

CASE STUDIES IN IMPROVING URBAN AIR QUALITY

2016



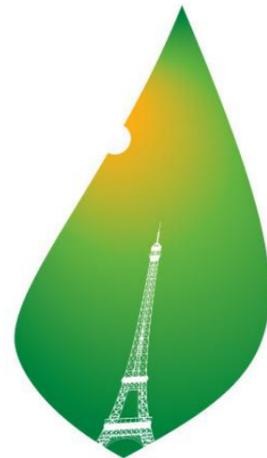
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Introduction

The entry into force on November 4, 2016 of the Paris Agreement,¹ reflects the priority given to tackling climate change at the highest levels of global political leadership.² As of October 2016, as many as 86 countries have ratified the agreement, including the US, China and India, which are among the world's largest emitters.³ The European Union, which officially joined the Paris agreement in October 2016,⁴ plans to continue taking a leadership role in driving climate action.



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In addition to climate change, air pollution is an increasing priority for local, national and international governance.

Around the world, 300 million children, mostly in South Asia, breathe highly toxic air because of dangerous pollutants like air particles known as PM_{2.5}.⁵ Despite significant improvements in urban air quality in the past decades, air pollution remains a serious problem across much of the European Union too. The human and health-related costs associated with air pollution are immense.

The European Environmental Agency estimates that in 2012 fine particulate emissions alone caused more than 400,000 premature deaths within the European Union (EU).⁶ The direct economic cost of air pollution in the EU was around EUR 23 billion (\$25 billion) in 2010, and the total health-related costs associated with air pollution (including both direct and indirect costs) could have been as high as EUR 940 billion (\$1,025 billion) in the European Commission's estimate.⁷

¹ The United Nations. "Paris climate agreement to enter into force on November 4." 2016, available at: <http://www.un.org/sustainabledevelopment/blog/2016/10/paris-climate-agreement-to-enter-into-force-on-4-november/>

² The United Nations. "UN chief hails new climate change agreement as monumental triumph." 2015, available at: <http://www.un.org/sustainabledevelopment/blog/2015/12/un-chief-hails-new-climate-change-agreement-as-monumental-triumph/>

³ The United Nations Framework Convention on Climate Change. "Paris Agreement: Status of Ratification." 2016, available at: http://unfccc.int/paris_agreement/items/9444.php

⁴ F.Y. Chee, "With EU backing, Paris climate deal clears last hurdle to taking effect." Reuters, October 4, 2016, available at: <http://www.reuters.com/article/us-climatechange-eu-idUSKCN1241X5>

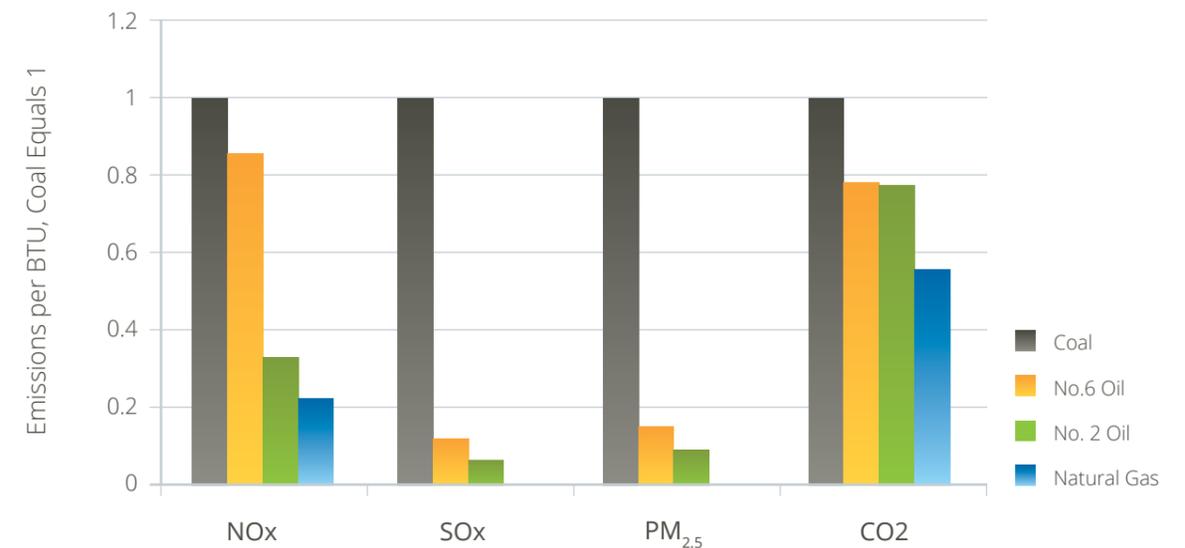
⁵ G. Anand, "300 million children breathe highly toxic air, UNICEF reports." New York Times, October 30, 2016, available at: <http://www.nytimes.com/2016/10/31/world/asia/unicef-children-toxic-air.html?hp&action=click&pgtype=Homepage&clickSource=story-heading&module=second-column-region®ion=top-news&WT.nav=top-news>

⁶ European Environment Agency. "Air Quality in Europe-2015." No.5, 2015, p.42-44, available at: http://www.eea.europa.eu/publications/air-quality-in-europe-2015/at_download/file

⁷ Ibid., p. 12.

In response, major European cities are increasingly galvanized to act not only by environmental concerns, but by health and economic considerations as well. This report, which expands on a previous report by the International Gas Union about urban air quality,⁸ presents case studies in four European cities – Berlin, Dublin, Krakow, and Rotterdam. It shows how Berlin and Dublin have taken decisive steps to reduce air pollution, and Krakow and Rotterdam are using more natural gas to improve air quality. The combustion of natural gas emits around half as much CO₂ as coal, and a fraction of the SO_x, NO_x, and particulate matter (PM) of coal or fuel oil.⁹ Moreover, natural gas – unlike coal and biomass – produces negligible emissions of benzo(a) pyrene (BaP), a potent carcinogen, when used for domestic home heating.¹⁰ Fuel-switching efforts in these cities have demonstrated that natural gas can play a significant role in reducing both greenhouse gas emissions and the damaging effects of air pollution on human life.

Figure 1: Comparison of Emissions from Different Fuels



Source: EPA AP-42 Compilation of Air Pollutant Emission Factors; CenSARA Area Combustion Emissions Inventory Enhancement Project – Final Report 2011

⁸ International Gas Union. "Case Studies in Improving Urban Air Quality." 2015, available at: http://www.igu.org/sites/default/files/IGU_Urban%20Air%20Quality%20FINAL%20for%20web%20etc.pdf

⁹ Ibid., p.7

¹⁰ European Environment Agency. "Air Quality in Europe-2015." No.5, 2015, p.14, 33, available at: http://www.eea.europa.eu/publications/air-quality-in-europe-2015/at_download/file



BERLIN: Gas Takes Center Stage in Cleaning Up the Air and Reducing Carbon Emissions



With more than 3.5 million residents and a land area of 344 square miles,¹¹ Berlin is Germany's largest and most populous city, and has the status of a city state within Germany's federal structure.¹² Today, Berlin is one of the cleanest major cities in Europe. A 2012 green city index compiled by the Economist Intelligence Unit ranked Berlin above the average of both German and other European cities in overall environmental performance as well as in measures of air quality.¹³ By 2008, Berlin's mean annual NO_x concentrations were 20% lower than the average of 41 major European cities, PM concentrations were 23% lower and SO_x concentrations were 25% below the European average, according to European Environmental Agency data.¹⁴

But this was not always the case, as Berlin's relatively low air pollution today is a result of a remarkable transformation of the city's energy system after Germany's reunification in 1989. In the intervening 26 years, Berlin's SO_x emissions dropped by 95%, NO_x emissions decreased 76% and PM₁₀ emissions were on track to decline by 83% between 1989 and 2015.¹⁵ Meanwhile, the city's population increased slightly between 1989 and 2015.¹⁶

A widespread shift from coal to natural gas in power and heat generation, as well as in residential heating played perhaps the most important part in cleaning up Berlin's air in the decades after reunification.¹⁷ The share of natural gas in the city's primary energy balance increased from 17% in 1990 to 41% 2012, and gas use in absolute terms more than doubled during this period.¹⁸ At the same time, the share of coal declined from 37% of primary energy consumption in 1990 to 17% in 2012. The burning of the especially polluting lignite within the coal mix declined particularly steeply, by nearly three quarters, in this period.¹⁹

¹¹ Source: citypopulation.de, <http://www.citypopulation.de/Deutschland-Berlin.html>

¹² Senate Department for Urban Development and the Environment (2014a), Air Quality Plan for Berlin 2011-2017, p.25, http://www.stadtentwicklung.berlin.de/umwelt/luftqualitaet/de/luftreinhalteplan/download/lrp_150310_en.pdf

¹³ Economist Intelligence Unit, German Green City Index: Assessing the environmental performance of 12 major German cities, p.20-23, http://www.siemens.com/entry/cc/features/greencityindex_international/all/en/pdf/report_german_gci.pdf

¹⁴ Ibid.

¹⁵ Senate Department for Urban Development and the Environment (2016), Long-Term Development of Air Quality (2016 Edition), p.3, http://www.stadtentwicklung.berlin.de/umwelt/umweltatlas/e_text/ek312.pdf

¹⁶ Source: citypopulation.de, <http://www.citypopulation.de/Deutschland-Berlin.html>

¹⁷ Other factors contributed—albeit to a lesser extent—to the reduction of air pollution in Berlin over time. These include the closure of some heavily polluting industrial plants (particularly in East Berlin), large-scale building energy efficiency retrofits and the introduction of stricter fuel quality standards and catalytic converters in road transport, among many others.

¹⁸ Statistik Berlin-Brandenburg (2015), Statistischer Bericht (E IV 4 – j / 12): Energie- und CO₂-Bilanz in Berlin 2012, p.24, https://www.statistik-berlin-brandenburg.de/publikationen/stat_berichte/2015/SB_E04-04-00_2012j01_BE.pdf

¹⁹ Ibid.

Direct coal burning in the residential and commercial sector all but disappeared by the early-2010s. The number of coal-fired furnaces – mainly used for residential heating in the Eastern part of Berlin – dropped sharply, from 400,000 in 1990 to around 40,000 by 2010,²⁰ and were mainly replaced by gas-fired units or district heating.²¹ As a result of this switch, the share of coal burned directly by end-users (primarily for home heating) declined to a minuscule 0.2% in the final energy mix by 2012 from about 12% in 1990.²² Natural gas also gained ground in the city's coal-dominated power and district heat generation sectors: by 2012, the share of gas in the power generation mix rose to 37% (from 26% in 2001),²³ and the share in district heating reached 49% by 2012.²⁴

The Promotion of Natural Gas Vehicles in Berlin

Road transport remains the largest source of emissions for many air pollutants in Berlin, particularly NO_x, Carbon Monoxide, particulate matter and organic gases (Ozone).²⁵ To address traffic-related emissions, Berlin has promoted the use of natural gas vehicles since 2000, and continues to do so under the city's current air quality plan for the 2011-2017 period.

Although the share of CNG vehicles remains very low, at less than 1% of the active vehicle fleet,²⁶ the air quality impacts can be quite significant on the local level, especially in areas with a high concentration of taxi traffic (e.g., around airports and train stations). Acknowledging natural gas as a “clean alternative” to diesel vehicles in transportation, the city's plan envisions steps to support CNG vehicles with public sector vehicle purchases, reduced tolls for natural gas-powered trucks and a widespread communication campaign highlighting the benefits of natural gas vehicles, among other measures.²⁷

²⁰ Senate Department for Urban Development and the Environment (2010), Building Heating Supply Areas –Predominant Heating Types (Edition 2010), p.7, http://www.stadtentwicklung.berlin.de/umwelt/umweltatlas/e_text/ekb801.pdf

²¹ Senate Department for Urban Development and the Environment (2014a), p.65

²² Statistik Berlin-Brandenburg (2015), p.25

²³ Statistik Berlin-Brandenburg (2007), Statistischer Bericht (E IV 4 – j 04): Energie- und CO₂-Bilanz im Land Berlin 2004, p.16, https://www.statistik-berlin-brandenburg.de/publikationen/stat_berichte/2007/SB_E4-4-j01-04_BE.pdf

²⁴ Statistik Berlin-Brandenburg (2015), p.27 and p.29

²⁵ Senate Department for Urban Development and the Environment (2016), p.2-4

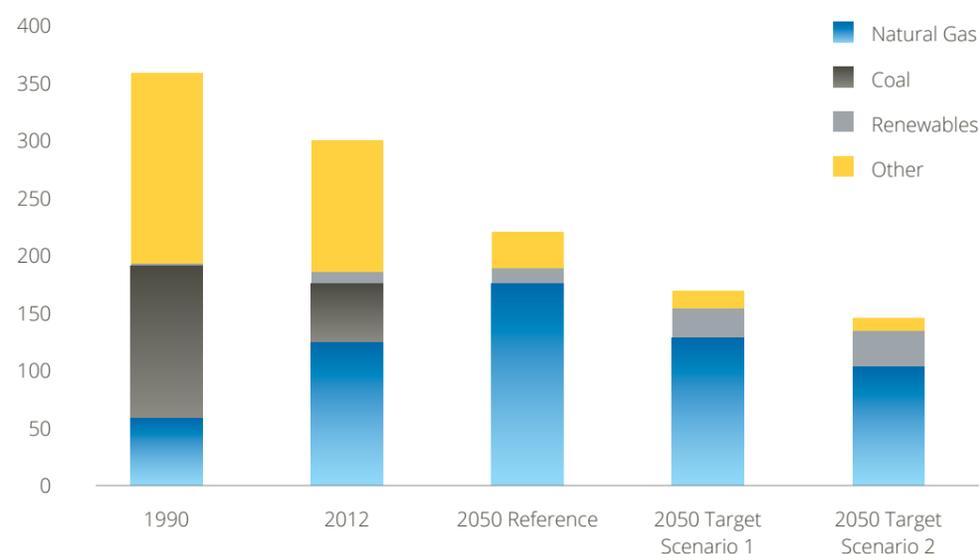
²⁶ Senate Department for Urban Development and the Environment (2014a), p.103-104

²⁷ Ibid. p.153



But city officials recognize that more can be done to “clean up” Berlin’s air and energy system. As of 2012, about 40% of Berlin’s district heat and 53% of its electricity was still generated from coal.²⁸ Reducing coal use would further reduce greenhouse gas emissions and contribute to lower air pollution. A detailed feasibility study commissioned by the city Senate in 2014 concluded that Berlin can achieve ambitious climate goals, if it continues on the path of replacing coal with cleaner fuels in its energy mix.²⁹ Natural gas would play a leading role in this strategy: the share of gas in the primary energy mix would rise from 41% in 2012 to somewhere between 70% and 76% in 2050 (depending on how the targets are achieved).³⁰ At the same time, coal would be completely eliminated from the city’s primary energy mix to meet the goal. The absolute level of natural gas demand can increase 3% or decrease 18% from 2012 levels, depending on the less carbon intensive pathway chosen, and between 24% and 30% of the projected gas demand would be met with biogas from renewable sources, according to the report.

Figure 2: Historical and Projected Primary Energy Balance of Berlin in The Reference Case and Two “Climate-Neutral” Scenarios³¹



Source: Berlin Senate – Department for Urban Development and the Environment

²⁸ Statistik Berlin-Brandenburg (2015), p.27 and p.29

²⁹ Senate Department for Urban Development and the Environment (2014b), Climate-Neutral Berlin 2050: Results of a Feasibility Study, p.4 and p.26, http://www.stadtentwicklung.berlin.de/umwelt/klimaschutz/studie_klimaneutrales_berlin/download/Machbarkeitsstudie_Berlin2050_EN.pdf

³⁰ Senate Department for Urban Development and the Environment (2014c), Machbarkeitsstudie Klimaneutrales Berlin 2050 – Anhang, p.429-430, http://www.stadtentwicklung.berlin.de/umwelt/klimaschutz/studie_klimaneutrales_berlin/download/Machbarkeitsstudie_Berlin2050_Anhaenge.pdf

³¹ A city is regarded “climate-neutral” if its greenhouse gas emissions—at 2 metric ton of CO₂ equivalent per capita—are sufficiently low to keep global warming below the dangerous threshold of 2°C. In the case of Berlin, this means that annual CO₂ emissions have to be reduced to 4.4 million tons by 2050, a reduction of about 85% from 1990 levels and about 77% from 2013 levels.

Source: Senate Department for Urban Development and the Environment (2014b), p.4

Increased use of natural gas can only address part of Berlin’s air quality issues, however, because of cross-border pollution. A detailed analysis by the city’s development office shows that only about a third of Berlin’s particulate matter pollution is “home-made” (and thus can be addressed by local measures), while two-thirds of the PM₁₀ emissions originate outside the city, most probably in Poland across Germany’s eastern border,³² where coal is still widely used for power generation and home heating. Fine particulates, which are especially damaging to human health, remain in the air for several weeks and can travel hundreds of miles on the wind.³³ Further analysis showed that Berlin breached EU air quality rules for PM₁₀ emissions in 2009 and 2010, even though the city could have easily stayed within EU emission limits absent any cross-border pollution from Poland.³⁴

A study by the WWF and others confirms that Germany is a major recipient of coal burning-related cross-border pollution from Poland, which causes an estimated 620 premature deaths across Germany each year.³⁵ Berlin city officials have tried to address the issue of cross-border pollution by facilitating direct consultations between the Polish and German governments, and by urging the European Commission to design and enforce more stringent emission rules that meaningfully reduce coal-related pollution in Poland and other Eastern European member states.³⁶ These efforts have so far had little effect; if anything, the share of PM₁₀ emissions originating outside of Berlin has increased, not decreased in recent years.³⁷

Berlin has managed to become one of Europe’s cleanest big cities, thanks in a large part to an ongoing transition from coal and other dirty fuels to natural gas. The case study of Berlin shows that reducing air pollution and greenhouse gas emissions in a major city can be accomplished through displacement of coal with natural gas and more deployment of renewable energy sources in the energy mix. But Berlin’s example also illustrates that a city alone may not be able to fully address its own air pollution problems, at least not without cooperation with neighboring countries and a variety of stakeholders across its broader region.

³² Senate Department for Urban Development and the Environment (2014a), p.87-93

³³ Ibid. p.91

³⁴ Ibid. p.94

³⁵ HEAL, CAN, WWF and Sandbag (2016), Europe’s Dark Cloud: How Coal-Burning Countries Make Their Neighbours Sick, p.8 and p.23 https://sandbag.org.uk/site_media/pdfs/reports/dark_cloud_report.pdf

³⁶ Senate Department for Urban Development and the Environment (2014a), p.193-195

³⁷ Ibid.



DUBLIN: Gas Makes Inroads at Coal's Expense



In the late 1980s, Dublin's air quality was among the worst in Europe due to policies that encouraged the burning of cheap bituminous coal. The city's air pollution was directly associated with increased fatalities and was so intense that it blocked sunlight for as long as two weeks at a time, especially in cold winter months.³⁸ In response to several bouts of severe coal-related winter smog, the city government implemented Dublin's "smoky coal ban" in 1990 and achieved a remarkable improvement in the health of its citizens, reportedly preventing as many as 359 deaths per year in a city of 500,000 since the policy's introduction.^{39,40} The ban drove a rapid expansion in the consumption of natural gas for residential use (especially for home heating), as well as commercial and transportation use. By 2009, Dublin's air quality had improved dramatically according to the European Green City index that ranked Dublin 21 out of 30 leading European cities.⁴¹

Dublin initiated its air quality improvement efforts in 1990 with the prohibition of the sale, marketing, and distribution of bituminous coal, which was eventually extended to ban the home burning of bituminous coal altogether in 2012.⁴² These measures succeeded in significantly reducing benzene, carbon monoxide, SOx, and smog levels,⁴³ with particulate matter concentrations falling 80-90% from 1990 to 2014.⁴⁴

³⁸ Dublin City and South Dublin City/County Councils. "Dublin Regional Air Quality Management Plan: 2009-2012." 2009, p. 6, available at: http://www.dublincity.ie/sites/default/files/content/WaterWasteEnvironment/AirQualityMonitoringandNoiseControl/Documents/Dublin_Regional_Air_Quality_Management_Plan_2009_2012.pdf

³⁹ O. Kelly, "How the coal ban dealt with Dublin's burning issue." The Irish Times, September 26, 2015, available at: <http://www.irishtimes.com/news/environment/how-the-coal-ban-dealt-with-dublin-s-burning-issue-1.2367021>

⁴⁰ Dublin City and South Dublin City/County Councils. "Dublin Regional Air Quality Management Plan: 2009-2012." 2009, p. 5, available at: http://www.dublincity.ie/sites/default/files/content/WaterWasteEnvironment/AirQualityMonitoringandNoiseControl/Documents/Dublin_Regional_Air_Quality_Management_Plan_2009_2012.pdf

⁴¹ Siemens. "European Green City Index." 2009, p.10, available at: http://www.siemens.com/press/pool/de/events/corporate/2009-12-Cop15/European_Green_City_Index.pdf

⁴² Dublin City Council, "Fuel regulations." 2016, available at: <http://www.dublincity.ie/main-menu-services-water-waste-and-environment-air-quality-monitoring-and-noise-control-air/fuel>

⁴³ Dublin City and South Dublin City/County Councils. "Dublin Regional Air Quality Management Plan: 2009-2012." 2009, p. 5, available at: http://www.dublincity.ie/sites/default/files/content/WaterWasteEnvironment/AirQualityMonitoringandNoiseControl/Documents/Dublin_Regional_Air_Quality_Management_Plan_2009_2012.pdf

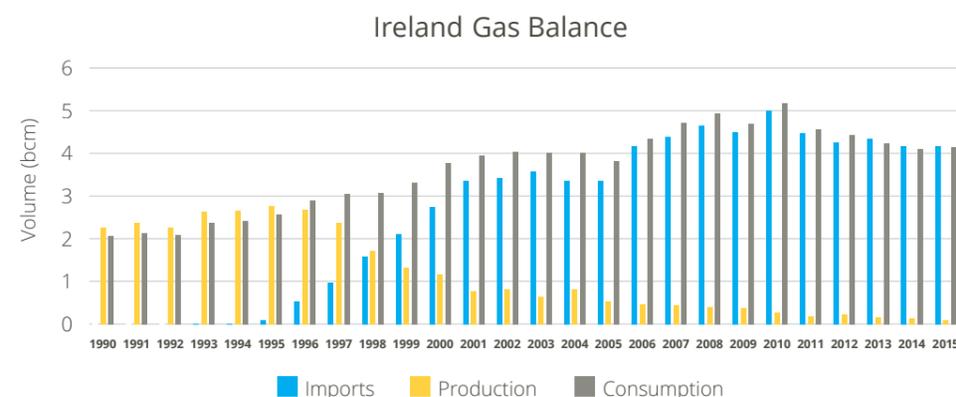
⁴⁴ J.A Kelly, "Solid fuel regulation: Residential smoky coal 1990-2013." 2013, available at: <http://www.policymeasures.com/measures/detail/solid-fuel-regulation/>
Ireland Environmental Protection Agency, "Environmental Indicators." 2014, available at: <http://www.epa.ie/irelandsenvironment/environmentalindicators/#air>

Dublin's success encouraged twenty-nine⁴⁵ other cities and towns to introduce similar legislation between 1990 and 2013, including a further tightening of the legislation banning the burning of bituminous coal.⁴⁶ Similar results throughout Ireland drove the government to issue a nationwide ban on bituminous coal burning in 2015, which is set to take effect in 2018. This expansion is expected to see monetary benefits reaching upwards of \$57 million per year.⁴⁷

Importantly, political opposition to the ban has been low, allowing for relatively smooth passage and implementation. The population has been largely supportive due to the noticeable improvements in air quality and health, while the lack of an established coal mining industry meant that there was no labor force to bear the brunt of curtailed coal demand.

Irish distributors and consumers are able to source increased supplies from British pipeline gas fed from the Scotland interconnector, which, in turn, is connected to Europe's most liquid gas market.⁴⁸ Looking ahead, domestic gas production from Shell's Corrib field, located off the north west coast of Ireland, is projected to meet between 40-60% of Ireland's annual gas demand after ramp-up.

Figure 3: Post-smoky Coal Ban Sees Greater Consumption, Import of Natural Gas



The sharp reduction in residential coal consumption driven by the Dublin coal ban, and its subsequent expansion into the surrounding counties of Ireland, has largely been backfilled with natural gas. Roughly 67% of households in Dublin now use natural gas, and gas now accounts for over 75% of energy demand in Dublin's residential sector,^{49,50} compared with 7% for oil and 0.4% for coal.

⁴⁵ Green Heat, "Smokeless zones." 2016, available at: <http://www.greenheat.ie/useful-information/smoky-coal-ban/>

⁴⁶ Prima. "Bituminous (smoky) coal ban." 2016, available at: <http://www.ecofuelbriquettes.com/articles/smoky-coal-ban>

⁴⁷ Department of Housing, Planning, Community and Local Government, "Smoky Coal Ban." 2016, available at: <http://www.housing.gov.ie/environment/air-quality/coal/smoky-coal-ban>

⁴⁸ In addition, the EU is supporting the costs of the Twinning of the Southwest Onshore Scotland pipeline which will increase Ireland's energy security.

⁴⁹ Dublin City Council, Codema, "Dublin City Sustainable Energy Action Plan 2010-2015." December 2010, p.12, available at: <http://www.dublincity.ie/sites/default/files/content/WaterWasteEnvironment/Sustainability/Documents/SEAP-FINAL%20version%20for%20website.pdf>, p.12

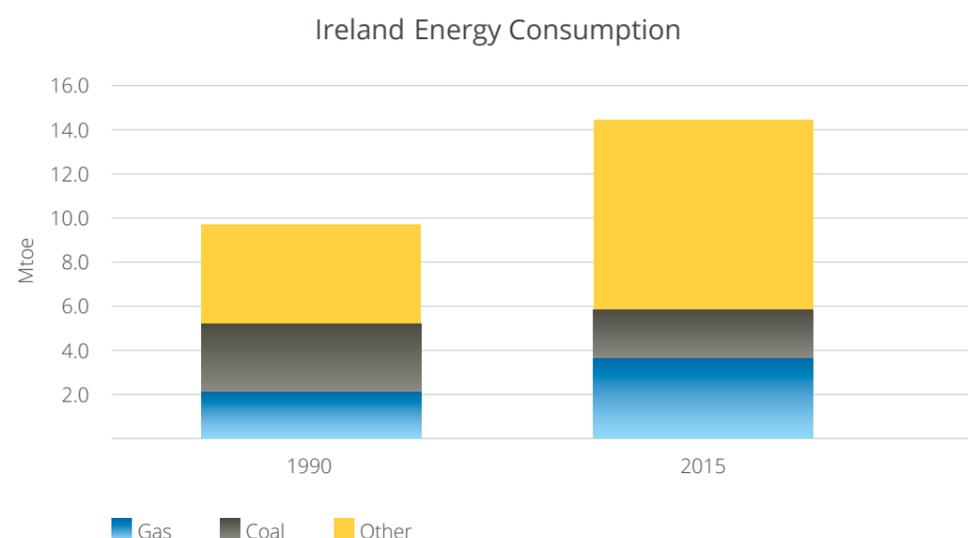
⁵⁰ Dublin City Council, Codema, "Dublin City Sustainable Energy Action Plan 2014." December 2013, p.14-15, available at: http://www.codema.ie/images/uploads/docs/Sustainable_Energy_Action_Plan_-_Monitoring_and_Progress_Report_2014.pdf



Across the rest of Ireland, oil has played a greater role, along with natural gas, in substituting coal. Oil accounts for 36% of residential fuel consumption nationwide, while gas only accounts for 20%.⁵¹ Liquid gas, peat, biomass, biofuel, kerosene and electricity account for the rest. Still, nationwide gas consumption doubled between 1990 and 2015, twice the rate of total energy consumption, while coal consumption declined by nearly 40% over the same period.⁵²

Although coal is still permitted for use in electricity generation, its share of the country's electricity portfolio has declined over the past decades to 21% as of October 2016, from 40.2% in 1990. This compares with 37.8% for gas and 34.6% for renewables for current consumption.⁵³ Between 2000 and 2012, solid fuel use (peat, lignite, anthracite and manufactured ovoids, bituminous coal) in residential fell by 23%, while natural gas usage increased by 37%, making it the most relied upon fuel in Ireland over this period.⁵⁴

Figure 4: Decline in Ireland's Coal Use



Source: Ireland's SEAI, The Rapidan Group

The smoky coal ban has yielded both air quality and public health benefits, but there is room for Ireland to build even further off of Dublin's momentum. Although overall Irish air pollution levels met limits set out by the Clean Air for Europe (CAFE) Directive in 2012,⁵⁵ the country was still exceeding the WHO's Air Quality Guidelines for PM and ozone.⁵⁶ In addition, the EU's mandated emissions ceilings for NOx were breached in 2013 due to rising traffic volumes, indicating officials will need to take further action to curtail NOx emissions. While natural gas use has plateaued since its peak in 2010, both in overall consumption and in residential use, it has strong potential to expand given the projected rise in electricity demand as well as gas' role as a backstop for renewable generation, which is projected to double from 7% of total energy demand in 2013 to 16% by 2020.

Dublin's success demonstrates that gas-for-coal substitution can be an effective way to improve air quality. The decrease in Dublin's concentrations of SOx has been directly linked to the enforcement of the smoky coal ban, the switch to natural gas for residential heating and the adoption of low-sulfur fuel oils.⁵⁷ Ireland's ability to substitute gas for coal was made easier because it benefited from gas supply security and from the lack of a large domestic coal industry that could have lobbied against the ban. The ability to similarly shift toward gas may be more challenging in other EU member-states (especially Poland, Germany, Czech Republic, Bulgaria), as coal is not only a leading baseload fuel in those countries, but its production is a source of employment and economic activity.

⁵¹ Sustainable Energy Authority of Ireland, "Energy in the Residential Sector 2013 Report." 2013, p.11, available at: http://www.seai.ie/Publications/Statistics_Publications/Energy-in-the-Residential-Sector/Energy-in-the-Residential-Sector-2013.pdf

⁵² BP, "BP Statistical Review of World Energy-2016 Full Report." 2016, available at: <https://www.bp.com/content/dam/bp/pdf/energy-economics/statistical-review-2016/bp-statistical-review-of-world-energy-2016-full-report.pdf>

⁵³ EirGrid Group, "How the Grid Works-System Information." October, 2016, available at: <http://www.eirgridgroup.com/how-the-grid-works/system-information/>

⁵⁴ North South Ministerial Council, "Residential Solid Fuel and Air Pollution Study." Issue 3, 2016, p. 70, available at: http://www.housing.gov.ie/sites/default/files/attachments/north-south_residential_solid_fuel_and_air_pollution_study_1.pdf

⁵⁵ According to Irish air data, 2014 saw values of SO₂, nitrogen dioxide (NO₂), carbon monoxide (CO), particulate matter (PM₁₀ and PM_{2.5}), heavy metals, benzene, and polycyclic aromatic hydrocarbons (PAH) <http://www.epa.ie/irelandsenvironment/air/>

⁵⁶ Ibid

⁵⁷ Dublin City and South Dublin City/County Councils. "Dublin Regional Air Quality Management Plan: 2009-2012." 2009, p.73, available at: http://www.dublincity.ie/sites/default/files/content/WaterWasteEnvironment/AirQualityMonitoringandNoiseControl/Documents/Dublin_Regional_Air_Quality_Management_Plan_2009_2012.pdf



KRAKOW: Gas Replaces Coal to Clean Up One of Europe's Most Polluted Cities



More than two decades after the demise of postwar socialist heavy industry, air pollution remains a very serious problem in Krakow, the second most populous city in Poland and home to more than 760,000 people.⁵⁸ The Malopolska province surrounding Krakow has about 3.4 million inhabitants.⁵⁹ A 2013 survey of air quality in 386 European cities by the European Environmental Agency found that Krakow had the third most polluted air (as measured by concentrations of particulate matter) within the European Union,⁶⁰ and was the most polluted city with a population of over 500,000.

Poor air quality in Krakow is predominantly a result of coal burning for residential heating.⁶¹ Today an estimated 30,000 coal-fired boilers and stoves remain in use in Krakow,⁶² and about 150,000 in the wider Malopolska region,⁶³ each burning cheap but heavily polluting domestic coal. Largely uncontrolled, residential coal burning contributes substantially to elevated concentrations of fine particulate matter (PM₁₀ and PM_{2.5}), NO_x, and highly carcinogenic benzo[a]pyrene (BaP) in particular.⁶⁴

PM₁₀ concentrations in Krakow exceeded EU safety limits on 188 of the 365 days in 2014,⁶⁵ and, at times, can reach six times the recommended maximum level.⁶⁶ Fine particulate emissions alone contribute to an estimated 45,000 premature deaths across Poland,⁶⁷ and a significant portion of these likely occur in and around Krakow, the country's most polluted area.⁶⁸

⁵⁸ Source: Statistical Office in Krakow, <http://krakow.stat.gov.pl/en/>

⁵⁹ Ibid.

⁶⁰ <http://www.nytimes.com/interactive/2013/10/15/business/international/europe-air-quality.html>

⁶¹ European Parliament (2016), Report by the Policy Department A: Economic and Scientific Policy, Implementation of the Ambient Air Quality Directive, p.38-40, [http://www.europarl.europa.eu/RegData/etudes/STUD/2016/578986/IPOL_STU\(2016\)578986_EN.pdf](http://www.europarl.europa.eu/RegData/etudes/STUD/2016/578986/IPOL_STU(2016)578986_EN.pdf)

⁶² Beth Gardiner (2015), "The air is stinking, it's dirty: the fight against pollution in Krakow," The Guardian, April 13, 2015, <https://www.theguardian.com/cities/2015/apr/13/air-dirty-fight-pollution-krakow-poland-ban-wood-coal>

⁶³ European Parliament (2016), p.50

⁶⁴ Krakow Smog Alert, "The Air in Krakow: problem, impacts, reasons, solutions," <http://bankwatch.org/documents/AirInKrakow.pdf>

⁶⁵ European Parliament (2016), p.87

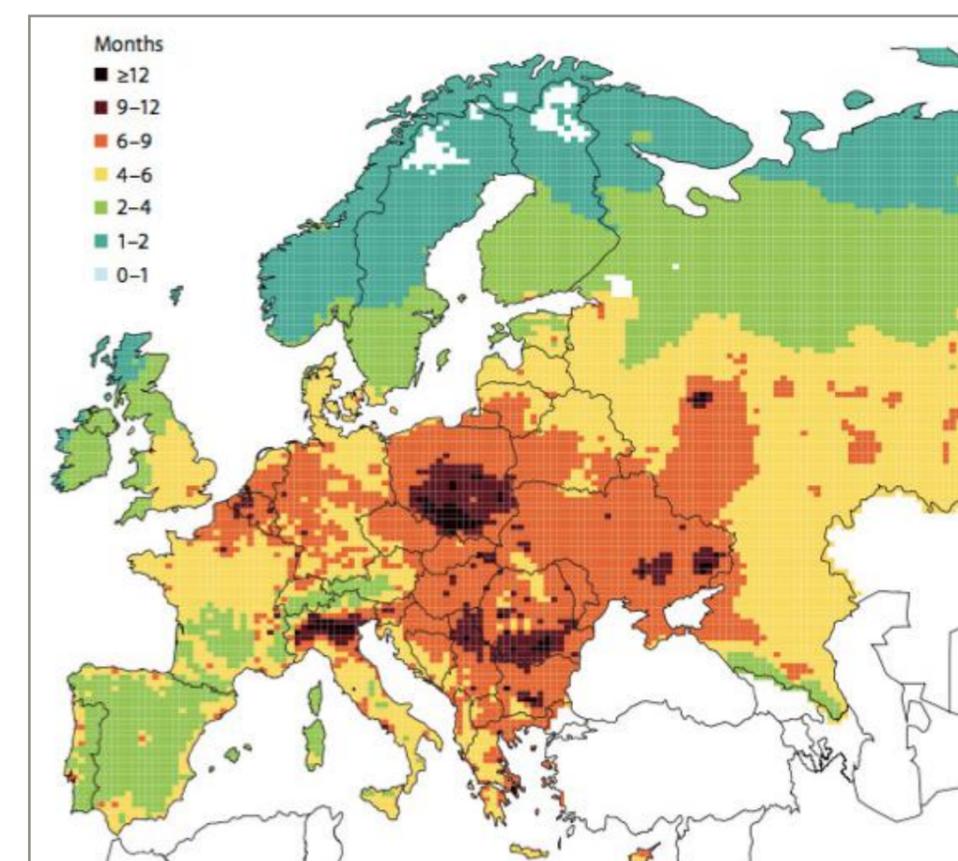
⁶⁶ Gardiner (2015)

⁶⁷ European Environmental Agency (2015), Air quality in Europe — 2015 report, p.44, http://www.eea.europa.eu/publications/air-quality-in-europe-2015/at_download/file

⁶⁸ UNECE (2016), Towards Cleaner Air – Scientific Assessment Report 2016: Summary for Policymakers, p.viii, https://www.unece.org/fileadmin/DAM/env/documents/2016/AIR/EB/CLRTAP_Policymakers_Summary_Report_v28-4-2016.pdf

Benzo(a)pyrene concentrations remain far higher in Krakow than in any other major European city,⁶⁹ at times exceeding eight times recommended limits.⁷⁰ Local activist group Krakow Smog Alarm compares the health impact of the city's BaP concentrations to smoking 2,500 cigarettes each year.⁷¹ Other health impacts associated with coal-related emissions include respiratory and cardiovascular diseases (such as chronic obstructive lung disease, asthma, heart attack or stroke), lung cancer, birth defects, irritation to the eyes and throat and nose bleeding, among many others.⁷²

Figure 5: Loss in life expectancy due to fine particulate emissions in Europe⁷³



⁶⁹ Krakow Smog Alert, "Air Pollution in Krakow," p.3, <http://bankwatch.org/documents/KrakowSmogAlert-timeline.pdf>

⁷⁰ Gardiner (2015)

⁷¹ Krakow Smog Alert, "The Air in Krakow: problem, impacts, reasons, solutions," p.3-4, <http://bankwatch.org/documents/AirInKrakow.pdf>

⁷² European Parliament (2016), p.17

⁷³ UNECE (2016), p.vi



Beyond the disastrous health consequences, Krakow's air quality problems can hurt the Polish economy in other ways. Poland already faces legal challenges – and potentially huge fines of up to PLN 4 billion (\$1 billion)⁷⁴ – for non-compliance with the European Union's ambient air quality standards across much of the country, including in the Krakow metropolitan area.⁷⁵ Air pollution in the wider region around Krakow is also a growing concern for the area's otherwise vibrant tourism industry.⁷⁶ Popular travel websites and forums now routinely warn prospective visitors about the health hazards associated with the dirty air in Krakow, especially during the winter months.⁷⁷

Local residents have been increasingly vocal about their discontent with their city's poor air quality, especially since 2012 when local campaign group Krakow Smog Alert was established.⁷⁸ Yielding to popular pressure – including numerous protests, petitions and a billboard campaign – local officials in Krakow approved a city-wide ban on coal and wood burning for home heating in 2013, the first of its kind in Poland.⁷⁹ The measure would have banned the installation of new solid fuel-fired stoves from 2014 and phased out existing units completely by 2018.⁸⁰ According to a poll conducted by CEM Market and Opinion Research, 85% of city residents supported the coal ban around the time of its adoption.⁸¹

However, in August 2014,⁸² a regional court declared Krakow's coal ban unconstitutional, and the subsequent legal battle left it in limbo for more than a year.⁸³ After further campaigning by local environmental groups in Krakow – and under growing pressure from the European Commission to comply with EU air quality rules – the Polish government eventually adopted an “anti-smog” law in 2015, which gave local authorities broad powers to regulate coal burning in the residential sector.⁸⁴

⁷⁴ <http://www.polskieradio.pl/13/273/Artykul/1556484,Polska-bedzie-sadzona-za-smog-Grozi-nam-nawet-4-mld-zl-kary>

<http://www.thenews.pl/1/9/Artykul/197135,Poland-with-most-polluted-air-in-EU>

⁷⁵ http://europa.eu/rapid/press-release_IP-15-6225_en.htm

⁷⁶ Jamie Stokes, “Krakow's Air Quality Among the Worst in the World,” Krakow Post, November 6, 2015, <http://www.krakowpost.com/6285/2015/11/krakows-air-quality-among-the-worst-in-the-world>

⁷⁷ See for example:

<https://www.lonelyplanet.com/thorntree/forums/europe-eastern-europe-the-caucasus/poland/warning-disastrous-air-pollution-levels-in-krakow>

https://www.tripadvisor.com/ShowTopic-g274723-i959-k8564620-Krakow_pollution-Poland.html

https://www.tripadvisor.com/ShowTopic-g274772-i961-k8983548-o10-Disastrous_air_pollution_levels_in_Krakow-Krakow_Lesser_Poland_Province_Southern_Poland.html

<http://www.fodors.com/community/europe/krakow-europes-3rd-most-polluted-city-in-europe.cfm>

<http://www.expat.com/forum/viewtopic.php?id=608047>

⁷⁸ Krakow Smog Alert, “Air Pollution in Krakow,” p.4, <http://bankwatch.org/documents/KrakowSmogAlert-timeline.pdf>

⁷⁹ Agnieszka Barteczko (2013), “Poland's Krakow bans coal burning to heat homes,” Reuters, November 26, 2013, <http://www.reuters.com/article/us-poland-environment-idUSBRE9AP0X120131126>

⁸⁰ Jan Cienski, “Krakow: enough of the coal,” Financial Times, November 27, 2013, <http://blogs.ft.com/beyond-brics/2013/11/27/krakow-enough-of-the-coal/>

⁸¹ Krakow Smog Alert, “Air Pollution in Krakow,” p.9, <http://bankwatch.org/documents/KrakowSmogAlert-timeline.pdf>

<http://bankwatch.org/documents/KrakowSmogAlert-timeline.pdf>

⁸² <http://inside-poland.com/t/court-overturms-out-smog-busting-coal-ban-in-krakow-poland/>

⁸³ Soraya Sarhaddi Nelson, “Plagued By Smog, Krakow Struggles To Break Its Coal-Burning Habit,” NPR, April 11, 2015, <http://www.npr.org/sections/parallels/2015/04/11/394878756/plagued-by-smog-krakow-struggles-to-break-its-coal-burning-habit>

⁸⁴ <http://www.thenews.pl/1/9/Artykul/223780,Polish-president-signs-antismog-law>

The Krakow city council moved swiftly, and in January 2016, it reintroduced the city-wide coal ban with an updated deadline of 2019 to completely phase out coal stoves from home heating.⁸⁵ Greenpeace called Krakow's now legally-binding coal ban a “big deal” immediately after the approval of the measure.⁸⁶

But without financial support, replacing coal-fired stoves with gas-fired ones would be costly for most households and for some, prohibitively so. Early-critics of the Krakow coal ban liked to point out that the measure would disproportionately hurt the poorest residents in the city,⁸⁷ who are more likely to use coal for home heating than wealthier citizens. Recognizing the challenges associated with financing and energy poverty, Krakow offers a number of grants and other financial incentives to reimburse up to the full cost of replacing coal-fired boilers.⁸⁸ The city also offers targeted subsidies to protect its poorest residents from the increased heating bills following the switch to cleaner fuels,⁸⁹ particularly to natural gas. The city draws on both regional and EU structural funds to support its air quality and energy poverty alleviation programs.⁹⁰

In addition to banning residential coal burning and mandating the replacement of coal-fired stoves, Krakow's air pollution reduction program also aims to expand the city's gas distribution network, modernize its district heating system and promote renewable energy sources for domestic heating, among other measures.⁹¹ These – taken together – can eliminate a substantial portion of the city's harmful emissions by the time they are fully implemented towards the end of the decade.⁹²

Krakow's case also shows that targeted measures, such as fuel subsidies and grants for poor households, can go a long way to address some of the concerns with increased natural gas use, particularly those related to higher heating bills and the high upfront cost of switching to cleaner fuels. Sustained lower natural gas prices, greater infrastructure robustness, and the abundance of flexible LNG supplies in the global gas market should also help reduce the cost of switching from coal to gas in residential heating.

⁸⁵ <http://www.krakowskialarmsmogowy.pl/en/aktualnosci/szczegoly/id/261>

⁸⁶ Krystina Shveda, “Poland air pollution: Why Krakow's domestic coal ban is a big deal,” Greenpeace Energy Desk, January 21, 2016, <http://energydesk.greenpeace.org/2016/01/21/poland-air-pollution-krakow-coal-ban/>

⁸⁷ Barteczko (2013)

⁸⁸ Gardiner (2015)

⁸⁹ <http://www.krakowskialarmsmogowy.pl/en/onas/index/id/149>

⁹⁰ Gardiner (2015) and Krakow Smog Alert, “Air Pollution in Krakow,” p.9, <http://bankwatch.org/documents/KrakowSmogAlert-timeline.pdf>

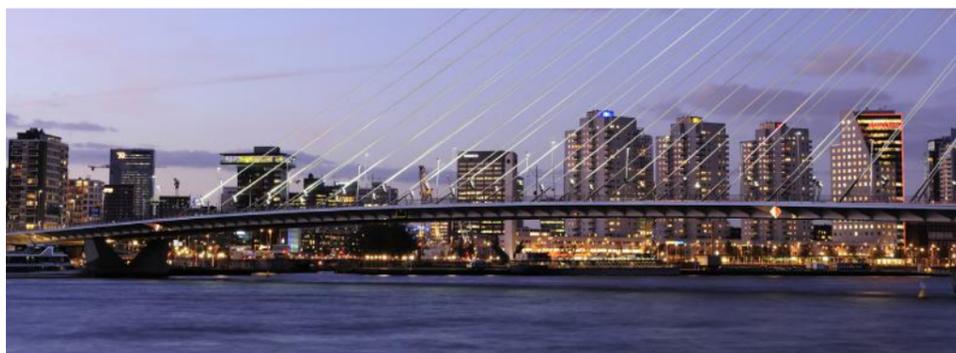
⁹¹ European Parliament (2016), p.48

⁹² Ibid.

⁹³ Ladka Mortkowitz Bauerova and Maciej Martewicz, “As Europe Drops Coal, Poland Embraces It,” Bloomberg, June 24, 2016, <http://www.bloomberg.com/news/articles/2016-06-24/as-europe-drops-coal-poland-embraces-it>



ROTTERDAM: A Hub for LNG-Fueled Transportation



Despite being the second-largest city in one of Europe's most prosperous countries, Rotterdam is still coping with serious environmental challenges. In 2014, the lifespan of a Rotterdam resident was three years shorter than the average Dutch citizen due to the high levels of air pollution.⁹⁴ Breathing the air of Rotterdam is the equivalent of second-hand smoking 6 cigarettes a day.⁹⁵ Although air quality improved between 2004 and 2013, with the concentration of NOx in the air dropping 13%,⁹⁶ Rotterdam's NOx emissions have reportedly increased again and are exceeding EU standards.⁹⁷ The Port of Rotterdam is ground zero for the city's struggle against pollution, and is implementing initiatives to improve citywide and regional air quality by lowering emissions through the expanded use of LNG as a fuel for seagoing and inland waterway vessels.⁹⁸ LNG emits less PM, SOx, NOx and CO₂ than traditional bunker fuels, such as heavy fuel oil, marine gasoil or diesel fuel. The pioneering role that the Port is playing in supporting the use of LNG as a fuel will contribute to reduced air pollution in Rotterdam and the surrounding areas.

The Rotterdam Climate Initiative (RCI), which was introduced in 2010, aims to improve air quality in the port, the city and the surrounding industrial areas.⁹⁹ As a port city, many of Rotterdam's air pollution challenges stem from port operations, port-related traffic and nearby industrial facilities.¹⁰⁰ The industrial sector (which is heavily concentrated around the port area and responsible for 85% of Rotterdam's greenhouse gas emissions) has played a leading role in advancing the climate initiative. The widespread adoption of LNG in the port is one of the initiative's key pillars.¹⁰¹

⁹⁴ Dutch Daily News, "Rotterdam to tackle air pollution, ban old cars from city centre." Nov 28, 2014, available at: <http://www.dutchnews.nl/news/archives/2014/11/rotterdam-to-tackle-air-pollution-ban-old-cars-from-city-centre/>

⁹⁵ J. Pieters, "Amsterdam air pollution equal to smoking 6 cigarettes per day: Environmental group." August 17, 2016, NL Times, available at: <http://nltimes.nl/2016/08/17/amsterdam-air-pollution-equal-smoking-6-cigarettes-per-day-environmental-group>

⁹⁶ Port of Rotterdam, "Port Vision 2030-Progress Report 2014." 2015, p. 21, available at: <https://www.portofrotterdam.com/en/the-port/port-vision-203>

⁹⁷ Dutch Daily News, "Dutch air quality breaks EU standards in some cities." May 11, 2016, available at: <http://www.dutchnews.nl/news/archives/2016/05/dutch-air-quality-breaks-eu-standards-in-some-cities/>

⁹⁸ The port of Rotterdam is the largest in Europe, with annual throughput of an estimated 465 million tons (mt). It covers an area equal to 12,500 hectares of land and water, with a port area of more than 40 km. Each year an estimated 30,000 seagoing vessels and 110,000 inland vessels stop at the port.

⁹⁹ Rotterdam Climate Initiative, 2016, available at: <http://www.rotterdamclimateinitiative.nl/UK>

¹⁰⁰ P. Fenton, Shipping in a Changing Climate, June 2014, p. 18-19, available at: https://www.researchgate.net/publication/272356497_The_role_of_port_cities_and_networks_reflections_on_the_World_Ports_Climate_Initiative

¹⁰¹ Rotterdam Climate Initiative, "LNG in the port." 2010-2016, available at: http://www.rotterdamclimateinitiative.nl/uk/port/ongoing-projects/lng-in-the-port?project_id=223&p=1

Switching to LNG in the port can reduce NOx emissions by up to 90% and SOx and PM emissions by up to 100%.¹⁰² LNG's lower carbon content can also help reduce emissions by up to 20% when it replaces heavy fuel oil.¹⁰³

Because LNG is considered a cleaner alternative propulsion fuel, the European Union is strongly supporting LNG refueling points at maritime and inland ports.¹⁰⁴ With this policy support in place, marine LNG consumption can be expected to spread in the future, both for EU internal waterways and the high seas.

In addition, the International Maritime Organization decided in October 2016 to reduce the permitted sulfur content in marine fuels from 3.5% to 0.5% for all vessels operating outside the designated Emission Control Areas (ECAs) starting on January 1, 2020.¹⁰⁵ Although LNG adoption has been largely limited to inland vessels thus far, port operators report significant interest among ship owners in switching to LNG bunker fuel, especially for new build vessels.¹⁰⁶

Offering LNG bunker fuel is increasingly a source of competitive advantage for ports like Rotterdam.¹⁰⁷ LNG-propelled vessels are already compliant with the stricter emissions standards that have been in place in the English Channel, Baltic and the North Sea since 2015, and will also meet the more stringent sulfur requirements post-2020.

Rotterdam started LNG bunkering operations in August 2016 and is planning to have three LNG fueling berths installed by the end of 2016. In addition, Shell will supply Rotterdam with an LNG bunkering vessel in 2017.¹⁰⁸ Meanwhile, there are already four inland vessels in Rotterdam that are using LNG as a fuel.

In addition to growing its LNG bunkering capabilities, the port has incorporated LNG truck loading facilities that will boost its ability to supply smaller quantities of LNG to both Rotterdam and landlocked cities across the Netherlands, facilitating emission reductions in road transportation. In January 2016, the Gate regasification terminal loaded its thousandth truck with LNG, continuing the steady increase of road-transported LNG after loading 174 trucks in 2014 and 788 trucks in 2015. A second loading platform is currently under construction.¹⁰⁹

¹⁰² World Ports Climate Initiative, "LNG fueled vessels." 2016, available at: <http://www.lngbunkering.org/lng/environment/benefits-of-LNG>

¹⁰³ Ibid

¹⁰⁴ https://ec.europa.eu/energy/sites/ener/files/documents/1_EN_ACT_part1_v10-1.pdf p3, p.11

¹⁰⁵ Ship & Bunker World News, "Update: IMO: .5% global sulfur cap to take effect from 2020." October 27, 2016, available at: <http://shipandbunker.com/news/world/601087-update-imo-05-global-sulfur-cap-to-take-effect-from-2020>

¹⁰⁶ Columbia University, "Sulfur Regulations on the High Seas: The Challenges and Implications of the IMO's Forthcoming Emissions Limits." 2016, Center on Global Energy Policy, p. 6, available at: <http://energypolicy.columbia.edu/sites/default/files/energy/Columbia%20Global%20Energy%20Dialogue%20Report-Sulfur%20Regulations%20on%20the%20High%20Seas.pdf>

¹⁰⁷ Another European initiative called GAINN4MOS aims to improve sustainable operations for ports and shipping through LNG.

¹⁰⁸ Hellenic Shipping News, "Rotterdam: The Port Authority signs international LNG agreement." October 10, 2016, available at: <http://www.hellenicshippingnews.com/rotterdam-the-port-authority-signs-international-lng-agreements/>

¹⁰⁹ Port of Rotterdam, "Thousandth LNG truck load at Gate terminal." January 2016, available at: <https://www.portofrotterdam.com/en/news-and-press-releases/thousandth-lng-truck-load-at-gate-terminal>



The port of Rotterdam's efforts in curbing air pollution around the port and city have demonstrated that this can be done without negatively impacting economic growth and the port's international attractiveness. Despite a steep increase in maritime traffic between 2005 and 2015, GHG emission levels in the port of Rotterdam stayed flat,¹¹⁰ with associated drops in NOx (13% reduction), SOx (55% reduction), and PM (27% reduction) concentrations between 2004 and 2012.¹¹¹ This air quality improvement is mostly due the port's clean air action program which started in 2006. Key measures include setting ultra-low sulfur caps for inland shipping, giving economic incentives to green vessels such as discount on port dues, and providing onshore power supply rather than using the vessels' diesel generators.¹¹² More widespread use of LNG in and around the port of Rotterdam will further improve local air quality in the area, and demonstrate that major port cities can become more sustainable without losing business.

Conclusion

Addressing urban air pollution is one of the most important environmental/health challenges the world currently faces. With a growing global urban population, particularly in middle-income and developing countries, the challenge of addressing this air pollution problem will only increase.

Many of the policies that can address urban air pollution also reduce GHG emissions (and vice-versa). Recognizing the connections between the health-damaging pollutants and climate damaging pollutants can help maximize the benefits and efficiency of policy actions.

The city case studies examined in this paper demonstrate that tackling air pollution does not have to mean sacrificing economic growth and the expansion of energy services. Berlin, Dublin, Krakow and Rotterdam each faced and still face different pollution challenges. Each city has done or is looking to enact a comprehensive set of policies – including promoting fuel switching – to make real progress in reducing the air pollution burden without harming economic growth. The examples of Berlin, Dublin and Krakow demonstrate the significant improvement of urban air quality thanks to the reduction and full replacement of heavy-polluting coal with cleaner burning natural gas for power generation and heating.

The use of natural gas as a fuel for both road and marine transport pioneered in Berlin and Rotterdam shows that the positive impact of natural gas goes well beyond the more well-known use as a fuel in power and heat generation.

Continuing to examine and monitor the impact of policies in these cities can help define a path for other developing and developed cities and countries to meet their air quality and climate goals.

¹¹⁰ Port of Rotterdam, "Port Vision 2030-Progress Report 2014." 2015, p. 21, available at: <https://www.portofrotterdam.com/en/the-port/port-vision-2030>

¹¹¹ Ibid

¹¹² P. Maurits, "Reducing air emissions in the Port of Rotterdam (PoR)." December 2012, p. 7-9, available at: <http://www.theicct.org/sites/default/files/Maurits%20Prinssen.pdf> p7-8-9

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