics facilities of the container terminal and Jurong Port. More on the north there is a strip of chemical companies which is mainly composed by the Jurong Business Park where most of the important companies of this sector have offices.



Central Business District

The central business district happens to be the major site of communication between the companies and the different sectors. Being some companies of the different sub-cluster in the same office buildings the way of communication often keeps being by telephone.

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