# Supplementary Material: Details of trends in energy policy related to coal consumption in key countries

The following supplementary material lists the trends in energy policy related to steam coal[[1]](#footnote-1) consumption in key countries from a Colombian perspective. The order is hereby adjusted to the possible construction of new coal power plants as indicator. Global figures reveal enormous pre-construction capacities of 548 GW which can be divided into the different phases of announced (42%), pre-permit (38%) and permitted (20%) projects. Experiences from the last years quantified by cancellation figures of 931 GW since 2010, however, reveal that only a smaller share of these construction plans will actually evolve. (Coalswarm, Sierra Club, and Greenpeace 2017)

Table 4: List of planned and existing coal plants by country (in MW; July 2017)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Country | Pre-Construction | Construction | Shelved | Operating | Cancelled 2010-2017 |
| China | 152,775 | 147,143 | 413,249 | 922,062 | 206,165 |
| India | 101,370 | 43,418 | 81,670 | 218,091 | 451,667 |
| Turkey | 59,630 | 2,640 | 19,469 | 16,012 | 26,654 |
| Japan | 15,120 | 5,313 | 0 | 44,244 | 2,200 |
| Chile | 2,162 | 375 | 485 | 5,101 | 6,880 |
| Germany | 1,100 | 1,100 | 920 | 50826 | 18,393 |
| U.S. | 895 | 0 | 400 | 281,127 | 26,873 |
| United Kingdom | 570 | 0 | 0 | 13,100 | 9,398 |
| The Netherlands | 0 | 0 | 0 | 5,860 | 1,311 |
| Israel | 0 | 0 | 0 | 4,900 | 1,260 |
| Rest of the world | 214,731 | 63,972 | 80,457 | 404,045 | 180,845 |
| Total globally  | 548,353 | 263,961 | 596,650 | 1,965,368 | 931,646 |

Source: Coalswarm, Sierra Club, and Greenpeace (2017).

# China

For over a decade up until recently, the narrative of China’s steam coal demand has been one of continual, rapid growth. As a result, China was responsible for over half of the world’s steam coal consumption or 3205 Mt in 2014, and estimated 3094 Mt in 2015 (IEA/OECD 2016b, xviii). The rapid growth in steam coal demand was primarily due to a large increase in power demand over the past decade; since 2005, however, the share of coal in electricity generation started shrinking slowly reaching 73% in 2014 (IEA/OECD 2016c, III.64). China is also the world’s largest coal producer, supplying almost exclusively its own demand. The main coal deposits are located in the interior provinces of Shanxi, Inner Mongolia, Xinjiang, Shaanxi and Henan; whereas demand is concentrated in coastal regions, where coal deposits are small and tend to have high mining costs and poor quality (C. Wang and Ducruet 2014, 4–5).

While China’s steam coal demand is primarily met by production from its own coal reserves, it was still the largest importer of coal on the international market in 2014 with 292 Mt of steam coal. This represents about 7% of domestic consumption (but constituting about 22% of total global steam coal trade). Estimates for 2015, however, observe a strong reduction to 204 Mt of coal imports which is slightly below India´s import figures of 222 Mt. (IEA/OECD 2016b, xv) The geographical mismatch between supply and demand means that domestically-produced coal has high associated transport costs. 60% of China’s coal production is transported by railway, along with 30% by water and the remainder by road. In the past, insufficient rail and shipping capacity has resulted in congestion and supply bottlenecks (C. Wang and Ducruet 2014). Therefore, the rationale for importing steam coal is largely one of cost-minimization, rather than domestic supply shortages. In a situation termed the “coal-power conflict”, liberalization of the coal sector has caused domestic coal prices to increase, to the extent that imported coal is sometimes more affordable for power generators (for whom the price of electricity is still government-controlled) (Rui, Morse, and He 2015, 81–84). Recent investments have alleviated this issue (EIA 2015c, 27): The Chinese government set out a program to expand transport infrastructure, on the one hand, and to integrate coal producers and power generators to establish “coal-power bases”; which enable the transport of “coal-by-wire”, on the other hand (Rui, Morse, and He 2015). In the meantime, this arbitrage behavior by Chinese power generators has implications for global steam coal trade and prices (Morse and He 2015, 407). A 6% tariff on imported steam coal was reintroduced in late 2014 (having previously been phased out between 2005 and 2007) (*Reuters* 2014), in order to stabilize the domestic market (which is oversupplied, with the majority of producers thought to be unprofitable at current prices) (Commonwealth of Australia 2015b, 29).

China’s future steam coal demand is shaped by the magnitude and sectoral composition of its economic growth, reductions in energy-intensity and environmental policies (Green and Stern 2017). The direction of China´s climate governance is hereby to a growing extent also influenced by the market and civil society, in addition to the before strongly dominating hierarchical state structure (P. Wang, Liu, and Wu 2017). Additional critical factors for the future of coal will be local pollution (Yang and Teng 2017; Gu, Teng, and Feng 2016) and water shortage at mining and electricity production sites (Cheng et al. 2016). In particular, recent years have seen increased ambition around addressing greenhouse gas emissions and air pollution from coal combustion, which implicitly or explicitly entail reduced coal consumption[[2]](#footnote-2) (cf. Table 5 for a summary of policy measures). Overall, this set of environmental policies will help to reduce China´s future coal consumption. Analysis indicates that China’s coal price elasticity of demand is increasing, which supports the effectiveness of a national emissions trading scheme (ETS) as a mechanism for reducing coal consumption (and associated emissions) (Burke and Liao 2015). Teng, Jotzo, and Wang (2017) argue that the effectiveness of a Chinese ETS critically hinges on liberalizing the electricity market, otherwise the effect on operational decision of power plants is distorted.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Target year | Decrease in carbon-intensity of GDP | Share of non-fossil fuels in TPES | Comments |
| 12th Five-Year Plan (2011)[[3]](#footnote-3) | 2015 | 17% from 2011 | 11.4% | Decrease in energy-intensity of GDP: 16% from 2011 |
| Action Plan on Prevention and Control of Air Pollution (2013) [[4]](#footnote-4) | 2017 |  |  | Share of coal in TPES: 65% |
| Energy Development Strategy Action Plan (2014)10 | 2020 |  | 15% | Coal consumption cap of 4200 Mt |
| National Plan on Climate Change (2014)10 | 2020 | 40–45% from 2005 | 15% |  |
| Intended Nationally Determined Contribution (2015)[[5]](#footnote-5) | 2030 | 60–65% from 2005 | 20% |  |
| Supply-Side Structural Reforms (2016)[[6]](#footnote-6) | 2019-2021 | Reduce coal production mine capacity by: 500 Mt through direct regulation, 500 Mt through reconstruction and consolidation; moratorium on approval of new mines |
| “Promoting the orderly development of China's coal” Plan (2016)[[7]](#footnote-7)  | 2019 | No approval of new coal-fired power station, halt for approved plants not yet under construction, scrappage of old inefficient plants before expiration of technical lifetime |
| 13th Five-Year Plan (2016)[[8]](#footnote-8) | 2020 | Cap coal-fired capacity at 1,100 GW; share of coal in TPES: 58% |

Table 5: Summary of policy measures in China targeting reduction of coal consumption directly or indirectly.

Source: Own compilation based on various sources.

In its New Policies Scenario (NPS), the IEA World Energy Outlook (WEO) predicts that China`s coal demand has already peaked in 2013, and will decline at an increasing pace until 2040 (IEA/OECD 2015a, Table 7.2). This is in line with the current developments and Chinese energy and climate policy goals. Coal consumption has peaked in 2013, and has since declined at an average annual rate of 1.3% for 2014-2016 (NBSC 2017). At the same time, the capacity factor of power plants decreased below 50% in 2015 and 2016 (A. Lin 2017).

While the WEO 2016 discusses the possibility of a decline of coal consumption in China, and warns against negative effects on the Chinese and global economy (IEA/OECD 2016a, 291), it excludes this trend from its central scenario.

Against the background of continued policy interventions further reducing future coal demand and supply (cf. Supply-Side Structural Reforms and “Promoting the orderly development of China's coal” Plan, and 13th Five Year development Plan described in Table 5) are very likely. Although China’s current policies are not in line with the decarburization requirements of a global least-cost 2°C trajectory with its current policies in place, a clear reorientation towards renewables and the initialization of a coal-phase out can be observed.

# India

India’s steam coal demand has accelerated rapidly between 2004 and 2014. In 2015, with a consumption level of 764 Mt India became the second largest steam coal consumer in the world behind China on a tonnage-basis (IEA/OECD 2016b, xviii). This was driven by increasing shares of coal in total electricity generation reaching 75% in 2014 (IEA/OECD 2016c, III.64).

India has considerable coal reserves, though they typically consist of poor quality coal with a low energy content and high inherent ash content. Production has been ramped up predominantly by boosting output in lowest energy content grades (IEA/OECD 2015a, 513), and India’s coal production sector has been systematically lagging behind the stark increase in demand. Next to the typical problems of a state-owned enterprise Coal India Limited (CIL) that contributes 80% to India’s coal production, the sector struggles to cope with a linkage system of coal distribution and prices, a poorly developed interface between the coal and the power sector, and complications and uncertainty around land-rights and acquisition that hinder the development of new mine projects (Carl 2015, 124). Moreover, it suffers from insufficient transport capacity and low productivity (Commonwealth of Australia 2015a). CIL produced the majority of domestic coal with 539 Mt out of 640 Mt total production (Ministry of Coal 2017). In addition, imports of steam coal have more than doubled in the last few years. Consequently, India became the largest coal importer with 222 Mt in 2015, representing almost a quarter of domestic demand (and constituting 17% of the total global steam coal trade) (IEA/OECD 2015b, III.31-44).

Future growth in coal demand will be shaped by India’s economic growth (especially in the energy-intensive manufacturing sector), increased electrification to overcome high levels of energy poverty (IEA/OECD 2015a, 448), and to some extent, environmental policies. In its “intended nationally determined contribution” (INDC) India has committed to reduce the carbon-intensity of GDP by 33 to 35% from 2005 levels by 2030 and, conditionally, to increase the share of non-fossil fuels in power generation capacity to 40% by 2030 (Government of India 2015a). Moreover, it targets to increase solar generation capacity to 100 GW and total renewables capacity to 175 GW by 2022 (Government of India 2015c). As an additional policy measure India has introduced a tax on imported coal of 0.8 USD in 2010, and has twice doubled the tax to 3.2 USD for 2015-2016 (Mittal 2014; Ministry of Finance 2015). Additionally, air pollution from coal combustion has the potential to become a significant issue for India (IEA/OECD 2015a, 504), and may compel more ambitious policies to curb coal consumption in the future.

The key question is whether future growth in energy demand will be met mainly by coal or by renewables: Coal was the prevailing theme before the new government came to power 2014. In such a scenario, the central issue for the international steam coal market was the extend to which this demand will continue to be met by imports. Because imported coal is significantly more expensive than domestic coal (even once adjusted for differences in energy content) (Carl 2015, 153), the Indian government was aiming to reduce import dependency – possibly to the extent of becoming self-sufficient in steam coal(Cornot-Gandolphe 2016). A strong domestic production targets of 1500 Mt/a for 2020 is in place, but its success will depend on whether present constraints on production can be overcome (EIA 2015d). Coal quality is a further consideration. A majority of 85% of the young Indian coal-fired generation fleet (two thirds are less than 20 old) has sub-critical design tailored for high inherent ash and low energy content Indian coal and cannot easily take other coal types but required blending if imported coal needs to be used which entails reduced plant efficiency (IEA/OECD 2015a, 440). Only the newest generation of power plants is suitable for imported coal (Carl 2015, 129). At the same time the Indian government has announced that the Thirteenth Five Year Plan (which commences in 2017) will require all new coal-fired generation capacity to use supercritical technology (Government of India 2015b). However, these would induce an ongoing need to import coal of a higher quality, e.g. from Australia but also from Colombia (Commonwealth of Australia 2015a, 82–83).

The new government, however, has given up the coal story, and is now pursuing a renewables story, instead. The New draft National Electricity Plan realizes the long lead-times to develop coal-fired power generation compared to now cost-competitive renewables. It includes no new coal capacity between 2022-2027 apart from the 48 GW already under construction and a 57% renewables share in power generation by 2030 (Central Electricity Authority 2016).

# Turkey

Turkey holds large amounts of lignite (11.8 Gt) and 1.3 Gt of hard coal, of which 530 Mt are proven and economically recoverable reserves (Ersoy 2015; IEA CCC 2014). Lignite mines are spread over the country, whereas hard coal is limited to one major field close to Zonguldak (IEA CCC 2014). In order to reduce its import dependency, the Turkish government aims at using indigenous resources, which are limited to coal, and therefore, explains the Turkish run on new coal-fired capacities (Hartlieb, Ruppel, and Wagner 2016; Berk and Ediger 2016). Consequently, steam coal use grew significantly from 3.1 Mt in 1990 to 25.9 Mt in 2014 (IEA/OECD 2016b, III.264). Thus, to cover its demand, Turkey´s steam coal import volumes heavily increased from 24.4 Mt in 2014 to 28.5 Mt in 2015 (IEA/OECD 2016b, II.10). Turkey currently relies on imports from Colombia and Russia, with each partner exporting between 7-9 Mt annually, followed by South Africa (~3 Mt per year) (IEA/OECD 2015b).

The most recent and defining initiative with respect to coal is the “coal strategy” published by the Ministry of Energy and Natural Resources (MENR 2014). It focuses on mainly three pillars and acknowledges the importance of coal, particularly domestic coal, for the future of the Turkish energy sector. Firstly, Turkey aims at full utilization of existing lignite and hard coal reserves for electricity generation by 2023. Secondly, more coal-fired plants shall be built, firing primarily domestic coal.[[9]](#footnote-9) Thirdly, domestic coal production is scheduled to increase and new coalfields to be explored (ISPAT 2015; IEA CCC 2014). This strategy might, however, be adjusted as the government agreed to ratify the Paris Agreement if additional climate funding is accredited through it (Michael Schneider 2017). Additionally, the Turkish civil society shows first signs of objecting coal expansion plans (Yeldan and Voyvoda 2015; Şahin et al. 2016).

# Japan

Japan is the world´s third largest economy and the fifth largest emitter of CO2 emissions. It used to have a reputation as climate leader also hosting the third international climate conference in Kyoto in 1997. After the climate conference in Paris in 2015, however, the future for Japan’s climate policies remains very uncertain. Being located on an island it is highly vulnerable to climate change impacts and therefore has incentives to comply with decarbonization targets (Oshiro, Kainuma, and Masui 2016). On the other hand, Japan is the only G7 member that is planning to open new coal-fired power plants, endangering national as well as global climate targets. Japan´s emission reduction target of 26% for 2030 and at 80% for 2050 are criticized to lie well above the 2°C benchmark (Dimsdale 2016). Consequently, Japan´s rating by the Climate Action Tracker initiative (CAT 2017) turned out to be “inadequate” in terms of supporting the 2°C target.

The Tohoku Earthquake leading to the Fukushima Daiichi nuclear disaster in 2011 caused a dramatic shift in Japanese´s climate and energy policy. Following this accident, the government ordered the shutdown of all 54 operating nuclear plants that were supplying 30% of Japan’s electricity at that point. This dropback was mostly compensated by liquefied natural gas (rising from 29% to 43%), oil (8% to 18%) and coal (25% to 28%). Renewable energy sources, particularly solar PV, have increased their electricity share steadily and are estimated to reach 7% in 2016. Originally five nuclear blocks were supposed to restart their operation in 2015 to be followed by eight further plants in 2016 (Yanagisawa et al. 2015). Technical and regulatory complications, however, resulted in only two plants being online in June 2016 (Schneider et al. 2016).

Current policies aim at complementing this increase of nuclear capacities with newly constructed coal power plants (Lim 2017). The existing plans for 47 new coal units account for 22.5GW (Dimsdale 2016). Reasons for the construction of coal power plants in Japan are matters of energy security and diversification as well as cheaper fuel prices for coal compared to gas or oil (Caldecott et al. 2016). Also, Japan, in addition, is the largest financier of coal overseas and a promoter of the so-called high efficiency and low emissions (HELE) coal power plants (Grandia 2016). These HELE coal power plants being constructed not only in Japan, but e.g. also in South Korea are suited for burning coal of high quality from Australia but might also use Colombian coal.[[10]](#footnote-10)

# Chile

Chile has almost no fossil resources (APEC 2006), and thus, depends on fossil fuel imports and renewables energies. Due to its geographic advantages, particularly hydro energy contributes greatly to power generation. Coal reserves are limited to one recently opened mine – the “Mina Invierno”, which began producing in 2013 (MaRS Advanced Energy Center 2015).[[11]](#footnote-11)

Chile’s energy policy is driven by two fears – droughts and natural gas supply shortage. From 2004 onwards, restrictions in the supply of natural gas from Argentina and only little rainfall in the years 2007-2010 resulted in a serious energy crisis and led to a transition to a more coal-based electricity system, which was not part of the original long-term energy strategy. In recent years, however, the Chilean society showed growing opposition and concerns about the electricity mix and its focus on coal. The increase in conflicts results in delays for implementing investments (Ministerio de Energía 2012). In 1990, the use of steam coal for electricity purposes was 3.23 Mt but increased to 11.62 Mt in 2014. The majority of the steam coal needs to be imported from mainly Colombia, but also the US and Australia totaling 9.21 Mt in 2015 (IEA/OECD 2016b, III.80-82).

Future energy policy is shaped by “The National Energy Strategy 2012-2030” which was defined and published by the Ministry of Energy and the Ministry of Environment (Ministerio de Energía 2012). Its main target is to increase the share in power generation of the “non-conventional renewable energies[[12]](#footnote-12)” from 3% to 10% in 2024. Regarding the role of coal, the strategy acknowledged that energy security cannot be guaranteed without coal playing a major role. The government, however, announced a new strategy in February 2018 planning to build no new coal plants without carbon capture and instead begin talks to replace existing capacity with cleaner sources.

# Germany

In the 1990s, the share of coal in the German energy mix has been at 60% and still is at 44% in 2015 (c.f. Table 4 in the main text). The domestic production of steam coal, however, fell sharply from 38 Mt in 1990 to 18.5 Mt in 2000. Since 2010 steam coal production has declined further, falling to its minimum with 2.8 Mt in 2015. To cover the slightly increasing demand, while production declined, Germany’s imports more than quadrupled between 1990 and 2013. In 1990, imports were 11.8 Mt, however, in 2000, imports climbed to 23.3 Mt already and further reached their all-time maximum with 46.5 Mt in 2013. In the following two years steam coal imports shrank slightly to 44-45 Mt. Most of these imports originate from Russia (in 2015: 14 Mt), Colombia (6.9 Mt) and the US (5.2 Mt). Germany is also one of the largest producers of lignite. Lignite production, however, was halved from values of 360-380 Mt in the 1970s and 80s to 170-180 Mt after 1990 mostly due to the industrial and structural changes in the course of German reunification. (IEA/OECD 2016b, III.120-128, 2016c, III.62)

In 2010, the German government published its “Energiekonzept” which outlines the national energy politics and the intended tools for reaching the climate goals. It sets minimum CO2 reduction targets of emissions by 40% and 80% in 2020 and in 2050, respectively, compared to 1990 levels. In terms of the electricity demand, the “Energiekonzept” intends to reduce the demand by 10% in 2020 and by 25% in 2050 as compared to 2008, while the share of renewable energies of the electricity generation shall increase above 35% in 2020 and 80% in 2050 (BMWI 2010). After the nuclear accident in Fukushima, the German government agreed on phasing out all nuclear power plants by 2022. As of August 2017, nine plants have been closed, while the remaining eight plants will close according to their individual schedule by 2022.

In July 2015, the German government agreed on closing several coal-fired plants. The plan provides for phasing out lignite-fired power plants with an overall capacity of 2.7 GW in the years 2017-2019. A large number of studies indicate a pathway to obtain an almost complete decarbonization of Germany’s electricity generation by 2050 going along with a coal phase-out in the 2030s or latest by 2040 (Nitsch 2013; Klaus et al. 2010; SRU 2013; WWF 2017; Agora Energiewende 2016; Oei et al. 2015; SRU 2017).

# U.S.

The U.S. has the world’s largest coal resources (World Energy Council 2013), with the vast majority of its coal production being steam coal from mines in the Powder River Basin (PRB), Appalachia and the Illinois Basin (EIA 2015a). With very low average cost of USD 12.5 per ton (IEA/OECD 2014c, 30), PRB coal is of particular interest for both the US and the international steam coal market. Currently, the discussion of PRB exports is, however, obsolete. Export is only possible via Canadian ports in British Colombia, where capacity is predominately used for Canadian coal exports. There are plans to construct export terminals along the US West Coast, in Oregon and Washington, but at the same time there are extensive concerns about local health and environmental impacts and consequences for global CO2 emissions (Western Interstate Energy Board 2012).[[13]](#footnote-13)

Historically, steam coal use underpinned industrialization and economic growth in the U.S., but has seen a steady decline over the past decade. The share of coal in total electricity generation declined from 52.3% in 2000 to 34.3% in 2015 (IEA/OECD 2016c, III.62). This is largely on economic grounds and in particular, due to the boom in production of low-priced domestic shale gas, and the availability of cheap renewable technologies as well as federal and state level promotion of wind and solar energy. Further important drivers are environmental policies that additional had a negative effect on the economics of coal-fired electricity generation. Under the umbrella of the Clean Air Act of 1970, the US Environmental Protection Agency (EPA) has introduced several regulations since 2011 that heavily influence the future of coal-fired power generation in the U.S.: inter alia, they regulate i) power plant emissions that contribute to ozone and/or fine particle pollution across state borders (Cross-State Air Pollution Rule, EPA 2017b); ii) mercury emissions and other hazardous air pollutants (Mercury and Air Toxics Standards (MATS), EPA 2017a); and iii) emissions of existing and new generation units (Carbon Pollution Standards, EPA 2016a, Clean Power Plan (CCP), 2016b).

Given the aging coal-fired power plant fleet (with 85% older than 30 years and 50% older than 40 years (Sussams and Grant 2015)), the environmental policies mentioned above were supposed to lead to power plants increasingly being decommissioned rather than refurbished (IEA/OECD 2014b, 196), and future coal-fired power generation capacity additions to be minimal (EIA 2015b, 26). As part of its new energy policy, the current U.S. administration, however, targets to take back measures introduced in the Climate Action Plan. The Trump administration is committed to support clean coal technology and is likely to soften emission standards for new coal-fired power plants. In his executive order (The White House 2017a), the US President has repealed rules that encouraged federal regulators to consider climate change in environmental reviews and has enforced lower social cost of carbon for future assessments. Moreover, he has lifted the moratorium on new coal mine leases, which his predecessor has introduced in 2016 (Warrick and Eilperin 2016) and announced to withdraw from the Paris Agreement (The White House 2017b). This marks yet another step-down from the role of the US as leader in climate change action under the Obama Administration

Nevertheless, already in 2015, analysts do not expect these trends to be affected by the possibility of future suspension or repeal of any of the environmental policies, given that investment decisions are already being made on the basis of these policies – and moreover, on the basis of the favorable economics of alternative fuels (Harvey 2015; Reuters 2015a; Sussams and Grant 2015). Questioning the rethoric of a “war on coal” Culver and Hong (2016) come to a similar conclusion. Houser, Bordoff, and Marsters (2017) conclude that for the next years the competitiveness of the US domestic coal sector will be governed by the evolution of the gas price and cost of renewables rather than by the rollback of environmental regulation by the Trump Administration. It is only for 2025 and after, that the deregulation agenda might have substantial effects on domestic coal consumption.

Projections of coal production in the U.S. exhibit a large spread reflecting the uncertainty created by the reorientation of U.S. energy policy, departing from a low carbon transition pathway. The U.S. Energy Information Administration’s Annual Energy Outlook (EIA AEO) 2017, shows a gap of 100Mt (for 2025; 250Mt by 2050) between projections that assume maintaining the Clean Power Plan (CCP) and those that assume abandoning it altogether (EIA 2017). The different production levels are forecasted to occur mainly in the Western and to a smaller extend in the Interior region (which include the Illinois Basin and Powder River Basin) while the Appalachian region is mostly unaffected. The gap is due to different forecasts regarding coal consumption in the U.S. electricity sector. On the demand side, the Annual Energy Outlook projects that 43 GW of coal-fired capacity will be decommissioned between 2015 and 2050 with no CCP, compared to 101 GW with the CCP in place. This is also reflected in projections of coal demand from the electricity sector, which evolve accordingly.

# United Kingdom

The UK possesses major resources for renewable energies as well as fossil fuels. In terms of fossil resources, the UK has natural gas fields in the Scottish sea covering almost 50% of its yearly natural gas consumption, yet, its productivity has been on the decline over the last years (DECC 2015). Since the run on shale gas, extensive amounts of shale gas have been found under the British mainland, although it is uncertain how much is economically exploitable (N. Smith, Turner, and Williams 2010). The steam coal use in the UK declined from 96.21 Mt in 1990 to 51 Mt in 2000, mostly due to a decreasing coal demand in power plants, where coal’s share in the electricity mix declined from 65% in 1990 to 22.9% in 2015 (cf. Table 4 in the main text) (IEA/OECD 2016c, III.62). In the summer of 2016 for the first time in over 100 years electrification of coal hit zero for several hours. Steam coal production decreased in total by some 88% from 91 Mt in 1990 to 18.1 Mt in 2010 and, eventually, to 8.4 Mt in 2015. While in the 1990s domestic production almost met the demand, the UK imports rapidly increased since the early 2000s. In 2010 imports totaled 20 Mt before doubling to 40 Mt in 2012 and falling back to 21 Mt in 2015. The main supplier in 2015 were Russia delivering 8.3 Mt, followed by Colombia with 7.6 Mt and the U.S., who exported 3.5 Mt of steam coal. (IEA/OECD 2016b, III.271-272)

The current energy politics are shaped by the UK Low Carbon Transition Plan, which was published in 2009 as an extension of the Climate Change Act 2008. It targets cutting CO2 emission by 18% below the 2008 levels in 2020 and by 80% below the 1990 levels in 2050. Since the end of 2010, coal-fired power plants with a combined capacity of 10.5 GW have been closed (8.85 GW) or converted to biomass (1.65 GW). The reasons for the shut downs are the large combustion plant directive of the EU, which forces old power plants to shut down if they do not fulfill the emission requirements on sulfate dioxide and nitrogen oxides, and the introduction of a minimum CO2-price. These closure have caused additional positive co-benefits for health, the economy, and the environment (A. C. Smith et al. 2016). With the “Energy Bill 2012-2013” the British government introduced the so-called “emission performance standard” restricting the construction of new coal power plants (DECC 2013). In November 2015, energy secretary Amber Rudd declared in a statement to phase out all UK coal plants by 2025 and to restrict their use by 2023 (Rudd 2015). Most policies affecting future coal consumption are hereby based on national regulation and will therefore not be affected by the currently discussed upcoming (Br-)exit from the EU.

# The Netherlands

While the Netherlands have no indigenous coal production and fully depend on international imports, it possesses large natural gas fields in the North Sea and, the biggest one, in the Groningen area (IEA/OECD 2014a). However, due to its long shorelines, which provide unlimited access to cooling water for power plants, and its two major ports, the Netherlands are primed for coal-fired power plants, and thus, have attracted big investments in coal technology, mostly from Germany. Coal-fired generation makes up 37% of the electricity mix in 2015 (IEA/OECD 2016c, III.62).

Although the Netherlands never used more than 10 Mt of coal per year, its imports of steam coal by far exceed this value. While until 2010 its imports were only about double its yearly usage, imports increased to 25 Mt in 2012 before leaping to 53 Mt in 2015. In 2015, its main trade partners were Colombia, which accounted for about 16.7 Mt, as well as the U.S. and South Africa. Most of the imported steam coal is being exported again via its main ports in Rotterdam and Amsterdam. In 2015, 36 Mt were exported of which 32 Mt were destined for Germany. Especially, Rotterdam has developed into the energy hub of Europe providing storage facilities and refineries for steam coal, oil and LNG as well as a strong chemical industry in the surroundings. (IEA/OECD 2016b, III.192-197)

The future energy mix is shaped by the “National Energy Agreement for Sustainable Growth”, published in 2013 (SER 2013), particularly with respect to coal. As of the 7 coal-fired power plants in the Netherlands, the agreement calls to phase out the five oldest coal-fired power plants, combining for a total 2.7 GW. Three of which were closed by January, 1st 2016 and two more are scheduled to be shut down by July, 1st 2017 (IEA 2014; industcards 2016; Agora Energiewende and Sandbag 2017). However, in contrast to most European countries, the Netherlands also built new coal-fired power plants with a combined capacity of 3.5 GW, and thus exceeding the capacity of the recently abandoned ones. The biggest one “Maasvltake 3” (1100 MW), operated by E.ON, is fired by coal and biomass and got its operation permit in 2016 (industcards 2016). RWE built a 1.6 GW coal and biomass fired power plant in Eemshaven (Eemshaven A+B), for which they eventually got the permission to operate it in September, 2015, after there had been trials questioning the compliance with nature conservation guidelines (IWR 2015). Moreover, GDF Suez began constructing another 800 MW power plant running on coal and biomass in 2013. However, in June 2015, for the first time ever, a court decision in the Netherlands legally requires the State to take further precautions against climate change implying a strong reduction of coal-electrification. Wynn (2016) therefore arguments that all three planned coal plants are at high risk of becoming stranded assets in the near future. The decision by the Dutch government in fall 2017 to support a coal phase-out by 2030 supports this argument (CAN 2017). In addition, rising opposition in Amsterdam and Rotterdam have resulted in claims to target both ports to be coal-free by 2030 (Climate Change News 2017; DutchNews 2017). This could also have consequences for coal imports to other European countries as these harbors are used as main hub for arriving coal imports, especially from Colombia.

# Israel

There are two coal-fired plants in Israel, both on the Mediterranean coast, built in the late 1970s and early 1980s. Overall, coal-fired capacity accounts for 30% of the installed capacity, while natural gas plants contribute 60% (IEC 2012). Israel possesses extensive natural gas resources offshore, especially since the discovery of the “Leviathan” field, which is the largest natural gas field discovered in the last decade. In total, the Israeli offshore fields are expected to have more than 700 bcm of natural gas, which should cover the Israeli demand for more than 50 years, while additional extensive findings are likely. Israel also has oil shale deposits, however, only small fractions are economically exploitable, and thus, are not expected to play a significant role in the future (OECD 2013).

Steam coal use has tripled from 3.73 Mt in 1990 to 14.3 Mt in 2012. In the last two years figures decreased back to 10.9 Mt in 2014 (IEA/OECD 2016b, III.156). Israel has no domestic production, due to the lack of steam coal resources, and is therefore, entirely dependent on imports. Half of the imports originate from Colombia (5.8 Mt in 2015); South Africa and Russia each account for around one quarter of the yearly imports (2.6 and 2.2 mt in 2015). Israel has annouced to reduce its GHG emissions by 20% by 2020 relative to a ‘Business-as-usual' (BAU) scenario to be in line with the Paris Agreement (Ayalon, Lev-On, and Lev-On 2015). For future projections the Ministry of Environment (Israel Ministry of Environmental Protection 2015, 2016) provides a BAU and an alternative scenario. Under the government’s BAU scenario the primary steam coal demand is not expected to change significantly compared to 2015. The alternative scenario, on the other hand, has a rather downward trend and is to require almost half of the primary steam coal demand in 2030 mostly due to the rapidly increasing capacity of natural gas.

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# Additional Figures



Figure S.1: Monthly prices for steam coal in USD/t (CIF Eurozone, FOB Richards Bay, and FOB Newcastle) and crude oil in USD/bbl (crude oil index) between April 1996 and April 2016.

Source: HWWI commodity prices in the Thompson Reuters Datastream database.

1. Coal is not a homogeneous commodity but is commonly categorized as steam coal, metallurgical or coking coal and lignite, based on its material properties and end-use. Steam coal is the set of coal types that are typically combusted to produce steam. Around 70% of steam coal is used to produce electricity and heat, and the remainder mostly for other industrial heat-consuming activities (IEA/OECD 2015b, III.68). According to the International Energy Agency (IEA), steam coal includes anthracite, other bituminous coal and sub-bituminous coal, with an energy content ranging from 20 GJ/t to as much as 30 GJ/t (IEA/OECD 2015b, I.25). Steam coal is mined at either surface or underground mines, mainly depending on the depth of the coal seam (Speight 2012). The raw coal is processed through crushing, screening and beneficiation/washing operations to meet customer specifications. To transport the coal to port or market, rail is most common, but river barges are also used (as well as other modes of transport over short distances). Where necessary along the supply chain, coal is stored in open air stockpiles or enclosed silos. [↑](#footnote-ref-1)
2. Even though total coal consumption is targeted, there are more available substitutes for steam coal rather than coking coal, so steam coal will be most affected. [↑](#footnote-ref-2)
3. Grantham Research Institute (2017). [↑](#footnote-ref-3)
4. X. Lin and Elder (2014). The Clean Coal Action Plan involves a range of measures and targets to improve the quality of coal consumed and the efficiency with which it is combusted (China Coal Resource 2015). From the start of 2015, quality standards for ash and sulfur content have been imposed on both imported and domestically-supplied coal (*Reuters* 2015b). [↑](#footnote-ref-4)
5. INDC People’s Republic of China (2015). Between June 2013 and June 2014, pilot ETS commenced in five cities and two provinces (Zhang 2015). China also has planned to introduce a national ETS in 2017, covering a number of key emissions-intensive sectors (The White House 2015). Although these plans are still valid, there is no new announced date for launching the Chinese ETS. [↑](#footnote-ref-5)
6. The State Council of the People’s Republic of China (2016). [↑](#footnote-ref-6)
7. Boren (2016), see <http://www.gov.cn/xinwen/2016-04/25/content_5067562.htm> for the official press release. According to Forsythe (2016) the main driver behind this policy may be economic rather than environmental concerns, as existing coal-fired capacity faces low utilization rates. [↑](#footnote-ref-7)
8. 13th Five Year Energy Development Plan (NDRC 2017; based on A. Lin 2017) [↑](#footnote-ref-8)
9. Currently, there are seven steam coal-fired plants in total, of which six run on imported coal and only one on domestic steam coal. Existing steam coal-fired capacity totals to 5 GW. As of end 2013, there are 14 hard coal plants (10.3 GW) in the application phase, eight (3.5 GW) are under examination evaluation and four (2.5 GW) are already approved and under construction, which are in total 26 plants for 16.2 GW which are scheduled to start generating (Deloitte Turkey 2013). [↑](#footnote-ref-9)
10. The construction of HELE power plants, despite higher efficiency values, however, is incompatible with the 2°C target (Wong, Jager, and Breevoort 2016). Until now, only four coal plants with an overall capacity of 1.9 GW have started construction in Japan. Succeeding in the construction of all currently planned units would exceed the required capacity to replace the retiring fleet by 191%. Such overcapacities, combined with rising competition from renewable energy sources, might result in significant stranded coal assets (Caldecott et al. 2016). [↑](#footnote-ref-10)
11. Here, 73 Mt of subbituminous coal reserves, with a calorific value of 4100 kcal/kg, can be exploited at an maximum annual production of 6 Mt, limited by the “resolución de Calificación Ambiental”.. [↑](#footnote-ref-11)
12. In Chile, that is: wind energy, solar energy and smaller hydroelectric plants (less than 20 MW). [↑](#footnote-ref-12)
13. There are differing perspectives on the potential effects on world market prices of PRB exports, Power and Power (2013) projecting an further decrease while EPRINC (2012) and IEA/OECD (2013, 119–20) assume it to substitute other infra-marginal suppliers. From a more general viewpoint, Morse and He’s (2015) finding that China’s import levels are a dominant factor in determining world prices imply that PRB`s exports would not have major effects on the world market (assuming that the demand is not very price elastic). [↑](#footnote-ref-13)