

Curtailment Assessment Report for customer:

Example Site

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Table of contents

1. Introduction

- 1.1 Baseline Characteristics
- 1.2 List of Active Constraints
- 1.3 Sites above in the LIFO stack

2. Curtailment results

- 2.1 Constraint loadings before and after curtailment
- 2.2 Curtailed and uncurtailed generation profile
- 2.3 Curtailment per constraint
- 2.4 Curtailment heatmap
- 2.5 Discussion of results

Appendix A: Curtailment Studies assumptions

1. Introduction

You have applied for a 20.0 MVA Solar_Storage connection which has been identified to trigger distribution and/or Super Grid Transformer (SGT) transmission constraints. You have been offered a Flexible or Curtailable Connection to be able to connect flexibly ahead of the completion of distribution/transmission reinforcement works or on an enduring basis. If accepted, your site will operationally be managed by UK Power Networks' Distributed Energy Resources Management System (DERMS).

This report aims to provide you with more data and information to help you making an informed decision about your investment. It includes an indication on the estimated level of curtailment your site will be subject to operationally, including a breakdown of curtailment per constraint. The report contains information on the constraints your site has been identified to trigger together with their ratings, as well as information on the sites ahead of yours in the connections queue. The set of assumptions we have taken as part of the curtailment studies are captured at the end of this report, in [Appendix A](#).

The curtailment assessment is carried out outside of DCUSA Schedule 2D and has no contractual implications. Differences between the curtailment estimate, covered in this report, and the contractual curtailment limit, that you would have received as part of your connection offer, can be found [here](#)

1.1 Baseline Characteristics

This curtailment report provides an estimate of the energy (MWh) lost due to distribution and/or SGT constraints based on your site being at position 9 of the generation LIFO stack in Bramford GSP.

The connection baseline characteristics utilised to produce the curtailment study, as well as the final energy curtailed, are captured in Table 1.

Table 1: Curtailment key characteristics

Parameter	Value
SAP number	13579
Application date	06 June 2023
LIFO priority stack position	9
Generator technology	Solar_Storage
Flexible connection capacity	20 MW
Postcode	ABC 123
Closest substation	Thetford Grid
Point of Connection Voltage	33.0 kV
Energy before curtailment (MWh)	71,466.12
Capacity factor before curtailment (%)	40.80 %
Energy curtailed (%)	11.61 %

1.2 List of Active Constraints

The list of active distribution and/or transmission constraints triggered by your application, that have been considered in this curtailment study, together with their constraint limit, are captured below.

If the identified constraint is active post fault i.e. following the loss of a circuit or a transformer, UK Power Networks' DERMS system secures in anticipation of the fault, to avoid short term overloads occurring on the network. This is defined as summated constraint or Sum Constraint.

The rating associated to the transformer constraints, circuits constraints, Sum Constraints and SGT constraints linked to your site, are captured in Table 2, Table 3, Table 4 and Table 5 below, respectively. When there are no active constraints of a certain type, the respective table is omitted.

Limitations other than the seasonal ratings of the various network assets are captured in the "Other limitation" field, which can represent limitations due to protection devices (e.g., DOC), circuit breakers, or Technical Limits. For those cases where the "Other limitation" is different than the seasonal rating, the stricter limitation is used.

A margin of 10% is applied on the constraint rating to reflect the operational behaviour of DERMS, for more information refer to [Appendix A](#).

The name of circuit constraints is in line with the naming in the [Long Term Development Statement \(LTDS\)](#). Table 1 of the LTDS shall be consulted to get more details on the circuit constraint that your site has been identified to trigger, if any, including voltage level, location, and start and end of the circuit.

Table 2: List of Active Distribution **transformers** constraints linked to the site.

Constraint	Constraint Limit [MVA]
Thetford Grid 132kV_GT1	<ul style="list-style-type: none"> ● Winter: 117.00 ● Spring: 102.60 ● Summer: 90.00 ● Autumn: 102.60 ● Other limitation: N/A
Thetford Grid 132kV_GT4	<ul style="list-style-type: none"> ● Winter: 117.00 ● Spring: 102.60 ● Summer: 90.00 ● Autumn: 102.60 ● Other limitation: N/A

Table 3: List of Active Distribution **circuits** constraints linked to the site.

Constraint	Constraint Limit [MVA]
THETT_THET_1	<ul style="list-style-type: none"> ● Winter: 108.83 ● Spring: 101.05 ● Summer: 87.33 ● Autumn: 101.05
THETT_THET_4	<ul style="list-style-type: none"> ● Winter: 108.83 ● Spring: 101.05 ● Summer: 87.33 ● Autumn: 101.05

Table 4: List of Active **Sum Constraints** linked to the site.

Constraint	Constraint Limit [MVA]
SUM_Thetford Grid 132kV_GT1_Thetford Grid 132kV_GT4 Components: <ul style="list-style-type: none"> ● Thetford Grid 132kV_GT1 ● Thetford Grid 132kV_GT4 	<ul style="list-style-type: none"> ● Winter: 117.00 ● Spring: 102.60 ● Summer: 90.00 ● Autumn: 102.60 ● Other limitation: N/A

1.3 Sites above in the LIFO stack

Access to the network capacity is managed based on a Last-In-First-Out (LIFO) principle of access determined by the site's application date. Under LIFO, each flexible DER (generator and electricity storage) is assigned a position within a global priority stack. When a constraint is breached, the DERs at the bottom of the priority stack that have a contribution to the constraint, will be curtailed first and DERs at the top of the priority stack will be curtailed last. DERMS will move up the stack and curtail up to the point where the constraint has been resolved and curtailment is no longer required.

The GSP LIFO stack is created based on the latest available connection status information of DERs above in the stack. Cancellations, network reconfiguration, or subsequent SGT reverse power flow requirements for DERs above in the stack, might alter the overall position in the LIFO stack (the queue position will not change).

Your site is at position 9 of the LIFO stack. Generation sites ahead in the stack in the area where your application falls into, that have been considered into the curtailment studies, are captured in Table 6. DERs that hold a firm connection have not been included in this table but are included in the assessment.

Table 6: Sites above in the LIFO stack

LIFO position	Application Date	Capacity	Technology	Closest substation
1	04 February 2013	20.0	Solar	Thetford Grid
2	15 July 2020	30.0	Solar	Diss Grid
3	25 February 2021	46.99	Solar	Thetford Grid
4	17 October 2022	40.0	Solar	Bury Grid
5	14 April 2023	15.84	Solar And Storage	Drinkstone Primary
6	03 May 2023	19.8	Solar And Storage	Bury Grid
7	25 May 2023	19.75	Solar And Storage	Brandon Primary
8	26 May 2023	29.63	Solar	Stanton Primary
9	06 June 2023	20	Solar Storage	Thetford Grid
10	06 June 2023	30.0	Solar And Storage	Thetford Grid

2. Curtailment results

The estimated energy reduction due to distribution and/or SGT constraint(s) is captured in Table 7.

- The **Capacity Factor before curtailment** (in %) is the ratio of the energy generated based on the site's uncurtailed profile, to energy that could have been generated at continuous full-power operation during the same period.
- The **Capacity Factor after curtailment** (in %) is the ratio of the energy generated based on the site's curtailed profile, to the energy that could have been generated at continuous full-power operation during the same period.
- The **Energy before curtailment** (in MWh) is the sum of the energy produced by the uncurtailed profile of the site i.e. the energy that the site would have been generating if it was not curtailed by DERMS. UK Power Networks uses standard technology specific profiles to estimate the uncurtailed generation export throughout the year, available [here](#).
- The **Energy after curtailment** (in MWh) is the sum of the energy produced by the curtailed profile of the site i.e. the energy that the site is estimated to be generating after having been curtailed by DERMS to resolve the distribution and/or SGT constraints.
- The **Energy curtailed** (in MWh) is the difference between the uncurtailed and the curtailed profile, or between the 'Energy before curtailment' and the 'Energy after curtailment'.
- The **Energy curtailed** (in %) is calculated as the 'Energy curtailed' divided by the 'Energy before curtailment', both in MWh.

Methodology and assumptions used to produce curtailment results are captured in [Appendix A](#) of this report.

Table 7: Estimated curtailment results

Capacity factor before curtailment (%)	Capacity factor after curtailment (%)	Energy before curtailment (MWh)	Energy after curtailment (MWh)	Energy curtailed (MWh)	Energy curtailed (%)
40.80	36.10	71,466.12	63,169.89	8,296.23	11.61

2.1 Constraint loadings before and after curtailment

The graphs in Figure 1 below illustrate the expected loading before and after curtailment takes place, for each of the constraints your site has been identified to trigger, for the most recent one year of operation.

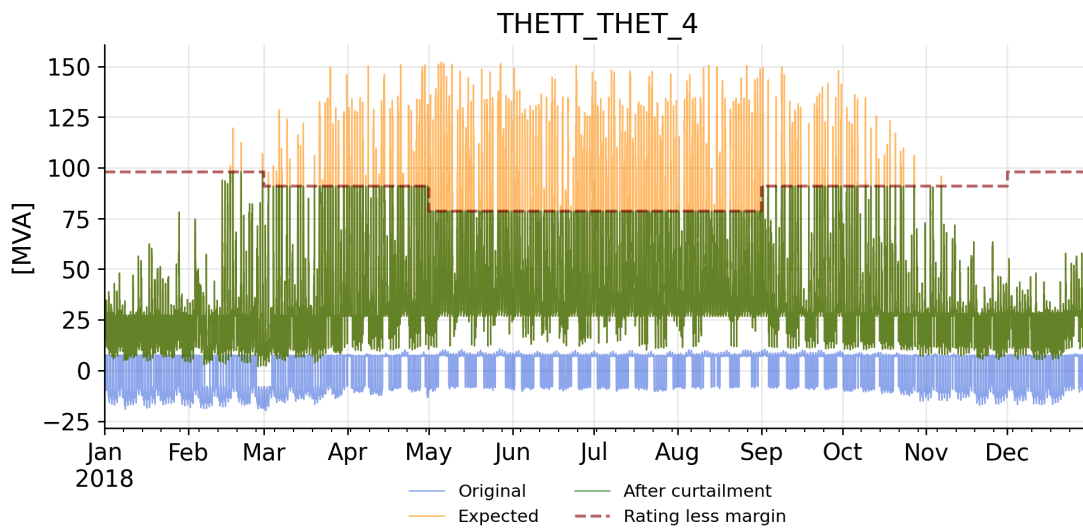
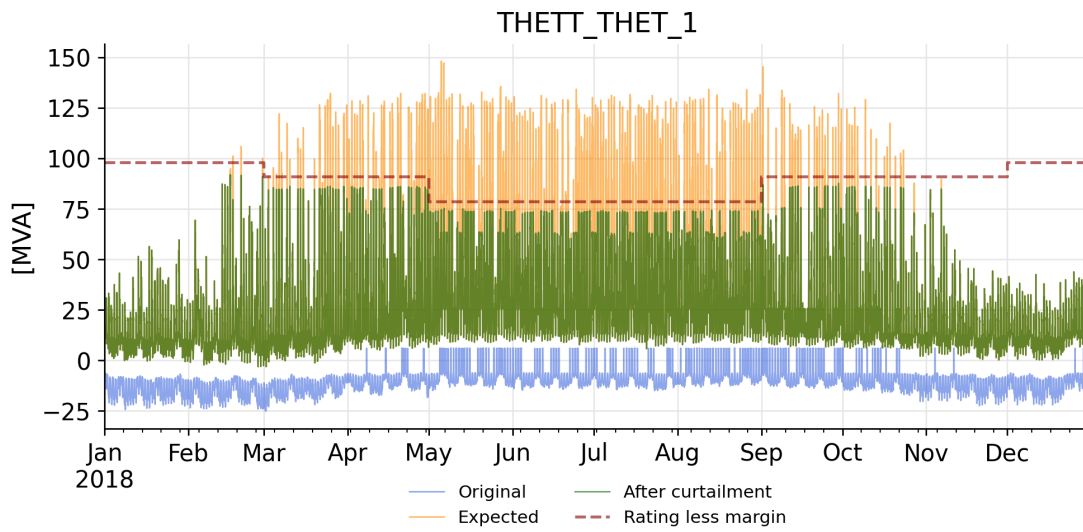
The blue line shows the historical observed power flow at the constraint. The contribution of accepted and offered connections is subsequently added to the historical power flow based on their technology specific profiles and sensitivity factors. The total expected power flow at the constraint is displayed in amber.

When the expected power flow exceeds the constraint limit (horizontal red line), the constraint has been breached and a curtailment instruction is initiated, based on LIFO principle of access and

sensitivity factors.

The expected power flow at the constraint after the curtailment instruction has been actioned, is displayed in green below.

Seasonal Rating, if available, are used in the curtailment assessment.



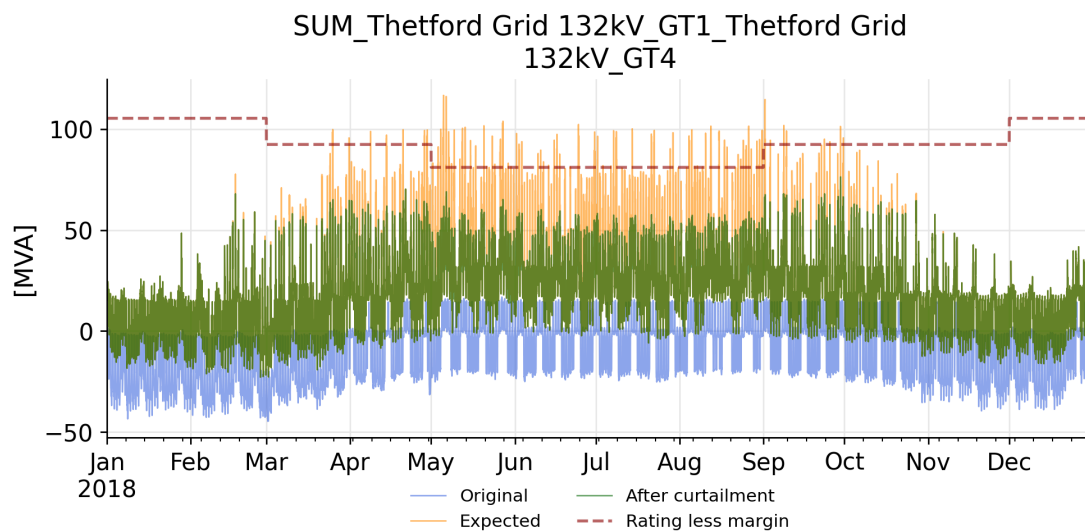
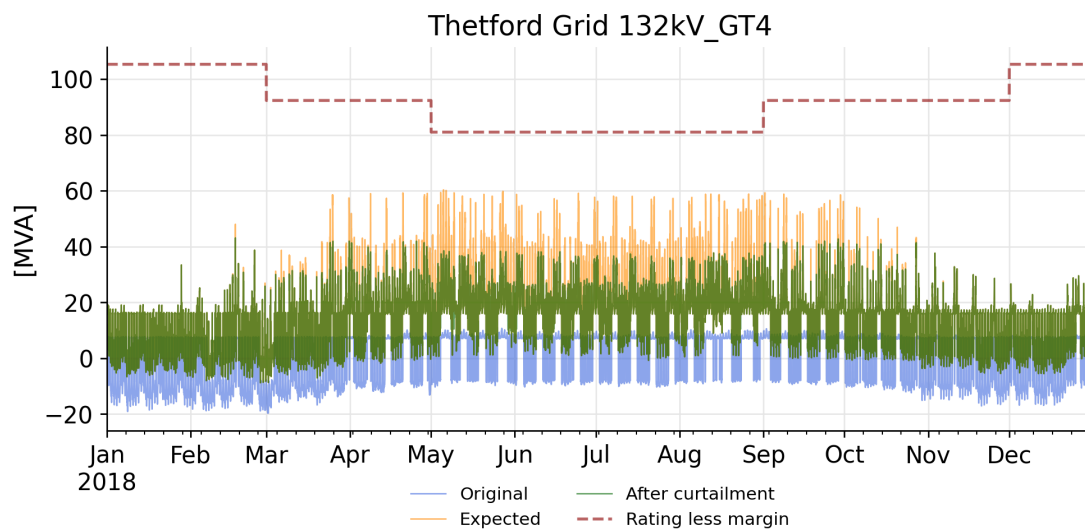
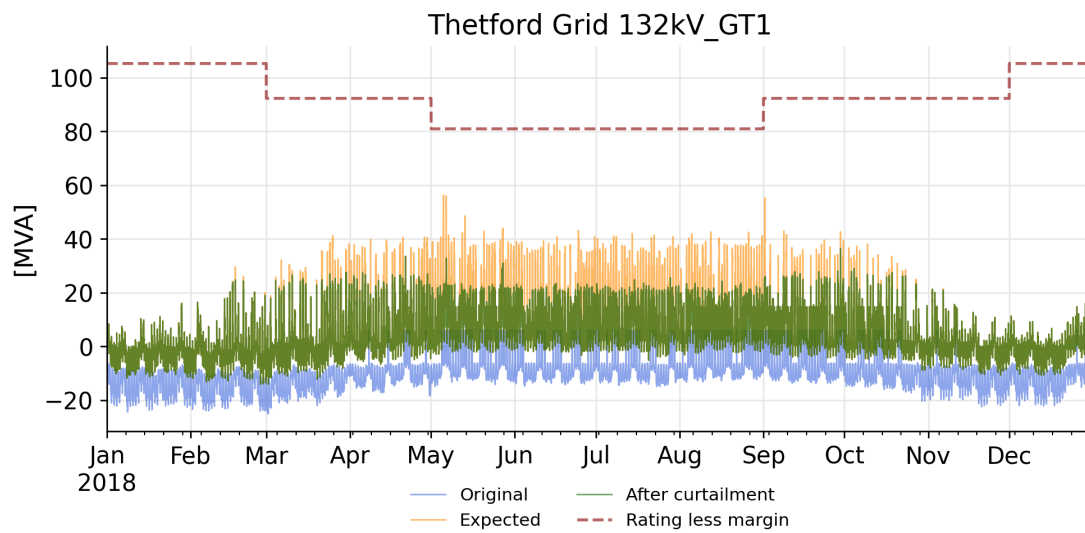


Figure 1: Power flows before and after curtailment in all constraints linked to the application

2.2 Curtailed and uncurtailed generation profile

The chart below illustrates the expected curtailed and uncurtailed profile from your site.

The original uncurtailed profile used to model the output of your site for one year of operation (i.e. the profile before any curtailment instruction is issued) is based on standard technology specific profiles and is displayed in blue in the graph below.

The expected curtailed profile is based on the output reduction required to bring the constraint loading below its admissible limits, based on LIFO stack and sensitivity factors and is displayed in amber in the graph below.

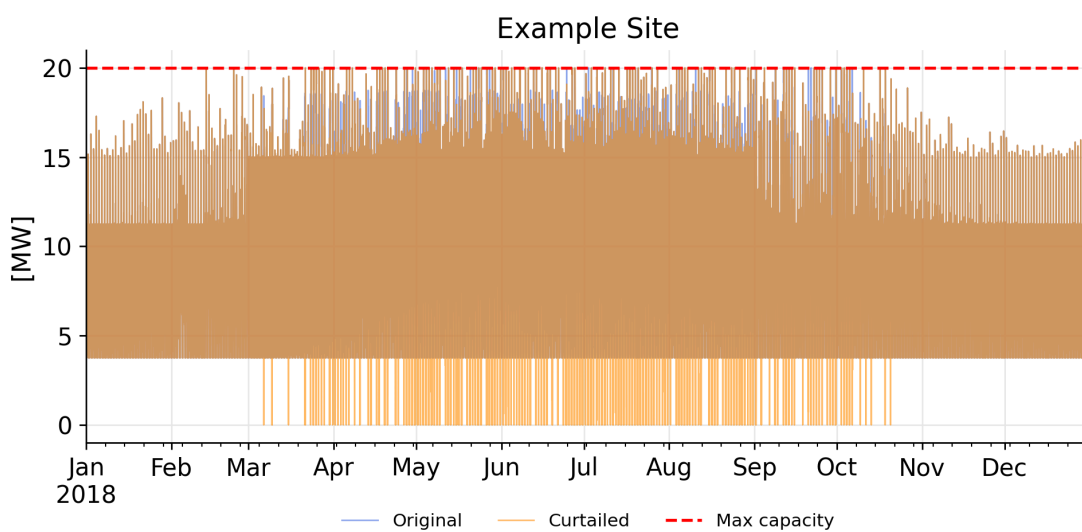


Figure 2: Curtailed and uncurtailed generation profile

2.3 Curtailment per constraint

The chart below illustrates the curtailment breakdown for each of the constraints that your site has been identified to trigger. The chart shows the proportion of curtailment per constraint, as a percentage of the total curtailment (in MWh), for the entire year.

If your site is subject to multiple nested constraints (i.e. electrically interconnected at multiple voltage level e.g. Primary transformer, 33kV circuits, Grid transformer, 132kV circuits and SGT), the curtailment algorithm mitigates the most local constraint first and if upstream constraints are still breached, it then moves up to higher voltage levels.

When the site is subject to multiple nested constraints, the curtailment breakdown per constraint might show that most or all the curtailment the site is subject to, is driven by the most dominant constraint. This doesn't necessarily mean that the other constraints are never going to be breached, as they might then become active if the most dominant constraint is lifted.

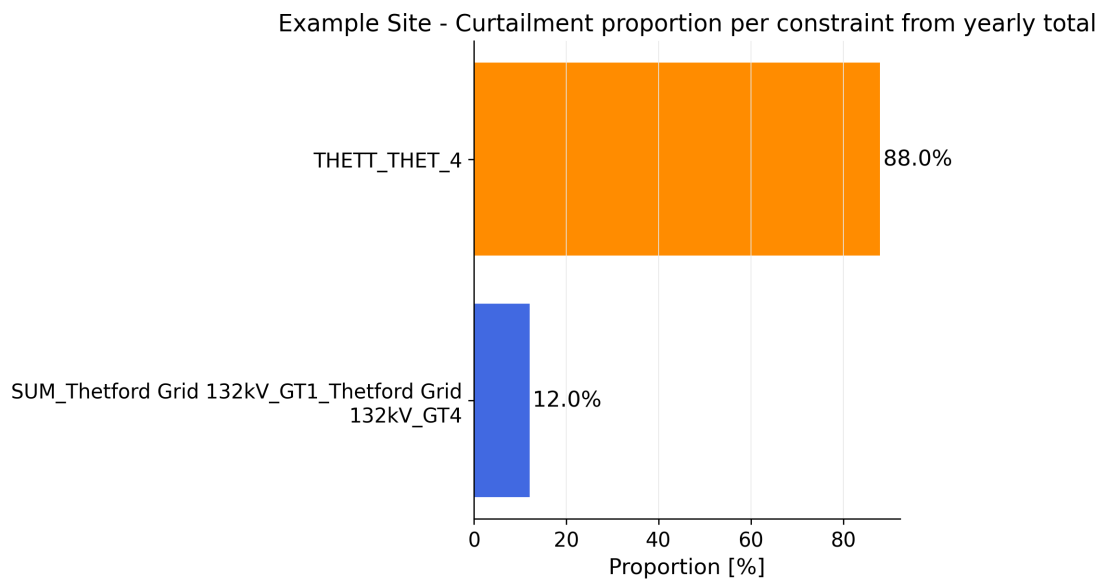


Figure 3: Curtailed apportionment per constraint

Table 8: Example Site - Curtailed apportionment per constraint

Constraint	Energy curtailed (MWh)	Energy curtailed (%)
SUM_Thetford Grid 132kV_GT1_Thetford Grid 132kV_GT4	997.46	12.02
THETT_THET_4	7,298.77	87.98
Total	8,296.23	100.00

2.4 Curtailment heatmap

The heatmap below illustrates the estimated curtailment for one year of operation.

Each cell represents the aggregated estimated curtailment (i.e., the sum) for a specific hour of the day (x-axis) and month of the year (y-axis) in MWh. The colour intensity varies from yellow to red, indicating lower to higher level of curtailment respectively.

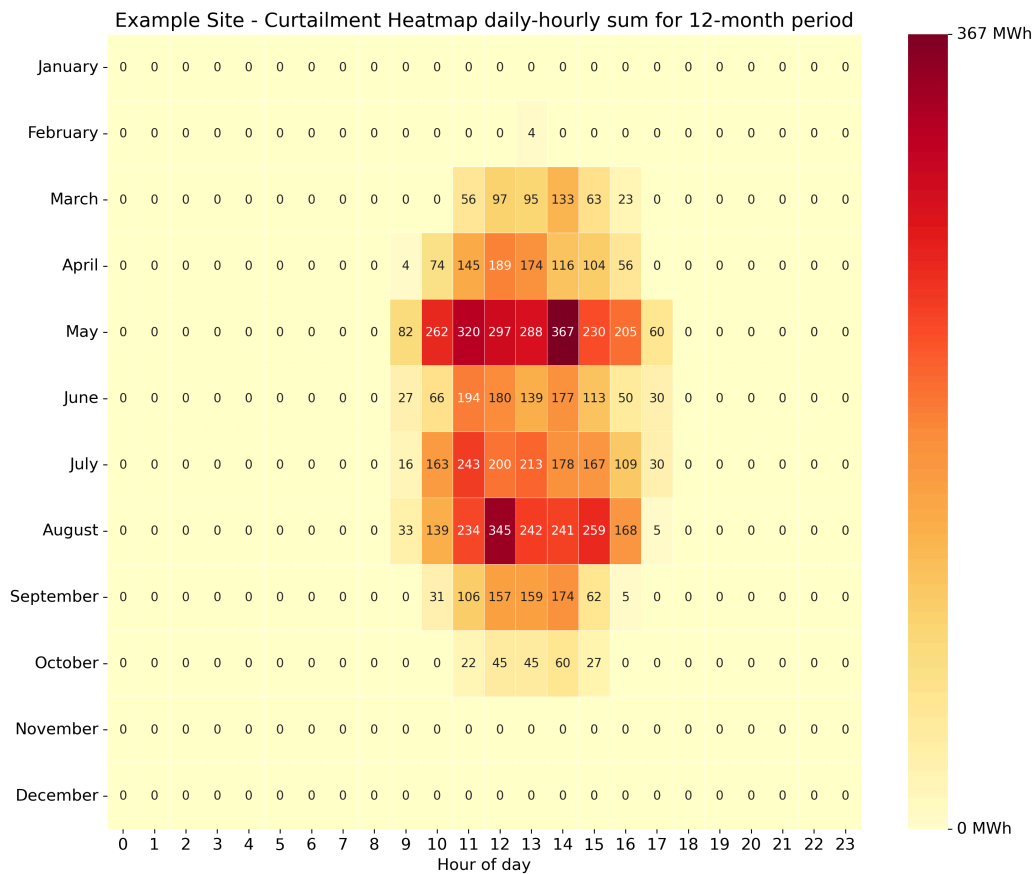


Figure 4: Curtailment heatmap for the year

2.5 Discussion of Results

Results are presented to give an indication curtailment estimates for Example Site with SAP number: 13579.

Network reinforcements or other changes that increase the useable capacity will reduce the curtailment imposed on generators. Growth in micro-generation outside of DERMS control, or decreases in demand, will increase the curtailment imposed on generators.

The assessment does not account for unplanned outages on the network or the failure of DERMS infrastructure such as communications links.

The results indicate that annual output for the Example Site site may be reduced by 11.61%, resulting in an effective production factor of 36.10%.

The results are intended to represent the highest expected levels of annual energy curtailment, subject to the uncertainties and risks that have already been highlighted. Due consideration and recognition of the estimated nature of the results should be given when using these results for financial appraisal of projects.

We're working hard to improve the data and information available so that you can make an informed investment decision. If there is anything else that would be helpful for you then please let us know.

Appendix A: Curtailment Studies assumptions

The main assumptions that have been considered in the curtailment studies are summarised in Table 9 below.

Table 9: Summary of assumptions

Assumption	Operation Area
<p>a) Network Configuration</p>	<ul style="list-style-type: none"> ● Curtailment studies are carried out for 12 months of intact running arrangement. Abnormal running arrangement including planned and unplanned network outages are not considered in the study ● In areas where significant reinforcement is due to be delivered (past Gate C), the future running arrangement is used in the curtailment study.
<p>b) Network Boundary</p>	<ul style="list-style-type: none"> ● If GSP running in isolation (e.g. Burwell) curtailment is run for the individual GSP; if multiple GSP running in parallel (e.g. Braintree and Rayleigh) curtailment is run for the group of GSP running in parallel.
<p>c) Constraint Ratings</p>	<ul style="list-style-type: none"> ● Seasonal cable and overhead line ratings are used in the study and come from PowerFactory. ● Transformer ratings from PowerFactory are used in the study and are applied where the nature of the constraint is thermal. If the limiting factor is the DOC or tap changer reverse power flow, these limits are used in the curtailment studies. ● Continuous seasonal ratings (if available) are used both for intact and post fault network constraints (managed pre-fault) Limits on the Grid Supply Points applied by National Grid through the Appendix G/F process are considered in the study, including Technical Limits.
<p>d) Curtailment thresholds</p>	<ul style="list-style-type: none"> ● If the identified constraint is active post fault i.e. following the loss of a circuit or a transformer, UK Power Networks' DERMS system secures in anticipation of the fault to avoid short term overloads on the network occurring. This is reflected in the curtailment studies where the asset limit is considered to be the N-1 capacity of the asset. ● The curtailment threshold is calculated applying an operational margin of 10% on the constraint rating to cater for power flow swings at the constraint and reflects the real-life implementations of DERMS.
<p>e) Principle of Access</p>	<ul style="list-style-type: none"> ● Last In First Out (LIFO) principle of access adopted, based on application date.
<p>f) Connected load and generators</p>	<ul style="list-style-type: none"> ● Load are modelled in PowerFactory based on observed demand in the latest calendar year. ● Generators connected for more than 2 years are modelled in PowerFactory based on their historical profiles. Once the site under study is operational, if the connected generators that have been modelled in these studies based on their technology specific profile

operate differently than how they have operated in the past, this might cause curtailment of the site under study to increase or decrease.

- Generators that have been energised less than 2 years ago, a technology specific profile is used.
- Half Hourly load flows are then executed for each 30 minutes for the most recent year worth of data available to produce the background power flow

g) Demand and small-scale generation growth

- No demand growth is assumed in the studies.
- No small-scale generation growth (G83/G98 and sub-200kVA G99) is assumed in the studies.

h) Acceptances and in-flight offers

- The contribution of acceptances and in-flight offers are added on top of the background power flow previously calculated.
- All Acceptances and in-flight offers are considered to materialise.
- Acceptances and in-flight offers are modelled based on their technology specific profile using the data in [here](#).

i) Uncurtailed profile of the site being studied

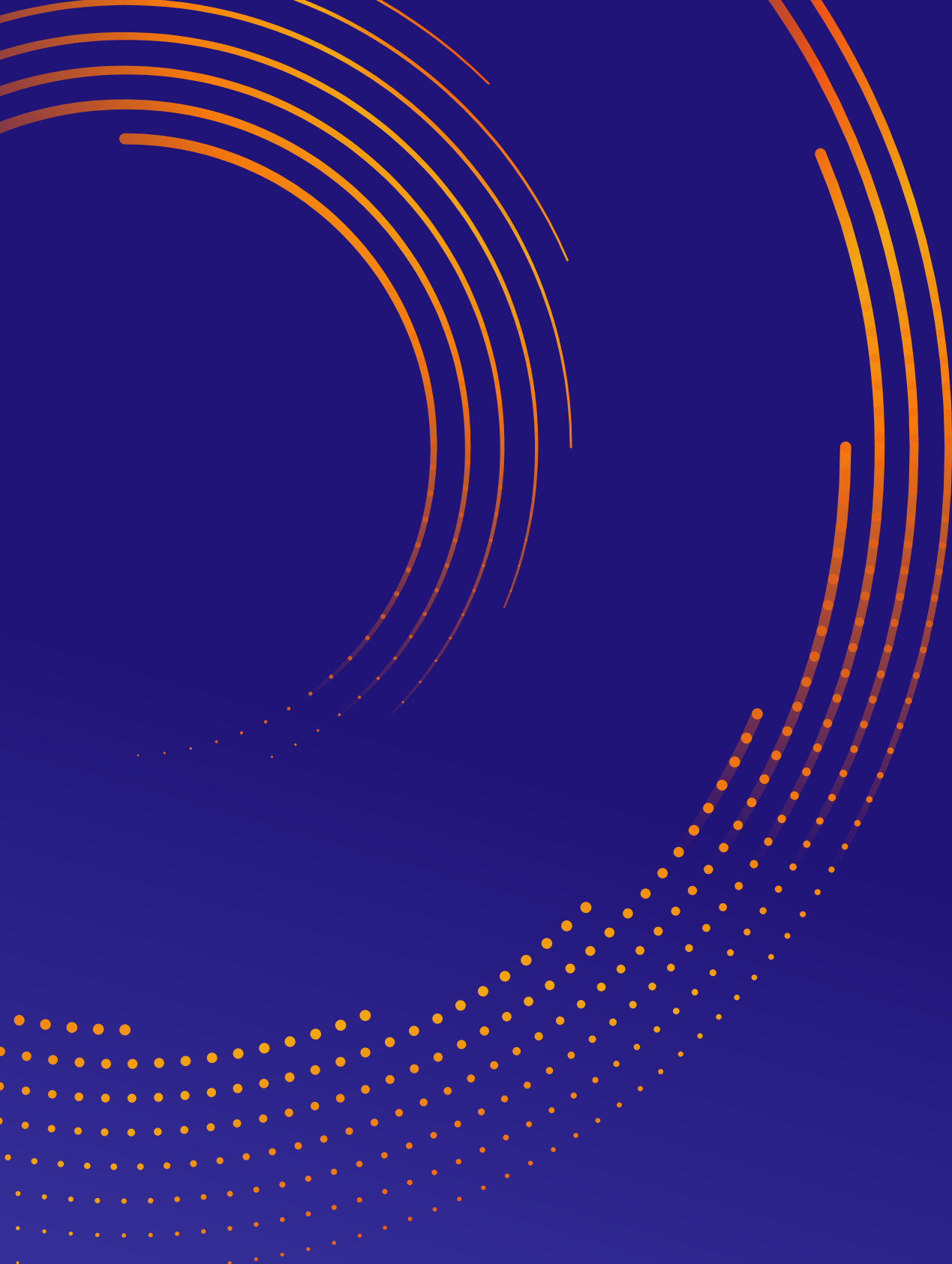
The site being studied is modelled based on its technology specific profile (in per unit) and multiplied for the export capacity of the site. Technology Specific profiles are available [here](#) and have the following capacity factor.

- Solar - 14.20% capacity factor
- Wind - 30.14% capacity factor
- Non-variable - 100% capacity factor
- Energy storage - 52.05% capacity factor
- Energy storage + solar - 54.61% capacity factor

The sites are modelled at unity power factor, no reactive power contribution is considered for curtailment studies. For this reason, active power (MW) can be considered equal to the apparent power (MVA).

j) Sensitivity Factor

DERMS uses sensitivity factors to establish a relationship between a constraint location and a DER. Sensitivity Factors are used to determine the volume of curtailment required to remove the network constraints. UK Power Networks has set a threshold sensitivity factor of 5% below which a customer is not considered to have a contribution to the constraint and will not be associated to it.



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