# Biomass Stack Emission Estimates for Drax power plants in the UK 2013-2017

Prepared For:

**Southern Environmental Law Center**
Attn.: David Carr
201 W. Main Street, Suite 14
Charlottesville, VA 22902-5065
Phone: 434-977-4090
Fax: 434-977-1483

Prepared by:

**Dr. Thomas Buchholz and Dr. John Gunn on behalf of:**

**Spatial Informatics Group, LLC**
3248 Northampton Ct.
Pleasanton, CA 94588 USA

*Project Administration*
Thomas Buchholz, Ph.D.
Email: tbuchholz@sig-gis.com
Phone: (802) 881-5590

**Date: March 1st 2017**

# CONTENTS

# INTRODUCTION

## BACKGROUND

The potential greenhouse gas (GHG) benefits of displacing fossil energy with biofuels are driving policy development in the absence of complete information. Getting the accounting correct is particularly important given the recent heavy emphasis on use of biomass energy to meet national and regional emissions reduction goals. For example, by 2020, between 8% and 11% of the UK's primary energy supply should be from biomass (UK DOT, 2012; see Beurskens & Hekkenberg, 2011 for renewable energy projections of other EU states). This goal was set with the assumption in mind that biomass is a low-carbon supply of energy.

UK policies have been instrumental in directing electricity providers to look for sufficient, reliable, and cost-competitive biomass across the globe. Drax is one of the UK's largest electricity production companies and sources large amounts of biomass from the southeastern US.

Drax operates six power plant units originally designed to run on 100 % coal at a capacity of around 660 MW each (Drax 2016). Starting in 2013 and finalized in December 2016 (Bioenergy Insight 2016a), Drax converted three units to 100% biomass. The Southeastern US has become a major provider of forest-derived biomass for the UK market, particularly in the form of wood pellets and supplied over 50% of Drax sourced biomass in 2013 and 2014 (Drax 2015).

Research suggests that the climate impact of biomass feedstocks is heavily dependent on the sourcing of the biomass. While there is widespread agreement that some biomass such as sawdust is climate-beneficial, other forms of biomass can be a greater challenge to account for in terms of their climate impact and supplying them in a climate-beneficial manner (Buchholz and Gunn 2015).

## OBJECTIVE

The objective of this report is to understand the development of Drax electricity production as well as stack emissions from 2013 (when the first unit was converted from coal to biomass) to the present, as well as projected emissions for 2017. This is a crucial first step in determining overall carbon dioxide ($CO_2$) emissions from both coal and biomass towards a full climate accounting of Drax.

## RESULTS

### TOTAL DRAX ELECTRICTY PRODUCTION

Estimated 2016 annual stack emissions of $CO_2$ from the three units that Drax has converted to biomass were 11.4 million metric tonnes (MT) $CO_2$ (Figure 1). Drax reported a total of 12.7 TWh of electricity from biomass during 2016 (Drax 2017), i.e. producing stack emissions of 0.897 MT $CO_2/MWh_{electric}$ (Table 2). This is a 2% increase in stack emissions compared to a scenario where the three units would have produced the same amount of electricity from coal with associated stack emissions of 11.1 million MT $CO_2$.

We estimate that from 2013, when Drax converted its first unit, up to the end of 2016, Drax's $CO_2$ stack emissions from biomass were around 31.3 million MT $CO_2$. Projecting out to 2017, this number increases to 43.3 million MT $CO_2$ (Figure 2).

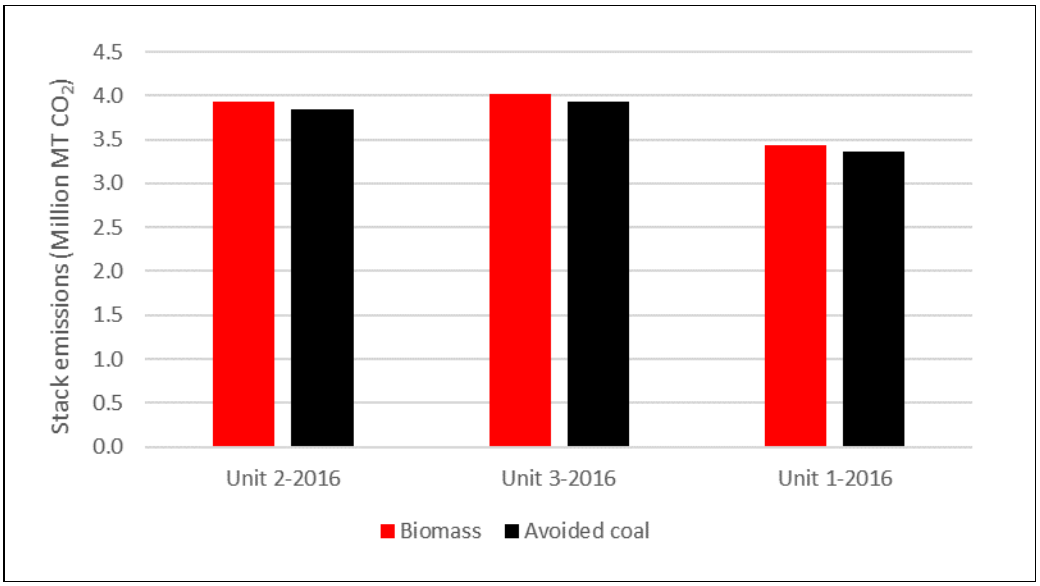


**Figure 1: 2016 biomass stack emissions for Drax biomass units. The avoided coal emissions assume an identical production of electricity when generated through the previously installed coal technology.**

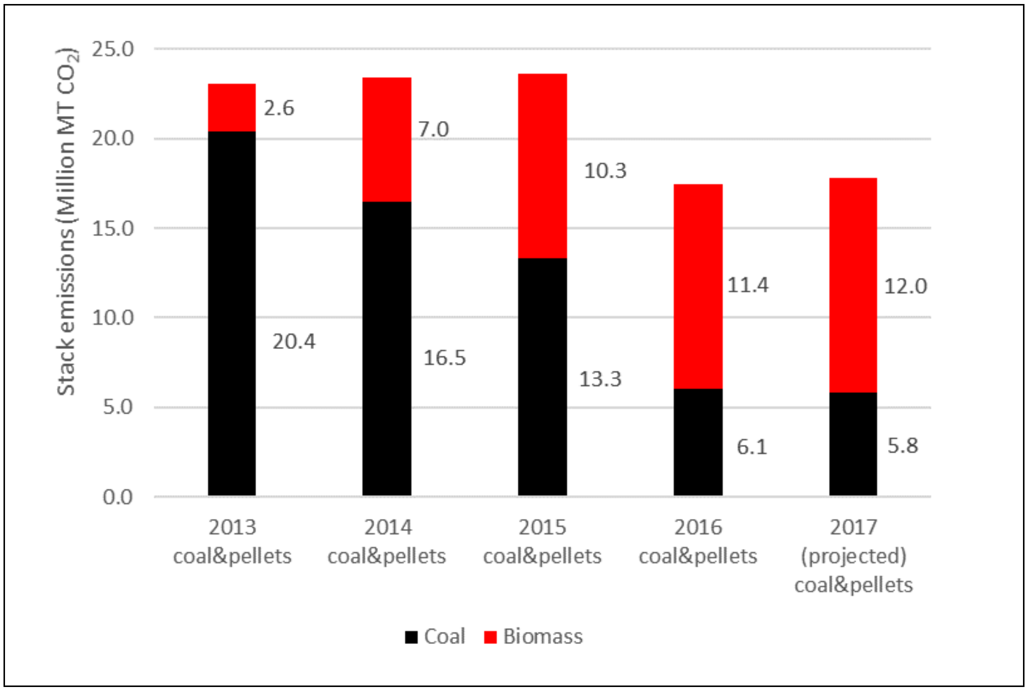


**Figure 2: Drax stack emissions 2013 to the end of 2017 (projected).**

## TOTAL DRAX ELECTRICTY PRODUCTION

We estimate that annual electricity production by Drax varied from 19.6 TWh (2016) to 26.7 TWh (2015; Figure 3). The percentage of biomass-derived electricity grew from 11% in 2013 to a projected 67% in 2017. We estimate a slight increase in 2017 electricity production compared to 2016 since more capacity is available for biomass power.

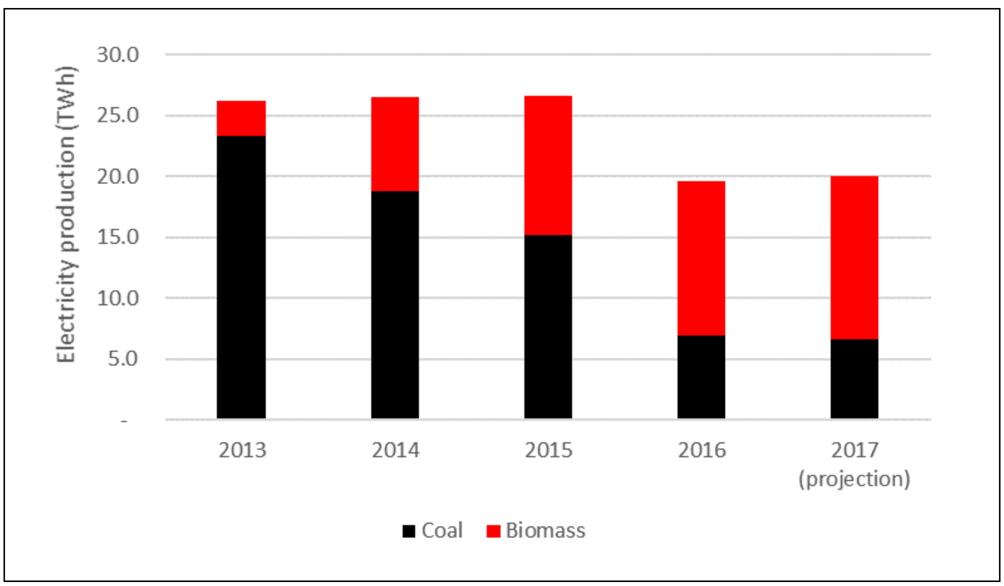


**Figure 3: Drax electricity production 2013 to the end of 2017 (projection).**

## TOTAL DRAX STACK EMISSIONS FROM COAL AND BIOMASS COMBUSTION

Drax stack emissions varied from an estimated 17.7 (2016) to 23.6 (2015) million MT $CO_2$ per calendar year (Figure 4). Biomass-related stack emissions accounted for 11% (2013) to 67% (projected for 2017). Compared to a scenario where no units would have been converted to biomass, Drax stack emissions were slightly higher over the time period analyzed. While biomass pellets in general produce more $CO_2$ emissions than coal for the same calorific quantity, the increased efficiency for biomass (38.6%; EC 2016) vs coal (35.9%; DUKES 2015) provide a counterbalance; resulting in Drax specific stack emission estimates of 0.877 and 0.897 MT $CO_2/MWh_{electric}$ for coal and biomass pellets, respectively.

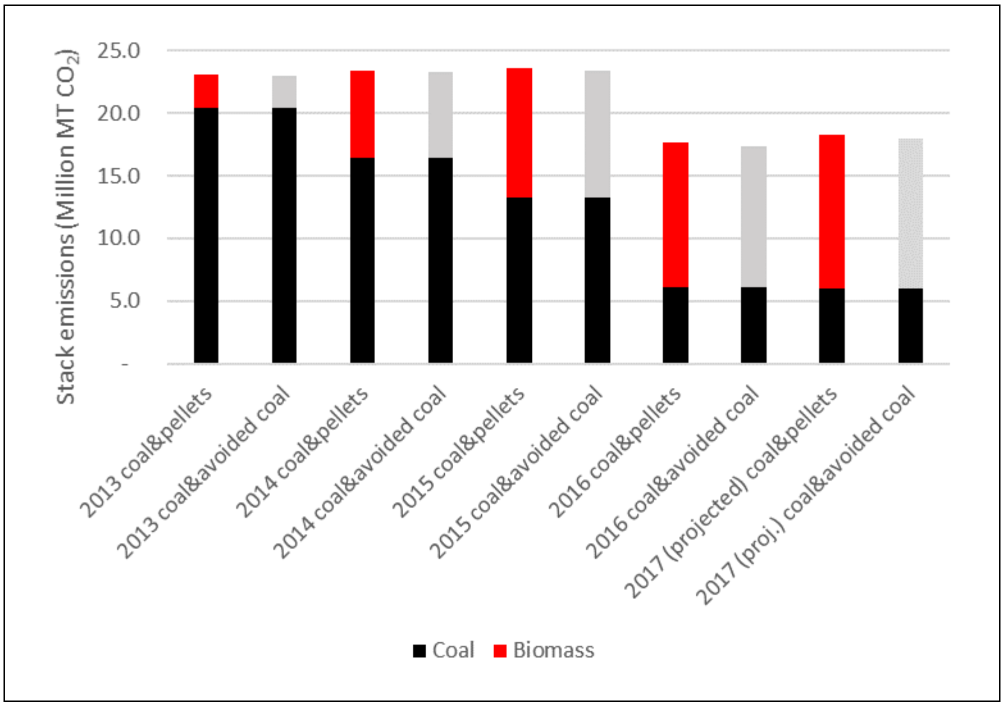


**Figure 4: Drax stack emissions 2013 to the end of 2017 (projected) including avoided coal emissions.**

## DRAX OVERALL $CO_2$ EMISSIONS FROM COAL AND BIOMASS COMBUSTION

To achieve real climate benefits from converting coal-fired electricity units to biomass pellets, it is essential to account for the full life cycle emissions of both coal and biomass pellets. A full life cycle assessment has to also account for fossil fuel emissions originating in the sourcing of the feedstock as well as, in the case of biomass, changes to the landscape carbon stocks from where the biomass is sourced. Biomass pellets from the southeastern US constituted over 50 % of Drax' total pellet supply in 2013 and 2014 (Drax 2015a) and around 69% or 4.6 million MT pellets in 2016 (Bioenergy Insight 2016b). Pellet production from Drax's own production constituted a fraction of this supply, i.e. 5% and 9% of annual demand in 2015 and 2016, respectively (Drax 2017). We estimate that Drax will require a total of 7.0 million MT pellets in 2017. Drax is aiming for a 20-30% self-supply of pellets and is actively expanding its US production capacity (e.g. Enviva 2017).

From January 1st 2013 to the end of 2017 (projected) and based on the estimates and results outlined above, coal related stack emissions at Drax will total for 62.3 million MT $CO_2$. 42.8 million MT $CO_2$ in coal-related stack emissions will be avoided by the end of 2017 due to the biomass conversion. In order to compare those avoided coal stack emissions to the new reality of biomass combustion, there is no full life cycle accounting study available using a Drax specific biomass sourcing portfolio.

The UK Solid and Gaseous Biomass Carbon Calculator (OFGEM 2015) calculator seeks to provide guidance in estimating life cycle emissions for a variety of fuels. However, this tool is not built to provide a full emission life cycle assessment, as it ignores changes in the landscape carbon stock in the case of biomass fuels. Instead, OFGEM assumes emissions neutrality for biogenic emissions per se.

However, previous studies (Buchholz and Gunn 2015; referred to as '2015 SIG report')[1] suggest that the fraction of biomass pellets of around 50% of total supply and sourced from the Southeastern US in 2013 and 2014 (and assuming a similar ratio in 2015), were responsible for emissions between 9.3 and 20.2 million MT $CO_2$ during the same time frame. This 2015 SIG report used an unaltered version of the Biomass Emissions And Counterfactual (BEAC) tool, a UK government-endorsed emission estimate tool that accounts for the full life cycle emissions of biomass fuels. The results of this lifecycle analysis which did consider carbon stock changes showed, that Drax, using Enviva pellets, would result in 2,677 kg $CO_2$e/MWh over 40 years and 3,478 kg$CO_2$e/MWh over 100 years, compared to 1,018 kg$CO_2$e/MWh for coal (BEAC 2015).

In order to get a true picture of Drax's and others carbon emissions, a full life cycle assessment including landscape carbon stocks (i.e. biogenic emissions) should be performed similar to the approach applied by the BEAC model.

---

[1] Using the Biomass Emissions And Counterfactual (BEAC) tool, a UK government-endorsed emission estimate tool that account for the full life cycle emissions of biomass fuels.

# METHODS

## SOURCES

To compute the Drax electricity production and CO2 stack emissions of coal and biomass combustion, we relied on official documents from Drax (Drax 2016, Drax 2015a,b,c,d), the European Commission (EC 2016), the UK government (Biomass Energy Centre 2016, BEAC 2015, DECC 2015, DUKES 2015), as well as Process Engineering UK (2014). Where possible, input data as well as output data were validated with additional sources.

## ANALYTICAL APPROACH

Table 1 to Table 4 provide an overview on the data input, relevant intermediate calculation results, as well as sources for all relevant calculations. Based on these inputs, we were able to estimate load factors for the biomass electricity plants to calculate overall stack emissions (Table 5).

**Table 1: Coal relevant data and assumptions.**

| Item | Unit | Measure | Comment | Source |
|---|---|---|---|---|
| **Coal** | | | | |
| **Calorific value coal (HHV)** | GJ/MT | 25.7 | | DECC 2015 |
| **$CO_2$ emissions** | MT/MT coal | 2.25 | | DECC 2015 |
| **Coal plant efficiency (HHV)** | % | 35.85% | 2013-14 average | DUKES 2015 |
| **Coal stack emissions** | MT $CO_2/MWh_{electric}$ | 0.877 | | Calculation output |

**Table 2: Pellet relevant data and assumptions.**

| Pellet data | Unit | Measure | Comment | Source |
|---|---|---|---|---|
| **Wood pellet emissions** | | | | |
| **Net Calorific Value (LHV)** | MWh/MT | 4.9 | 7% moisture | BEAC 2015 |
| **Net Calorific Value (LHV)** | GJ/MT | 17.7 | | Calculation output |
| **Calorific value pellets (HHV)** | MWh/MT | 5.3 | | BEAC 2015 |
| **Calorific value pellets (HHV)** | GJ/MT | 19.2 | | Calculation output |
| **Elec. conv. 100% pellet** | % | 38.6% | only for Unit 1 mentioned | EC 2016 |
| **Pellet consumption per MWh, 100% pellets** | MT/MWh | 0.53 | | Calculation output |
| **Elec. conv. 85% pellet** | % | 38.6% | Based on 100% pellet firing efficiency; pot. lower | N/A |
| **Pellet consumption per MWh, 85% pellets** | MT/MWh | 0.53 | | Calculation output |
| **C content pellets @ 10 % moisture** | % | 45% | | Biomass Energy Centre 2016 |
| **C content pellets @ 7 % moisture** | % | 46% | | Calculation output |
| **Stack emissions (100% pellets)** | MT $CO_2/Mwh_{electric}$ | 0.897 | | Calculation output |
| **Stack emissions (85% pellets)** | MT $CO_2/Mwh_{electric}$ | 0.897 | | Calculation output |

**Table 3: Drax specific data and assumptions – unit conversions.**

| Drax data | Unit | Measure | Comment | Source |
|---|---|---|---|---|
| **Internal elec. demand** | % of capacity | 10% | | SIG estimate |
| **Unit 2** | | | First unit converted | |
| **Start date** | Date | Apr-13 | No day specified, assume 15th of month | Drax 2015d |
| **Capacity** | $MW_{electric}$ | 630 | '[...] currently operating at a capacity of 630MW.'; could be up to 645 | Process Engineering 2014 |
| **% biomass** | % | 100% | | Process Engineering 2014 |
| **Unit 3 – co-firing** | | | Second unit converted | N/A |
| **Start date** | Date | May-14 | No day specified, assume 15th of month | Process Engineering 2014 |
| **Capacity (Biomass only)** | $MW_{electric}$ | 548 | | N/A |
| **% biomass** | % | 85% | | Process Engineering 2014 |
| **Unit 3 - 100% biomass** | | | | N/A |
| **Start date** | Date | Oct-14 | No day specified, assume 15th of month | Drax 2015d |
| **Capacity** | $MW_{electric}$ | 645 | Assume same as Unit 1 | N/A |
| **% biomass** | % | 100% | | Drax 2015c |
| **Unit 1 – cofiring** | | | | |
| **Start date** | Date | Jul-15 | | Argus Media 2015 |
| **Capacity** | $MW_{electric}$ | 645 | | EC 2016 |
| **% biomass** | % | 85% | | Canadian Biomass 2015 |
| **Net load factor** | % | 70.5% | | EC 2016 |
| **Efficiency (LHV)** | | 38.6% | | EC 2016 |
| **Unit 1 – 100% biomass** | | | | |
| **Start date** | Date | Dec-16 | | Drax 2017 |
| **Capacity** | $MW_{electric}$ | 645 | | EC 2016 |
| **% biomass** | % | 100% | | EC 2016 |
| **Net load factor** | % | 70.5% | | EC 2016 |
| **Efficiency (LHV)** | | 38.6% | | EC 2016 |

**Table 4: Drax specific data and assumptions – electricity production.**

| Drax data | Unit | Measure | Comment | Source |
|---|---|---|---|---|
| **Electric output from biomass** | | | | N/A |
| **1st half 2014** | TWh | 3.0 | | Drax 2015d |
| **1st half 2015** | TWh | 5.2 | | Drax 2015d |
| **2015** | TWh | 11.5 | | Drax 2017 |
| **2016** | TWh | 12.7 | | Drax 2017 |
| **2017** | TWh | 13.4 | Calculated | |
| **Pellet consumption** | | | | N/A |
| **2013** | Million MT | 1.6 | | Drax 2015c |
| **2014** | Million MT | 4.1 | | Drax 2015c |
| **Annual, Unit 1** | Million MT | 2.40 | | EC 2016 |
| **2015** | Million MT | 6.1 | Calculated | |
| **2016** | Million MT | 6.7 | Calculated | |
| **2017** | Million MT | 7.0 | Calculated | |
| **Elec. prod. from coal** | | | | N/A |
| **2013** | TWh | 23.3 | | Drax 2015c |
| **2014** | TWh | 18.8 | | Drax 2015c |
| **2015** | TWh | 15.2 | | Drax 2017 |
| **2016** | TWh | 6.9 | | Drax 2017 |
| **2017** | TWh | 6.6 | Calculated | |

**Table 5: Drax net load estimates for total biomass-fired capacity.**

| Combined bioenergy capacity | Year | Load factor |
|---|---|---|
| **System net load** | 2013 | 65% |
| **System net load** | 2014 | 79% |
| **System net load** | 2015 | 77% |
| **System net load** | 2016 | 71% |
| **System net load** | 2017 | 71% |

## REFERENCES


Argus Media 2015. Drax co-fires 85pc at Selby unit 1. http://www.argusmedia.com/pages/NewsBody.aspx?id=1077758&menu=yes [Last accessed on February 24 2017]

BEAC 2015. BEAC (Biomass Emissions And Counterfactual) Model Version BEAC2015. https://www.gov.uk/government/.../beac_2015.xlsm [Last accessed on February 10 2016]

Beurskens LWM, Hekkenberg M 2011. Renewable Energy Projections as Published in the National Renewable Energy Action Plans of the European Member States Covering all 27 EU Member States. ECN-E–10-069, European Environment Agency, Kopenhagen, Denmark, 244p.

Bioenergy Insight 2016a. 2017 outlook: Out of the woods? http://www.bioenergy-news.com/display_news/11736/2017_outlook_out_of_the_woods/ [Last accessed on February 2 2017]

Bioenergy Insight 2016b. EIA releases new monthly report on US wood pellet production. http://www.bioenergy-news.com/display_news/11562/eia_releases_new_monthly_report_on_us_wood_pellet_production/ [Last accessed on February 25 2017]

Biomass Energy Centre 2016. Carbon emissions of different fuels. http://www.biomassenergycentre.org.uk/portal/page?_pageid=75,163182&_dad=portal&_schema=PORTAL [Last accessed on February 10 2016]

Buchholz T Gunn J 2015. Carbon Emission Estimates for Drax biomass power plants in the UK sourcing from Enviva Pellet Mills in U.S. Southeastern Hardwoods using the BEAC model. Report prepared for the Southern Environmental Law Center. Spatial Informatics Group LLC, Pleasanton CA 17p. https://www.southernenvironment.org/uploads/audio/2015-05-27_BEAC_calculations_SE_hardwoods.pdf [Last accessed on February 10 2016]

Canadian Biomass 2015. U.K.'s Drax confirms unit 4 capacity market omission. http://www.canadianbiomassmagazine.ca/news/uks-drax-confirms-unit-4-capacity-market-omission-5325 [Last accessed on February 24 2017]

Department of Energy & Climate Change (DECC) 2015. Carbon Emission Factors and Calorific Values from the UK Greenhouse Gas Inventory (Ricardo-AEA, 2015) to support the EU ETS. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/425887/2015_EUETS_CEFs_and_GCVs-April_2015_for_publishing.xls [Last accessed on February 10 2016]

Drax 2015a. Biomass supply. http://www.drax.com/media/56583/biomass-supply-report-2014.pdf [Last accessed on February 10 2016]

Drax 2015b. Preliminary Results 12 Months Ended 31 December 2014. http://www.drax.com/media/56585/preliminary-results-presentation-for-the-year-ended-31-december-2014.pdf [Last accessed on February 10 2016]

Drax 2015c. Drax Group plc Annual report and accounts 2014. http://www.drax.com/media/56590/drax_ar14_final.pdf. [Last accessed on February 10 2016]

Drax 2015d. Drax Group plc half year results for the six months ended 30 June 2015. http://www.drax.com/media/66436/hy-report-2015-vfinal.pdf [Last accessed on February 10 2016]

Drax 2016. Our history. http://www.drax.com/about-us/our-history/ [Last accessed on February 10 2016]

Drax 2017. Preliminary results 12 months Ended 31 December 2016. https://drax.cdnist.com/wp-content/uploads/2017/02/2016-Prelims-Analyst-Presentation-Final.pdf [Last accessed on February 24 2017]

Enviva 2017. Enviva Pellets Sampson. http://www.envivabiomass.com/enviva-pellets-sampson-llc/ [Last accessed on February 24 2017]

European Commission (EC) 2016. State Aid SA.38760 (2016/C) (ex 2015/N) – United Kingdom Investment Contract for Biomass Conversion of the first unit of the Drax power plant. European Commission, Brussels, Belgium, 18p.

OFGEM 2015. The UK Solid and Gaseous Biomass Carbon Calculator. https://www.ofgem.gov.uk/publications-and-updates/uk-solid-and-gaseous-biomass-carbon-calculator [Last accessed on February 10 2016]

Process Engineering 2014. Fuel shortage forces Drax co-firing. http://processengineering.co.uk/article/2018549/fuel-shortage-forces [Last accessed on February 10 2016]

UK Energy Statistics (DUKES) 2015. Chapter 5 Electricity. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/447632/DUKES_2015_Chapter_5.pdf [Last accessed on February 10 2016]