Addressing the Information Gaps on Prices of Minerals Sold in an Intermediate Form

Case Study: Thermal Coal

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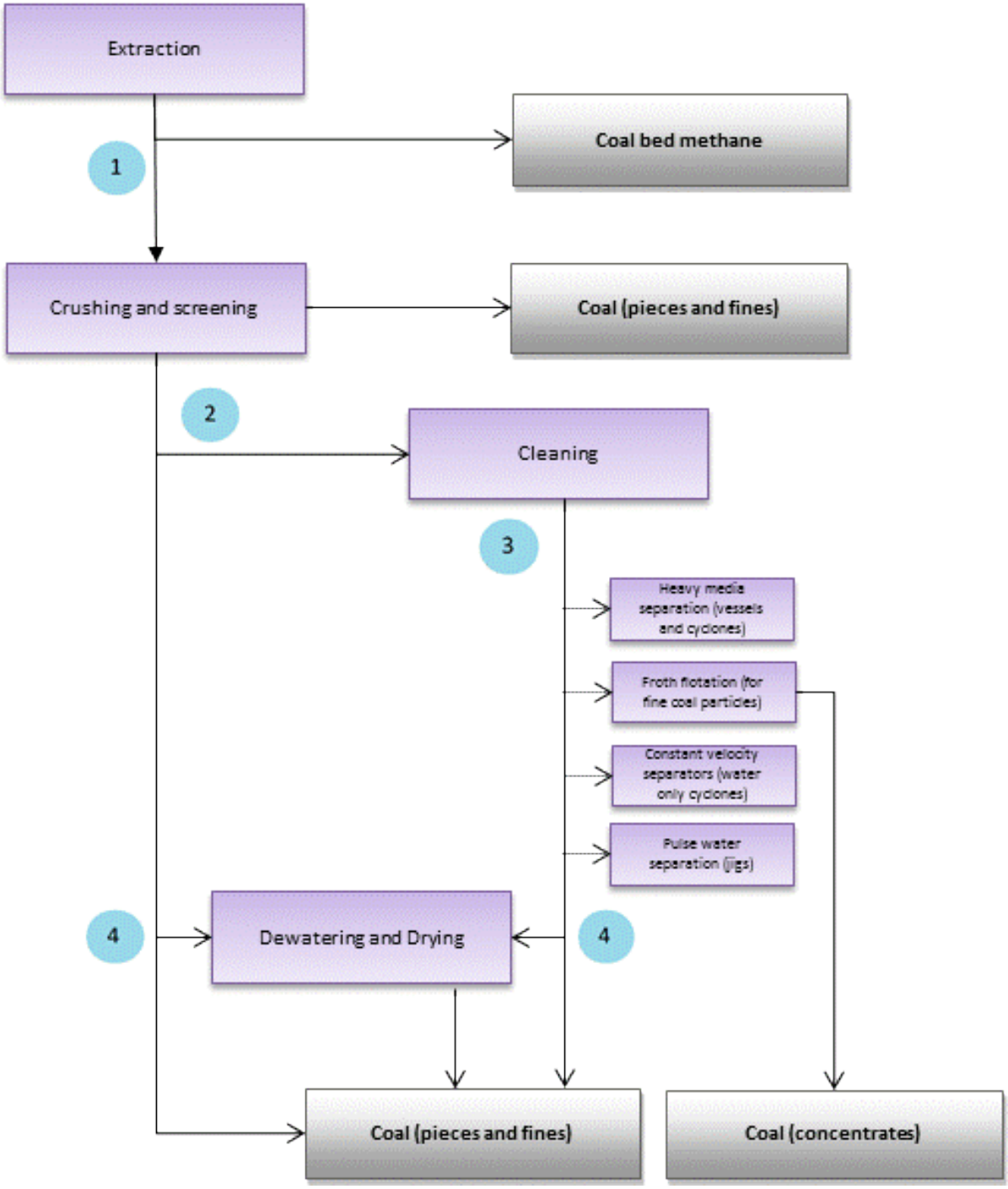
COAL MINING AND KEY COAL PRODUCTS

Thermal Coal Transformation Chain and Key Products



Note: Coal bed methane (CBM) may also be the primary focus of resource extraction, rather than coal mining. CBM is naturally produced as organic material becomes coal over time. The gas is stored on the many surfaces of the coal and held in place by water pressure (Lennon, n.d.). The mine may also recover coal bed methane from the seams of the coal bed, bringing it to the surface by pumping water through the coal bed. Pricing of CBM is outside the scope of this study.

Thermal Coal Mining

The coal must first be severed from the surrounding land, using mechanical digging processes. These processes include the use of dragline excavators at open pit mines to dig up the coal, or "bord and pillar" processes at underground mines, which use sections of the coal bed as pillars to hold up the roof of the mine as excavation occurs (Shaw, 2016).

The coal is then moved to an initial stockpile (the "run of mine") before beneficiation processes begin to transform the coal to a saleable product.

1. **Crushing and Screening**: The coal is transported to a series of crushers in a circuit, to reduce the pieces to a smaller, more uniform size. Screens are used to remove pieces that remain larger than the target size (e.g. 50 millimetres) and these pieces are sent back for further crushing.

2. Once the pieces are at their target size, they may be transported from the mine for delivery to customers (or traders) if impurities and quality are within acceptable limits. Alternatively, further cleaning processes may be required to remove surrounding waste material and to reduce the presence of impurities (particularly ash, sulphur and nitrogen).

3. **Cleaning:** Coal particles of different sizes may be separated and sent for different washing processes. Numerous processes are used to clean the coal, exploiting differences in the density of the coal relative to surrounding rock (the coal is lighter, IEA, 2014). For example, the coal may be fed into barrels and mixed with fluid causing the coal to float while heavier material sinks and is removed (OTC Journal, 2011).

   Very fine particles may be sent through a **flotation process**, in which slurry containing the fine coal particles is mixed with air bubbles, with the coal attaching to the surface of the bubbles and floating to the top of the tank as a froth, where they are removed and dried to form a concentrate (Huynh, n.d.).

   Cleaning may also include removing sulphur, especially sulphur dioxide. This may require **chemical processes** where the sulphur is chemically connected to the carbon.

4. **Drying/Dewatering:** Coal often requires drying to prepare it for sea transportation. Drying reduces transportation costs and improves the efficiency of coal in power generation.

   Dewatering processes depend on the type of water being removed (inherent, surface or free water held in the gaps between coal particles) and the type of coal (Speight, 2013). Surface water is often removed using screens which drain the water (particularly higher-rank coals) while finer pieces may require centrifuges or cyclones. Kilns then **dry** the coal.

THERMAL COAL USAGE AND MARKETS

Thermal, or steam coal[1] is an energy source consisting primarily of carbon. There is a range of coal with varying energy potential, grouped into four grades or "ranks", depending on its carbon content and energy available on combustion. Higher rank coals have more energy.[2] The ranks of coal, from lowest energy potential to highest, are:

- lignite (also known as brown coal);
- sub-bituminous coal;
- bituminous coal (also known as black coal); and
- anthracite coal.

The majority of thermal coal is used by utilities to generate electricity and commercial heat - around two thirds of all thermal coal is used this way.[3] Thermal coal is also used in manufacturing where industrial plants have their own power generation facilities or need for steam (such as in paper mills), as well as for concrete and transportation.[4]

Coal fired power plants vary in size and design, but put simply, utilities predominantly burn the coal.[5] This involves pulverising the coal and blowing it into a boiler where it burns at high temperatures, producing steam.[6] This steam then passes through a turbine to generate electricity.

A. Thermal Coal Markets and Trading

Economic Context

Thermal coal remains a major energy source, second only behind oil in primary energy consumption (coal represented around 30 percent of energy consumption in 2014).

Coal markets are competitive internationally, with arbitrage occurring geographically and also by blending coal grades to meet the particular requirements of the customer. But like other minerals, thermal coal markets have their own unique features and economic context. In particular, coal markets are influenced by external policy factors beyond the international supply and demand of the coal products themselves. For example:

[1] This study is on thermal coal. It excludes metallurgical or coking coal, a type of coal used to produce coke (a key input into iron and steelmaking), as well as coal bed methane, peat and oil shale/oil sands.
[2] More formally, coal is ranked by the amount of alteration it has undergone from its organic material stage. Higher rank coals are those which have undergone the greatest degree of transformation (ABARE, 1997).
[3] OECD countries use more than this and non-OECD countries less
[4] There are also smaller coal-to-liquid products in South Africa and China.
[5] A small percentage – less than 1 percent of world capacity – uses gasification processes, in which coal is converted to gas to produce a synthesis gas of hydrogen and carbon monoxide for use as fuel.
[6] Alternatively the coal can be burnt in a fluidised bed to create steam.

- The energy security policies and environmental policies (particularly policies to limit carbon emissions) of major importers and exporters influence the structure and evolution of coal markets.
- Tighter environmental regulation in China has changed the profile of coal imports to China away from high-impurity coals.
- The Indian Government has recently relinquished its role as the sole trader of coal (via Coal India Ltd) and allowing sub-national governments and private actors to mine and sell directly to end-users (IEA, 2016).

Coal Trade

In 2014, the total trade of thermal coal was 1.05 billion tonnes, of which around 945 million was traded by sea (IEA, 2015). Coal trade is therefore is a large international market, but this international trade only represented around 17 percent of total coal production (the remainder was produced and consumed domestically).

The Pacific Basin dominates the international trade of coal, since it is where the largest importers and exporters are located, with the Atlantic Basin being the other main international market.[7]

On the **export side**, the largest exporters by total tonnage in 2014 were Indonesia (estimated 421 million tonnes, mt), followed by Australia (196 mt), Russian Federation (127 mt), Colombia (85 mt) and South Africa (74 mt). On the **import side**, Asian buyers form the majority of coal importers by weight. China is the largest thermal coal importer, importing an estimated 219 mt in 2014 - representing over 20 percent of coal imports globally. This is followed by India (175 mt), Japan (137 mt), Republic of Korea (96 mt) and Chinese Taipei (58 mt). Countries in Europe and the Mediterranean are also significant purchasers, particularly Germany, United Kingdom, and Turkey.

Price developments in China are highly influential in international price formation, explained by that country's large share of total coal consumption.[8] The IEA observes that "… coastal South China is still the clearing market, i.e. the main place where price is formed, in the Pacific Basin, especially for low calorific coal. Imports mainly from Indonesia and Australia compete with domestic seaborne trade, and are sold at the prevailing spot price for the day when the deal was done or even at the prevailing spot price for the day that coal arrives at the port." (IEA, 2015)

Recently, several factors including falls in sea freight rates have worked to increase the integration between the Pacific and Atlantic basins, strengthening the ability of traders to arbitrage between the two markets. This means prices in the two main markets move in line with each other over time, with short-term differentials balanced by changes in trade flows.

[7] Russian Federation and South Africa are able to supply both, depending on price conditions.
[8] One unique feature of coal trading is that domestic coal sales are usually not linked to international price indices. Further information on domestic coal trading, particularly in China, is available from the IEA.

PRICING AND CONTRACTS

Customer Requirements

Understanding the economic context of the ultimate coal user is essential to understanding which coal they buy and their supply requirements (Shaw, 2016). For example, where there is a continuous need for power such as electricity generators that contribute to generating a region's base load electricity, or in smelting or continuous manufacturing operations, this would typically require a steady supply of coal and put a premium on ensuring consistent supply (some mines are adjacent to the utility, minimising transport costs). Alternatively, the user may have variable energy needs – for example, a power plant may be switched on only at certain times of day, affording the customer greater flexibility in scheduling purchases and using different suppliers.

1. Energy Content and quality

The primary price determinant for coal is its energy content (amount of heat), measured per unit mass of coal on combustion. This is indicated by its calorific value, which is the capacity of the coal to generate heat.[9] Energy content is measured in thousands of calories (kilocalories, or kcal) per kilogram of coal or the imperial equivalent, British thermal units per pound. Energy content ranges from approximately 3,400 kcal/kg to 6,700 kcal/kg.

End-users buy coals, first and foremost, based on the quality of the coal. This is to ensure the coal product is compatible with their boiler(s). There are sub-markets for coal products based primarily on the type of coal and its energy content, noting that lower-rank coals are not typically shipped long distances given the higher transport costs per unit of energy.

Parties to a coal transaction will agree either a fixed price, or refer to a coal price index that most closely represents the type of coal being traded and its export location. Fixed price contracts typically have shorter durations, ranging from spot sales to an agreed tonnage to be delivered over the course of one year.

For coal shipments with a calorific value close to the prescribed reference specification (such as small variations in different shipments), an arithmetic adjustment would be made to the price for the proportion of energy in the shipment relative to the price for the agreed reference grade. For example: if a contract refers to a price with energy content of 6,000 kcal/kg, a coal shipment of 5,900 kcal/kg might be discounted by 1.6 percent.[10]

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9 .There are two ways to express calorific value: gross calorific value or net calorific value. The GCV is the amount of heat liberated during a test in a laboratory, where the coal is combusted under standardised conditions at constant volume so that all of the water remains in liquid form. NCV is the maximum achievable heat in a boiler, because some energy is lost converting the water in the coal to vapour. (source: Thomas) NCV is therefore lower than GCV – it is the more "real world" calorific value. See Box for information on converting between GCV and NCV.

10 That is, the price would become (5900/6000)*(reference price). Standardised coal trading contracts such as the Coal Trading Association 2010 Master Coal Purchase and Sale Agreement also prescribe is approach, specified in BTU per pound (see Exhibit D annex).

Price Indices

Price Indices exist for several coal types originating from major supply ports including coals from South Africa, Australia, Indonesia, Colombia and Russian Federation. These indexes have shorthand names commonly used by traders, referring to the particular publications that monitor and report on prices for those trades.

- "API2" is the most commonly used reference price in the world. It is the benchmark price for imported coal to North West Europe (6000 kcal/kg NAR). The volume of API2-based derivatives is more than 2.5 billion tonnes.
- Other popular indices are API4 and API6. API4 is the benchmark price for coal exported from Richards Bay in South Africa (6000 kcal/g NAR). API6 is the benchmark price for coal exported from Newcastle in New South Wales, Australia (6000 kcal/kg).
- For the Americas, the Central Appalachian Coal Price Benchmark (CAPP) spot prices are the most widely referenced for thermal coal in the eastern USA. CAPP spot coal prices are commonly used to price both physical and financial transactions for short-term and long-term contracts. CAPP spot prices reflect the value of the coal at the CAPP Delivery Zone location. These prices do not reflect delivery costs from the delivery zone to another location, emission abatement costs nor any other handling charges (Tradition, 2013).

Given the range of qualities of coal internationally traded, there are different indices for different qualities. For example, ICI1-ICI5 are five indices published by Argus for coal exported from Indonesia, with calorific values ranging from 3000 to 6200 kcal/kg NAR).

2. Moisture

Moisture content simply refers to the water that is in the coal. As noted above, coal miners will remove as much water as possible, since it adds to transport costs and, if high enough, can pose a risk to the stability of the ship.[11]

Moisture is measured as a percentage of the "air dried" coal (that is, the moisture in the coal after achieving equilibrium with the atmosphere around it).[12] Agreements will typically specify a moisture percentage with a price penalty for small amounts above the agreed level and a maximum above which the shipment can be rejected. For example, total moisture may be specified at 13 percent, with a USD 0.20/tonne for each 0.1 percent above 13 percent up to a rejection level of 14 percent.

[11] In addition, low grade coals with high humidity content can self-heat, risking carbon emissions, spontaneous combustion or damage to equipment. For this reason they are not stored at power plants for long and need to be delivered efficiently (Osborne, 2013).

[12] Removing "residual" or "inherent" moisture are higher – they can be removed by heating the coal to above 100 degrees Celsius.

3. Impurities

Impurities in coal can damage equipment and/or must be mitigated when the coal is burnt according to environmental regulation, increasing costs. Impurities that routinely result in price penalties (when above commonly observed market levels) are ash and sulphur.

- **Ash Content:** Ash remains after the complete combustion of all organic matter and the oxidation of the mineral matter present in the coal – it is therefore the incombustible material present in the coal. It is measured as a percentage of the air dried coal sample. Since ash does not contribute to the calorific value of the coal, its presence increases costs. In particular, a higher ash content increases transport and handling costs per unit of energy contained in the coal, and also waste management costs because the ash requires disposal after combustion (ABARE, 1997). Coal with ash content exceeding standard contract specifications would therefore face a price penalty.

- **Sulphur Content:** Sulphur, broadly defined,[13] is a pollutant predominantly emitted as sulphur dioxide gas during combustion (unless utilities install mitigation measures). It can also damage plant equipment by for example, corroding metal surfaces. As a result, power plants usually prefer coals with naturally lower levels of sulphur, or purchase coals within maximum levels, either on their own or after blending.[14] Coal with sulphur above standard contract specifications would therefore expect to receive a price penalty.

Outside electricity generation, coal buyers using the coal as energy require coals meeting very precise specifications. In cement production however, tolerance to ash may be higher since it can be incorporated into the clinker, meaning that industry may be able to work with a wider range of qualities (IEA, 2015).

4. Other factors

- **Volatile matter:** This is the proportion of the air-dried coal released as gas or vapour during a standardised heating test (Skompska 1993). This proportion tends to decrease as the rank of a coal increases (ABARE, 1997). Higher volatile matter content indicates coal that is easier to ignite and which will burn with a large, steady flame.[15] However, if volatile content is too high (exceeding 30 per cent of the air dried coal), it increases the potential risk of spontaneous combustion (ABARE, 1997).

- **Grindability:** Coals with high grindability are relatively soft and easy to prepare for the boiler. Grindability varies with coal rank: it is generally relatively low for anthracite coal (very hard pieces), improving for bituminous coals (most grindable), before falling again for sub-bituminous and lignite coals (Thomas, 2002). The Hardgrove Grindability Index

[13] Sulphur can occur as elementary sulphur, as sulphates, sulphides or in organic combination in the coal (Speight 2013, in coal handbook).
[14] Alternatively, plants may purchase higher-sulphur coals and remove the sulphur either during or after combustion (but at their cost). Utilities in Japan, for example, routinely have sulphur-removing equipment.
[15] For this reason, volatile matter estimates are often used to calculate combustibility indexes, which indicate the reactivity of the coal.

(HGI) measures grindability. Price adjustments are not usually made for variations in HGI - rather, contracts usually specify a typical HGI value for each shipment, and a (lower) HGI value that would entitle the buyer to reject the shipment.

- **coal piece size distribution:** the size of coal pieces do not usually affect prices, because power plants pulverize the coal down to fine powder immediately before it is used. But contracts will typically specify the particle characteristics of the shipment, with maximum percentages of large pieces (above 50 millimeters) and very small pieces (under 6 millimeters).

Contract Periods

Spot transactions dominate the international trade in thermal coal. But there is a range of customer practices when purchasing thermal coal. The coal contract may specify a fixed price per tonne, or use an agreed reference price. Usually a fixed-price contract will be shorter, and not exceed 12 months. Agreements may be for a specified quantity of coal, delivered as either one shipment, or in multiple shipments within a specified period.

ADDITIONAL INFORMATION

Measuring Calorific Value

There are two ways to express calorific value: gross calorific value or net calorific value. The GCV is the amount of heat liberated during a test in a laboratory, where the coal is combusted under standardised conditions at constant volume so that all of the water remains in liquid form. NCV is the maximum achievable heat in a boiler, because some energy is lost converting the water in the coal to vapour. (source: Thomas) NCV is therefore lower than GCV – it is the more "real world" calorific value. See Box for information on converting between GCV and NCV.

Contract Units of Measurement and Common Terms

Tonnes and Tons: The quantity of coal to be priced will be clearly specified in contracts, either in metric tonnes (1,000 kilograms) or, in transactions involving USA firms, short tons (2000 pounds or equivalent to around 0.907 metric tonnes).

British thermal units (BTUs): approximately 1055 joules of energy (1 BTU/lb = 0.556 Kcal/kg)**.**

Dry Basis: Analytical concept where the coal is calculated to have zero moisture.

Dry Ash-Free Basis: Analytical data calculated to a condition of zero moisture and ash (i.e. first approximation to 'pure coal') to allow comparison of different coals. This is strictly a hypothetical basis because the ash is only generated on the incineration of the coal, but is used frequently because of convenience. Dry mineral matter free basis is more precise, but less easy to obtain.

Gross As Received (GAR) and Net as Received (NAR): contracts may use either gross or net as received as their standard valuation term. As noted above, the difference between GAR and NAR reflects the latent heat16 of the oxygen and hydrogen which lowers the effective calorific value in the boiler (Knowledge Infrastructure Systems, n.d.). To make an approximate conversion from GAR to NAR: NAR = GAR minus 260 kcal/kg (Thomas, 2002).

Fixed carbon content: measured as a percentage of the air dried coal sample, is approximated by taking the difference between 100 per cent and the sum of the estimated inherent moisture content, volatile matter content and ash content, also measured on an air dried sample basis.

"Long Term" Contract: For most countries, this refers to contracts of 1 year duration or less. However in the USA, this refers to contracts of 3 years or less.

16. Latent heat is the amount of energy absorbed or released by a substance during its change in physical state (such as from a solid to a liquid, or liquid to gas), measured in units of energy per "mole or unit of mass undergoing a change of state" (source: https://global.britannica.com/science/latent-heat)