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Consulting Engineers Limited

Grid Connection Assessment

Confederation of Paper Industries

Electrification of UK Paper Mills

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Document approval

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Executive Summary

Background

Meeting Net Zero targets will require industry to no longer use natural gas for heat use – with grid supplied electricity being identified as a key alternative. This paper considers the practicality and cost of providing grid connections to allow UK paper mills to transition from gas to electricity for their process heat requirements.

The UK has 46 paper mills ranging in production size from around 800,000 tpa to 1,000 tpa with a total sector production capacity of 4,200,000 tpa. To deliver a representative analysis of heat use within the sector, 19 of these sites (production capacity 2,787,000 tpa, or 66% of the sector production capacity) were examined in detail to address the following issues;

- To evaluate the potential increase in grid-supplied electricity demand at each paper mill if gas use were to be replaced completely with electricity.
- To identify potential connection locations and/or constraints for each paper mill using publicly available information from the Distribution Network Operator (DNO).
- To identify any potential limitations on the existing distribution network supplying each paper mill.
- To evaluate the cost of connection and infrastructure required for each paper mill to link to the national grid to replace gas with grid-supplied electricity.

These site-specific reports are commercially confidential and have been provided to each site operator for use in their own Net Zero planning. The results have been aggregated and used in this analysis.

Conclusions

The site-specific analysis concluded that the cost estimate to provide an appropriately sized boundary connection for the 19 mills considered in detail would be £223.7 million (all figures 2021). This would provide an additional grid connection capacity of 758.5MW – the amount required to replace current gas use with grid supplied electricity. The estimated cost was £294,920 per MW. To electrify all existing mills would require a total additional connection of 1250MW;

extrapolating these costs to all 46 mills gives a total cost of **£328.6m** to provide an appropriately sized electricity connection to the site boundary.

With appropriate investment inside the site boundary (essentially, a new distribution network and replacement of existing combustion equipment) this would technically allow the UK paper to swap from gas to grid supplied electricity.

However, within the set of 19 mills, four of the largest were hugely more expensive than the mean because the local grid simply could not cope with the additional demand from these sites. In these cases substantial grid reinforcement would be required. It follows that for these four sites (and likely others where substantial grid reinforcement would also be required) electrification may not be the most cost-effective technology – hydrogen or bio-based energy may be more appropriate.

This highlights the large additional costs imposed if local grid capacity is constrained.

If these four sites are excluded from the base data used to extrapolate costs to the whole sector, it reduces the overall sector cost to £275M.

The analysis assumes network capacity indicated on DNO heat maps is available on request as a single connection and makes no allowance for other local industries also requesting new capacity. For most of the sites analysed, the new connection would make the paper mill the largest user at the DNO substation, and consume a large proportion of the available spare capacity.

Making an application for a large amount of new capacity may trigger DNO or National Grid upgrade work which will affect the connection cost and timing.

1. Introduction

1.1 Background – Confederation of Paper Industries (CPI)

There are 46 paper mills in the UK with a combined energy demand of 12TWh (direct fuel) and 1.5TWh (imported electricity) per annum – much of which is currently supplied by gas fired Combined Heat and Power (CHP) or gas fired boilers. These sites manufactured 3.6m tonnes of paper, card and tissue based product (2020) – about 40% of UK consumption. With high recycling rates (almost 70%) the industry uses recycled fibre as its primary raw material, but the UK still exports considerable volumes of un-reprocessed paper for recycling in other countries.

The paper industry is preparing for significant emissions reduction across the portfolio of mills by evaluating technologies such as electrification, swapping natural gas to biogas or hydrogen, and a continued focus on energy/resource efficiency. Key parts of this evaluation are the practicalities and economics of particular pathways.

This report evaluates the grid connection and local infrastructure requirements necessary to support the potential electrification of UK paper mills through a detailed review of a sub-set of nineteen representative mills. These results have been extrapolated to cover all UK mills, identify key challenges and provide an estimated overall capital investment cost. The revenue cost issues around using grid supplied electricity have already been explored by CPI[1].

1.2 Objective

The objectives of this report are as follows.

1. Evaluate the potential increase in grid-supplied electricity demand at each paper mill if gas use is to be replaced.
2. Identify potential connection locations and/or constraints for each paper mill using publicly available DNO data.
3. Identify any potential limitations on the existing distribution network at each paper mill.
4. Evaluate the cost of connection and infrastructure required for each paper mill in order to replace gas with grid-supplied electricity.

These nineteen site studies have been extrapolated to draw sector-wide conclusions regarding patterns of load increase versus connection capacity. The site-specific data is commercially confidential, and so has been anonymised, with results presented in summary form. The intent of the research is to highlight key technical issues around electrification and inform the policymaking debate in this area. Individual mills are also using information generated by this report in their site development planning.

[1] Discussion Paper commissioned by the Confederation of Paper Industries (CPI) in partnership with Cornwall Insight. This paper is available at https://www.paper.org.uk/CPI/Content/News/Press-Releases/2022/Cornwall-Insight-and-CPI-publishes-analysis-into-the-economic-practicality-of-electrification.aspx

2. Conclusions

1. Electrification of the current thermal load would increase the electrical load by a mean factor of 3 to 5 times the existing electrical load.
2. Increases in connection availability can be summarised as follows:
    a. One third of mills considered in the detailed studies would have load increases within the capacity of the local grid (meaning the connection point for the existing supply could cope if the mill switched to 100% electricity), but note this could change as other consumers in the local area also electrify their energy use. The remining two-third of sites would require some degree of grid reinforcement, a supply from a higher voltage, or an alternative substation.
    b. If a higher voltage or replacement substation were to be developed half of the remaining mills included in the detailed study would have load increases within the capacity of the grid.
    c. The remaining mills (around a third of the original 19) would require significant levels of reinforcement or connections to the transmission network to enable the connection of the required load.
    d. No consideration has been given to the likelihood that the DNO would accept an application for a connection of the required magnitude to an existing substation, which consumes all spare capacity, nor competing demands from others seeking to increase their electrical demand. In all cases, the paper mill load would become the dominant load at the substation.
3. In all cases the existing site connections would not be capable of supplying the increased load and new boundary connections have been costed in all cases.
4. Typical new connection applications to the DNO currently take between 12 to 24 months to process and install.
    a. For the sites analysed in detail, electrification would require connection of a total of 758.5MW of new load. Extrapolation of the data to the remaining sites indicates a UK total of 1,250 MW.
    b. For the 19 sites analysed in detail, grid connection costs sum to an unclassified assessed total connection cost of £223M. Extrapolation for the remaining 27 sites added £52M, making a total cost of £275M for all 46 sites. This cost does not include new combustion equipment costs or new onsite infrastructure costs other than those required to provide a new incoming supply from the DNO to an incomer substation.

3. Recommendations

This report has provided a high-level overview of the implications of electrification of existing thermal load at UK paper mills. This can be used for comparison with other possible technical solutions.

To evaluate electrification further:

1. If the load increase is within DNO capacity, consideration is to be given to how much additional capacity the DNO can release and whether there are other generation or load projects that could influence the local situation.
2. For the remaining sites, consideration needs to be taken of whether electrification of part of the load is still useful or if other decarbonisation technologies are a more appropriate solution.
3. For sites where electrification is still preferred, the DNO needs to advise on the cost to upgrade the grid supply. For technical reasons it is likely that, for some of these sites, it will not be feasible.
4. In all cases, detailed assessment of the existing distribution network at the paper mill should be undertaken to determine on-site capabilities and requirements for reinforcement.

4. Discussion

4.1 Paper Mills

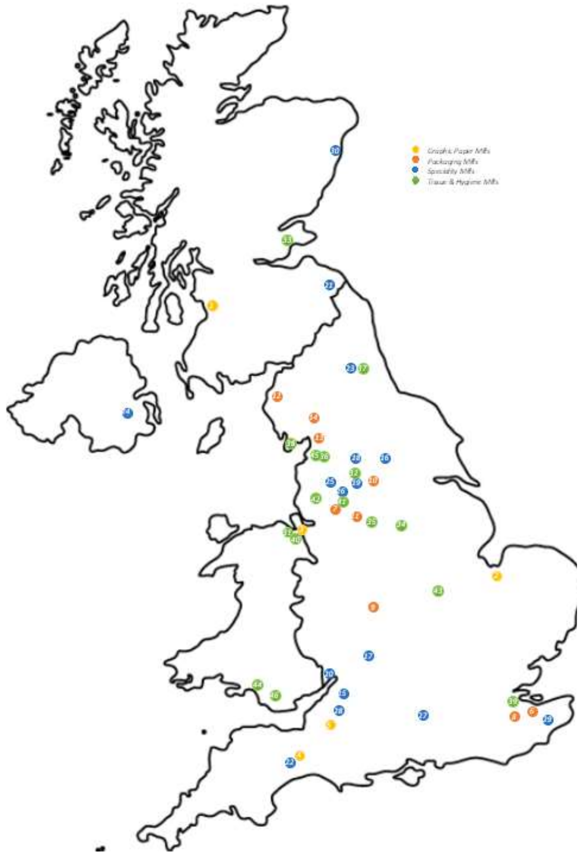
There are 46 paper mills currently in operation across the UK, varying in production capacity from 1,000 to 800,000 tonnes. The plants also vary in the fibre used in production (predominately recycled fibre and virgin wood pulp, but also abaca, cotton and glass for specialist uses). A map of plant locations is shown in Figure 1 and a list of mills and their location is included in Appendix A.

This evaluation is based on an assessment of a subset of UK paper mills, with results extrapolated to cover the whole sector.

For this assessment, information has been received for the following nineteen sites.

1. Arjo Wiggins Chartham
2. Smurfit Kappa SSK
3. DS Smith Kemsley
4. Arjo Wiggins Stoneywood
5. UPM Caledonian
6. Saica, Manchester
7. Romiley Board Mill
8. Palm Paper
9. Hollingsworth & Vose
10. Northwood Tissue - Chesterfield
11. Northwood Tissue - Disley
12. Northwood Tissue - Lancaster
13. WEPA Bridgend
14. Sonoco Stainland
15. Portals Overton
16. Sofidel Leicester
17. Kimberley Clark – Barrow
18. Kimberley Clark – Northfleet
19. Kimberley Clark - Flint

Figure 1: Map of UK paper mills



Source: Confederation of Paper Industries

The mills included in this assessment spread across the UK and cover all six of the Distribution Network Operators. Mills of all products and primary material are considered, covering an annual production range of 1,000 to 800,000 tonnes. Each of these sites has been considered with detailed feedback to the site operator. Site specific results have been treated as commercially confidential, so costing has been summarised for inclusion in the overall report.

4.2 Estimation of electricity requirements

The CPI has established an approach for arriving at an estimated size of additional capacity required to enable electrification to be used consistently across all paper mills. This approach follows the steps detailed below.

1. The maximum instantaneous demand in MW for each fuel (natural gas, biomass or waste) over a suitable period (assumed to be the most recent representative year, i.e. 2019) is determined from on-site monitoring systems, gas shipping data or bill summaries.
2. If the site has a CHP plant, the instantaneous MW generation is subtracted from the total maximum demand determined in Step 1 using the percentage of fuel referable to generation of electricity from the CHPQA certificate.
3. The maximum instantaneous demand figure (after deducting the CHP element) is then multiplied by 0.81. This reflects the generally recognised boiler efficiency of 81%.
4. A safety factor of 10% is then added to this figure to account for any underestimating of values.

This approach has been taken to account for the maximum fluctuations in the thermal demand that must be satisfied by the electrification of the boilers.

5. Results Summary

5.1 Assumptions

For all scenarios, we have assumed that any on-site generation (mostly gas-CHP) will be made redundant upon electrification of the boiler. This represents a considerable capital investment by the sector with plant being closed before the end of its economic life. However, it may be advantageous to retain the existing ability to use gas, so that the sites have flexibility to vary their electrical demand. The ability to vary demand may have commercial advantages, for example being able respond to variations in the availability of intermittent renewables such as wind and solar power.

We have assumed the new electrical load will be supplied from a separate new connection that will operate completely independently from the existing electrical infrastructure on site.

We have also assumed that load profiles for the sites are flat (i.e. constant load). We have not considered other sources of generation that may be connected by the DNO. Cable lengths have been calculated on a straight line basis and cable cost assessments based on installation method (essentially road or grass verge). Cost assessments are based on recent grid connections within Fichtner experience across the six UK DNOs. As such, they are not a classified estimate and are not based on a detailed engineering solution, but are sufficient to assess the approximate overall cost to inform decarbonisation discussions.

5.2 Grid Capacity

From detailed analysis, Figure 2 below provides an overview of the load at each mill considered in this assessment and the grid capacity available at the existing connection point, i.e. the feasibility of installing a new grid connection to the same substation and voltage at which the mill is currently connected.

The parameters in Figure 2 are defined as follows.

- Site demand: the existing paper mill site imported electricity and electricity generated onsite taken from the data provided by CPI (held for CCA reporting purposes);
- New load: the increase in load required by replacing gas with electricity, i.e. the producing the average heat currently generated from fossil fuels with electricity, based on 8,000 running hours per year;
- Site co-generation: the total of available capacity of the existing onsite generation (CHP plants for the majority of sites);
- Site supply: the existing DNO maximum import capacity to the site, taken from the Connection Agreement;
- Grid load: the demand of other consumers at the Grid Substation (Connection Point);
- Grid capacity: the firm capacity available at the Grid Substation (Connection Point) minus the existing site connection import capacity (Site supply);
- Headroom: (Grid capacity + Connection capacity – Grid demand) – (Site demand +New load).

The wider grey and black bars represent capacity of the network, and the blue bars represent load. As can be seen, the first six sites have load increases within the capacity of the local grid. Other sites would require a reduced increase in load, an alternate connection point or connection voltage, or more extensive reinforcement at the DNO substation.

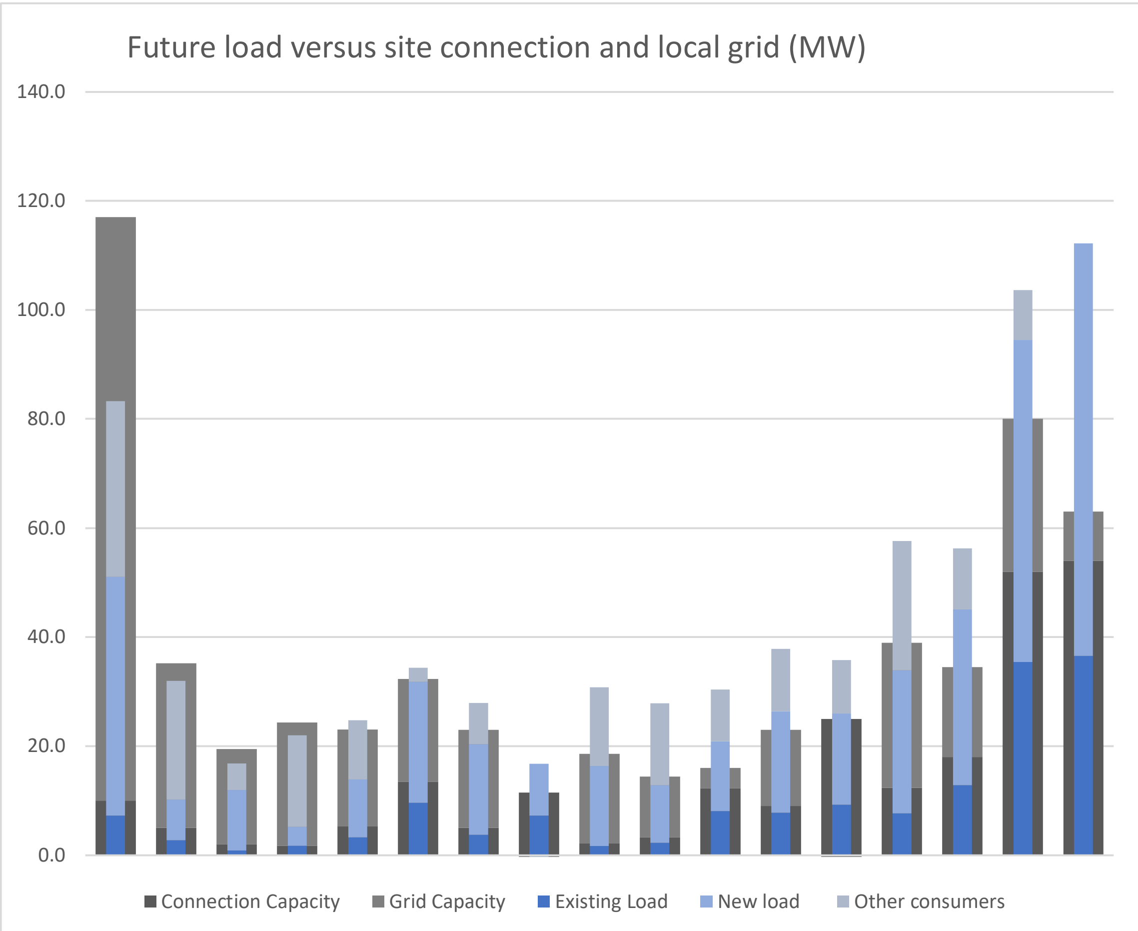
It can be seen from Figure 2 that site loads are increasing by between 3 and 5 times the existing load, which is a considerable change. Where the headroom is a positive number, there is capacity to accommodate the increased load from the paper mill at the existing connection substation. Where this is negative, there is insufficient capacity without reinforcement of the substation or considering a different connection location.

Figure 3 provides a summary of the load at each mill and the grid capacity available at a nearby connection point if necessary, either at the same voltage or an increased level. This does not consider upgrades to the existing connection point infrastructure, or any large National Grid reinforcement works. The details of possible connections have been discussed directly with each mill, but the detailed figures are considered to be commercially confidential.

As shown in Figure 3, the head room at some mills is still a negative number, i.e. the load requirements exceed the grid capacity. In these cases, further reinforcement works are required, involving significant costs and timescales.

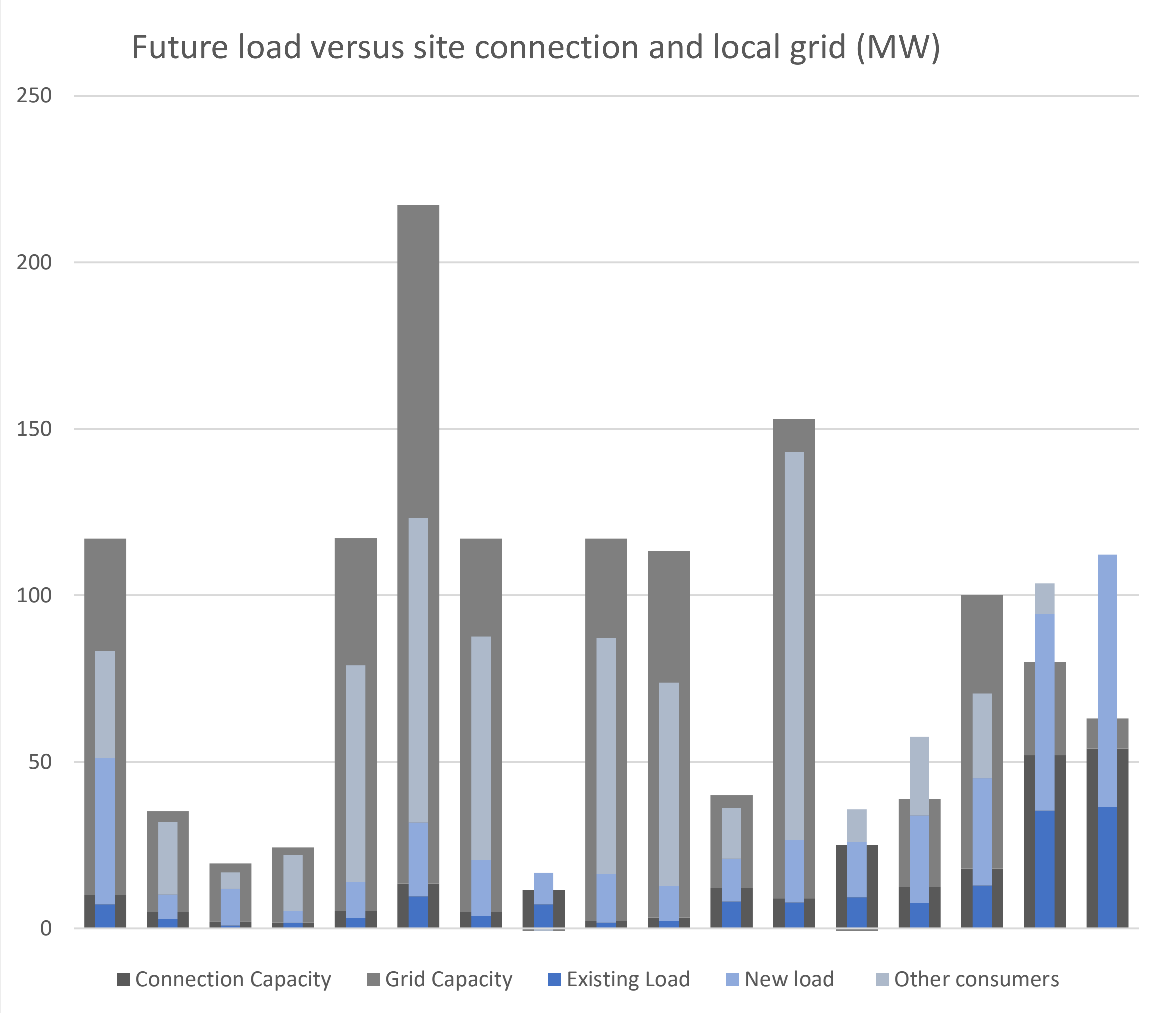
Typically, the lead time for a new DNO connection without significant substation reinforcement is 12-18 months. This is the time to plan and install the connection from the substation to the site. If substation reinforcement, and potential upstream reinforcement to the National Grid network, is required, a new connection lead time will be 12-24 months. Very large connections (those with demand capacities greater than 60MW) may have significantly longer lead times.

Figure 2: Future load versus site connection and local grid



The data now considers the availability of alternative connection points and connection voltages and is illustrated in Figure 3 below. As can be seen, there are now 12 sites where connection is possible without the need for significant infrastructure reinforcement.

Figure 3: Future load versus site connection and higher voltage connection



5.3 Connection costs

An unclassified cost estimate for a new connection to each site has been compiled based on DNO heat map information and Fichtner's experience of recent connections. A cost breakdown, alongside the detailed infrastructure requirements, has been provided direct to each site. The total costs for each site are summarised below.

Table 1: Connection cost summary

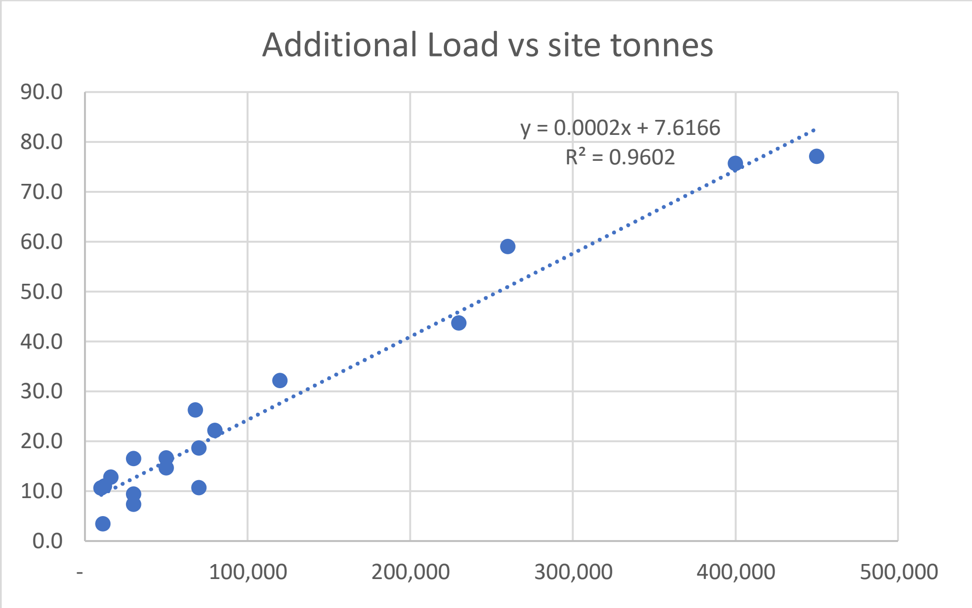
	Additional Load (MW)	Cost estimate (£)	£/MW
19 UK Paper Mills	**758.5**	**£223,704,555**	**£294,920**

5.4 Data extrapolation for UK overview

This report covers information provided by 19 sites out of a total of 46 sites represented by CPI. The approximate annual production tonnage for all 46 sites was also provided by CPI. This can be used for extrapolation to estimate the overall situation for all 46 UK sites.

The additional load (MW) versus site annual production (tonnes) is plotted on a scatter graph below. The largest data point was excluded from the plot as it was clearly a much higher future load than other sites and artificially skewed the data.

Figure 4: Site production (tonnes) versus future load increase (MW)



Source: CPI data

We have used the average data above to estimate the additional load based on site tonnes capacity for all 46 sites. This was then multiplied by the average connection cost per MW to give estimated connection costs. The comparison between calculated and estimated MW load increase and connection costs are shown in the table and graphics below.

This analysis gives a total additional load requirement across the 46 UK paper mills of 1250 MW at a cost of £275M. Figure 5 and Figure 6 illustrate the distribution of load and cost increase across the portfolio of paper mills. Outliers have been excluded.

Figure 5: Estimated MW load increase based on site capacity information (% of total MW increase for all sites)

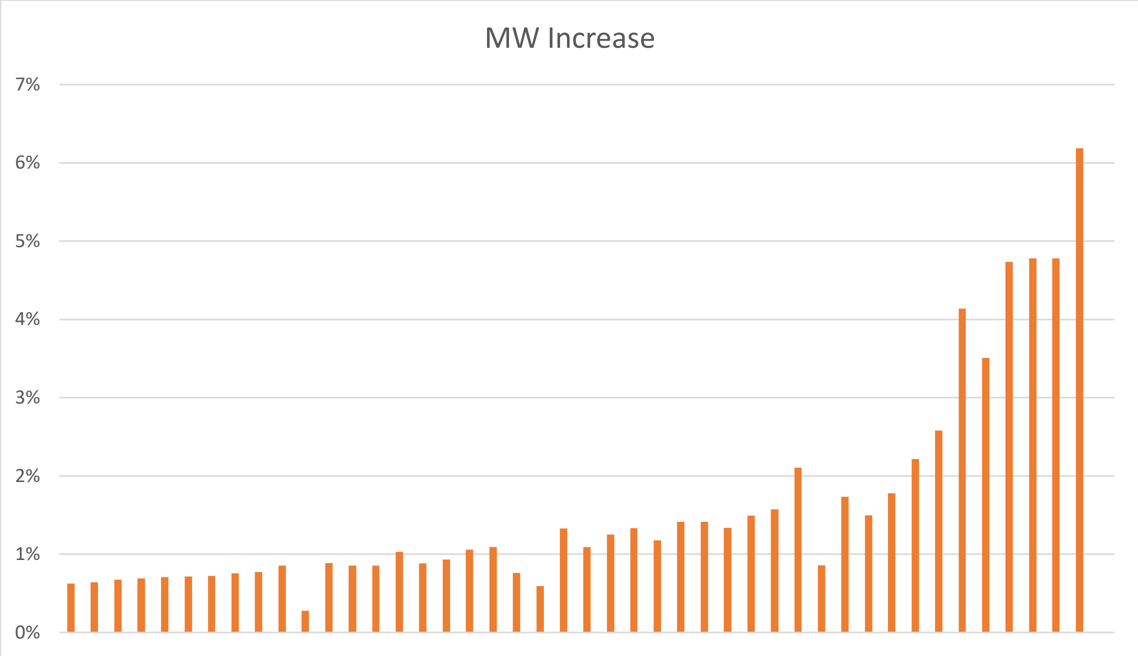
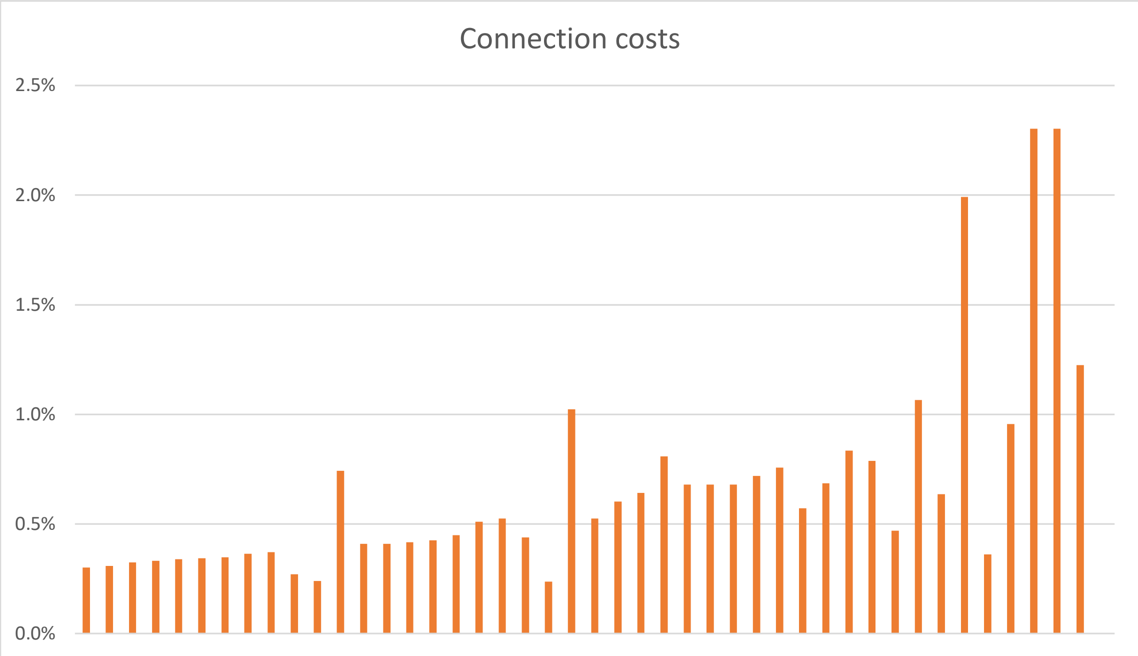


Figure 6: Estimated connection costs based on average £/MW and estimated load increase (% of total £ cost for all sites)



A UK Paper Mills

Table 2: UK Paper Mills

	Mill Name	Location	DNO	Primary Product Type	Production Capacity (tonnes)	Fibre Types
1	UPM Caledonian	Irvine, Ayrshire	SPEN	Graphic Paper	260,000	Wood pulp
2	Palm Newsprint	Kings Lynn, Norfolk	UKPN	Graphic Paper	400,000	Recycled
3	UPM Shotton	Shotton, Deeside	SPEN	Graphic Paper	260,000	Recycled
4	Higher Kings Mill	Cullompton, Devon	WPD	Graphic Paper	30,000	Recycled
5	St Cuthberts Paper Mill	Wells, Somerset	WPD	Graphic Paper	1,000	Wood pulp
6	DS Smith Kemsley	Kemsley, Kent	UKPN	Packaging	800,000	Recycled
7	Saica Manchester	Trafford, Greater Manchester	ENW	Packaging	450,000	Recycled
8	Smurfit Kappa Townsend Hook	Townsend Hook, Kent	UKPN	Packaging	260,000	Recycled
9	Smurfit Kappa SSK Birmingham	Birmingham, West Midlands	WPD	Packaging	230,000	Recycled
10	Sonoco Stainland	Halifax West Yorkshire	NPG	Packaging	70,000	Recycled
11	Romiley Board Mill	Stockport, Greater Manchester	ENW	Packaging	50,000	Recycled
12	Iggesund Paperboard	Workington, Cumbria	ENW	Packaging	220,000	Wood pulp
13	BillerudKorsnas Beetham	Beetham, Cumbria	ENW	Packaging	45,000	Wood pulp
14	James Cropper	Kendal, Cumbria	ENW	Packaging	50,000	Wood pulp / Recycled
15	Sundeala	Dursley, Gloucestershire	WPD	Speciality	5,000	Recycled
16	Weidmann Whiteley	Otley, West Yorkshire	NPG	Speciality	10,000	Wood pulp /Recycled
17	Hollingsworth & Vose	Cheltenham, Gloucester	WPD	Speciality	12,000	Glass
18	Carlson Filtration	Barnoldswick, Lancs	ENW	Speciality	2,000	Wood pulp
19	Union Papertech	Oldham, Greater Manchester	ENW	Speciality	6,000	Abaca
20	Glatfelter	Lydney, Gloucestershire	WPD	Speciality	17,000	Abaca/ Wood pulp
21	AhlstromMunksjo Chirnside	Chirnside, Scottish Borders	SPEN	Speciality	15,000	Abaca/ Wood pulp
22	Devon Valley	Cullompton, Devon	WPD	Speciality	7,000	Abaca/ Wood pulp

	Mill Name	Location	DNO	Primary Product Type	Production Capacity (tonnes)	Fibre Types
23	Fourstones Paper Mill	Hexham, Northumberland	NPG	Speciality	6,500	Recycled
24	Huhtamaki	Lurgan, Northern Ireland		Speciality	20,000	Recycled
25	Vernacare	Bolton, Greater Manchester	ENW	Speciality	9,000	Recycled
26	AhlstromMunksjo Radcliffe	Bury, Greater Manchester	ENW	Speciality	15,000	Abaca
27	Portals Overton	Overton, Hampshire	SSEN	Speciality	16,000	Cotton
28	Portals Bathford	Bathford, Somerset	WPD	Speciality	4,000	Wood pulp
29	Arjo Wiggins Chartham	Chartham, Kent	UKPN	Speciality	10,000	Wood pulp
30	Arjo Wiggins Stoneywood	Aberdeen	SSEN	Speciality	68,000	Wood pulp
31	Kimberly Clark Flint	Flint, North Wales	SPEN	Tissue & hygiene	30,000	Recycled
32	Essity Stubbins	Bury, Greater Manchester	ENW	Tissue & hygiene	55,000	Recycled
33	Sapphire Paper Mill	Glenrothes, Fife	SPEN	Tissue & hygiene	40,000	Recycled
34	Northwood Tissue (Chesterfield)	Chesterfield, Derbyshire	NPG	Tissue & hygiene	30,000	Recycled
35	Northwood Tissue (Disley)	Disley, Stockport	ENW	Tissue & hygiene	30,000	Recycled
36	Northwood Tissue (Lancaster)	Lancaster, Lancashire	ENW	Tissue & hygiene	11,000	Recycled
37	Essity Prudhoe	Prudhoe, Northumberland	NPG	Tissue & hygiene	100,000	Recycled/ Wood pulp
38	Kimberly Clark Barrow	Barrow, Cumbria	ENW	Tissue & hygiene	120,000	Wood pulp
39	Kimberly Clark Northfleet	Northfleet, Kent	UKPN	Tissue & hygiene	80,000	Wood pulp
40	Essity Oakenholt	Oakenholt, North Wales	SPEN	Tissue & hygiene	70,000	Wood pulp
41	Essity Manchester	Trafford Park, Greater Manchester	ENW	Tissue & hygiene	50,000	Wood pulp
42	Essity Tawd	Skelmersdale, W Lancs	ENW	Tissue & hygiene	28,000	Wood pulp
43	Sofidel Leicester	Leicester, East Midlands	WPD	Tissue & hygiene	70,000	Wood pulp

	Mill Name	Location	DNO	Primary Product Type	Production Capacity (tonnes)	Fibre Types
44	Sofidel Baglan	Baglan, South Wales	WPD	Tissue & hygiene	60,000	Wood pulp
45	Sofidel Lancaster	Lancaster, Lancashire	ENW	Tissue & hygiene	30,000	Wood pulp
46	WEPA Bridgend Paper Mill	Bridgend, Mid Glamorgan	WPD	Tissue & hygiene	50,000	Wood pulp

Source: Confederation of Paper Industries. Note production numbers are estimates as stated by each company and are not based on actual production.

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