LCP INSIGHT CLARITY ADVICE

National Grid

Storage in the UEM – proposed methodology

August 2017

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Storage coordination methodologies

UEM Storage Algorithms

Overview

The following four algorithms have been considered for simulating the actions of storage units in the UEM.

1. Meet first outage

2. Mimic baseload generation

3. Minimise LOLE

4. Minimise shortfall

UEM Storage Algorithms

Information pertaining to all algorithms

Key assumptions

- In all situations, the simplifying assumption is made that all storage units are fully charged at the start of a system event
- That all units have perfect foresight of outages

New inputs required for any storage technology

- Output capacity (MW) – maximum output in a given 30 min period
- Storage capacity (MWh)

Terminology

“Duration” is: Storage Capacity / Output Capacity and is assumed to be an integer multiple of 30 mins.

“Remaining storage capacity” is the available output in a 30 minute period subject to energy use in previous steps within the algorithm.

UEM Storage Algorithms

Information pertaining to all algorithms

Common modelling approach

- All possible storage output is used when required – i.e. total storage generation is unaffected by the coordination methodology
- If a plants “duration” is longer that the outage then surplus Storage capacity is wasted.
- With the exception of Approach 1 the order of the periods is not relevant and no ramping constraints are assumed. This allows periods to be reordered without loss of generality

Examples

Example plant setup

Name	Output Capacity (MW)	Storage Capacity (MWh)	Duration (periods)
Unit 1	5	10	4
Unit 2	15	15	2
Unit 3	10	5	1
Unit 4	5	2.5	1

- All of the dispatch examples in this presentation use the storage plants outlined above.
- Each line on the charts represents 5MW (or 2.5MWh as each bar is a 30 minute period).
- As storage plants are first used by duration then output capacity, this is the order that they are utilised in.

Examples

Aggregated example plant setup

Name	Output Capacity (MW)	Storage Capacity (MWh)	Duration (periods)
Unit A	5	10	4
Unit B	15	15	2
Unit C	15	7.5	1

- In order to make the algorithms more efficient, storage plants of the same duration can be aggregated.
- So in this example, both Unit 3 and Unit 4 are combined into the single Unit C by summing the output capacities and the storage capacities.
- Units 1 & 2 have been renamed accordingly.

UEM Storage Algorithms

Algorithm 1: Meet first outage

In this scenario, the storage units are used to reduce the unserved energy in each period to zero, in the order that the periods with unserved energy occur.

Sort storage units in order of descending duration
(this is so we don't end up with wasted unusable storage)

For each period, run through all of the storage plants and use the maximum amount of energy possible for each plant

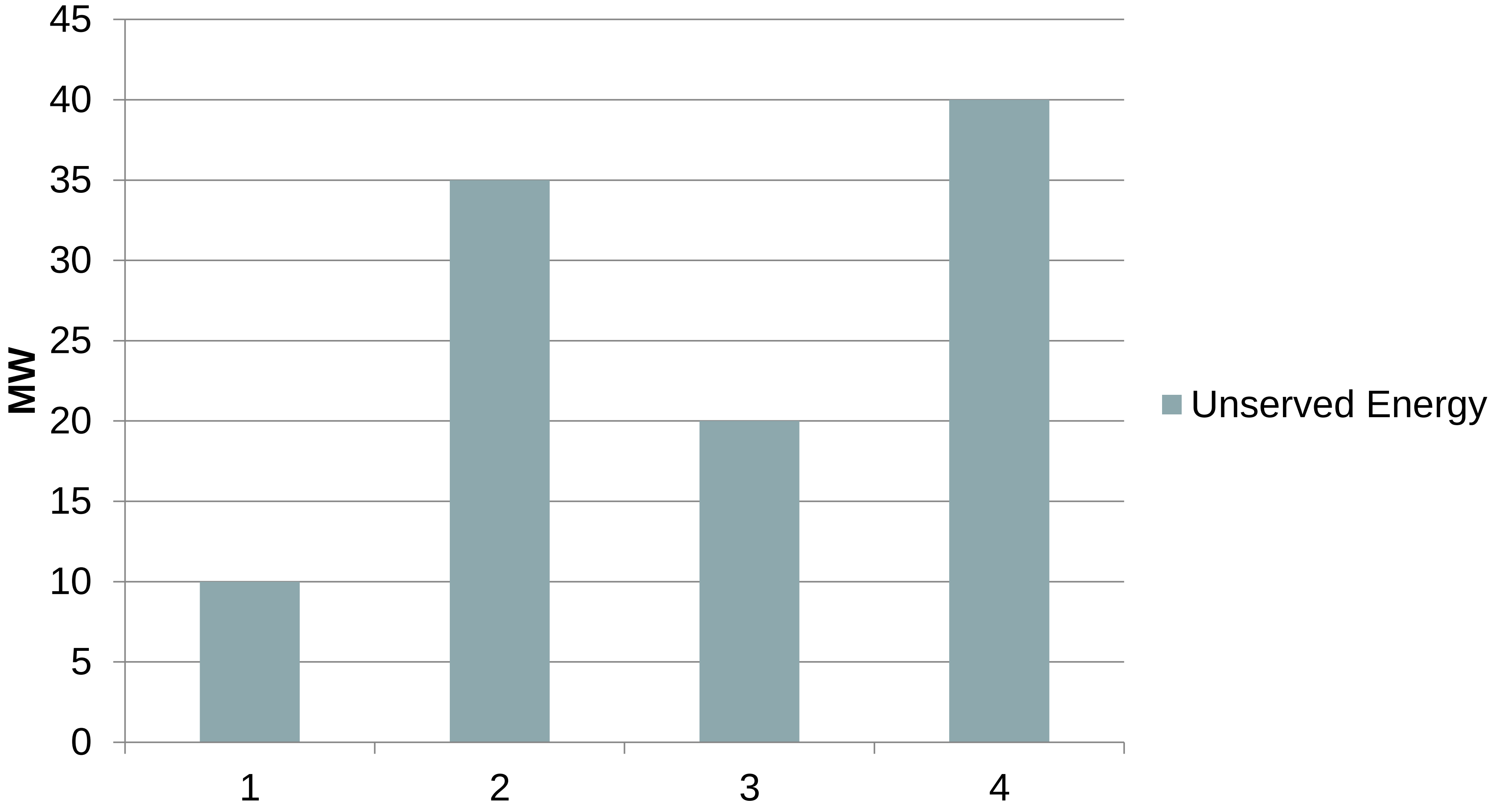
This maximum is the minimum of:

- Output capacity of this unit
- Remaining output capacity
- Amount of energy still unserved

If this action results in there being no unserved energy for this period, move on to the next period. Actions taken in one period affect actions taken in subsequent periods.

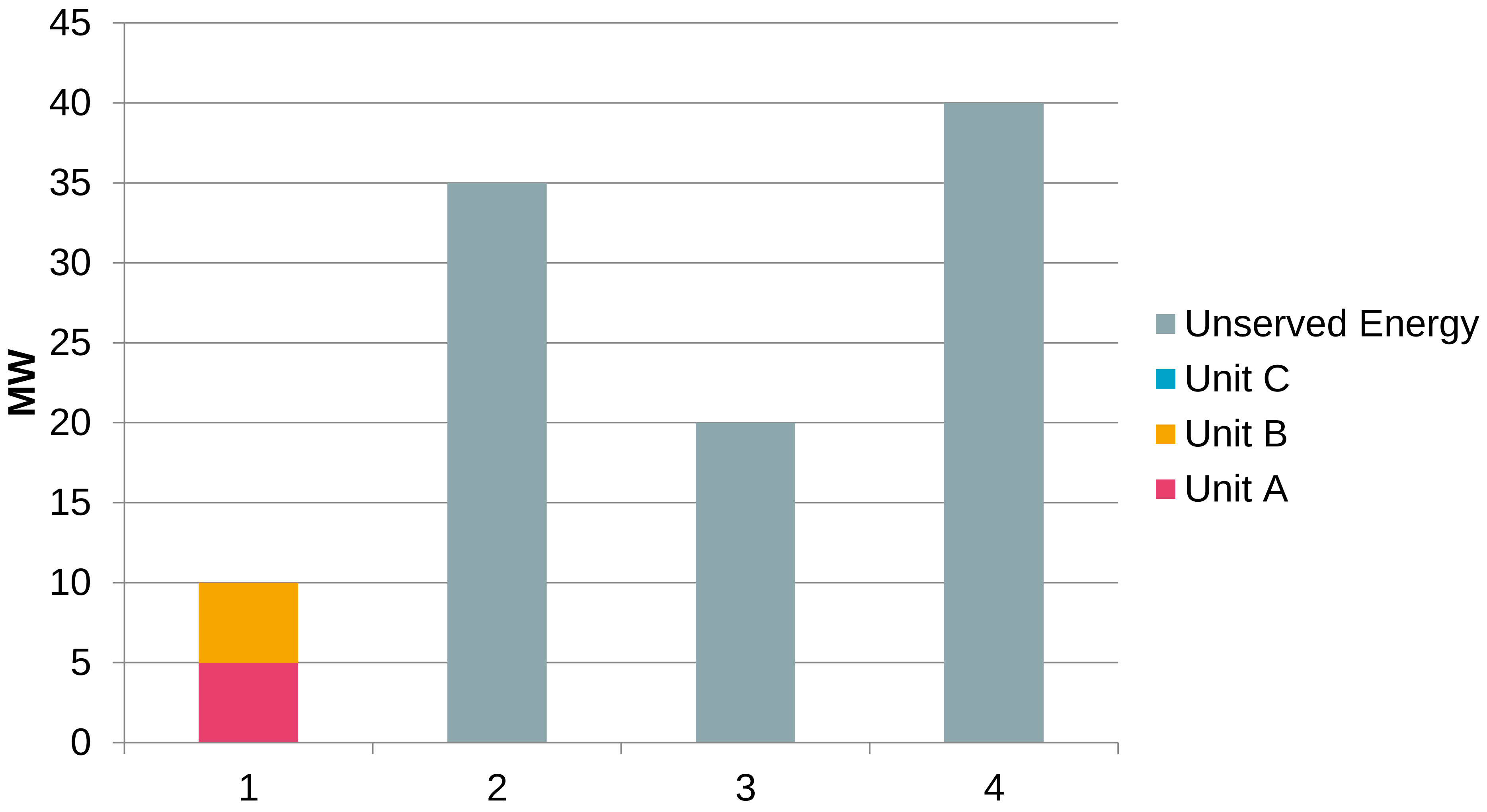
UEM Storage Algorithms

Algorithm 1: Meet first outage



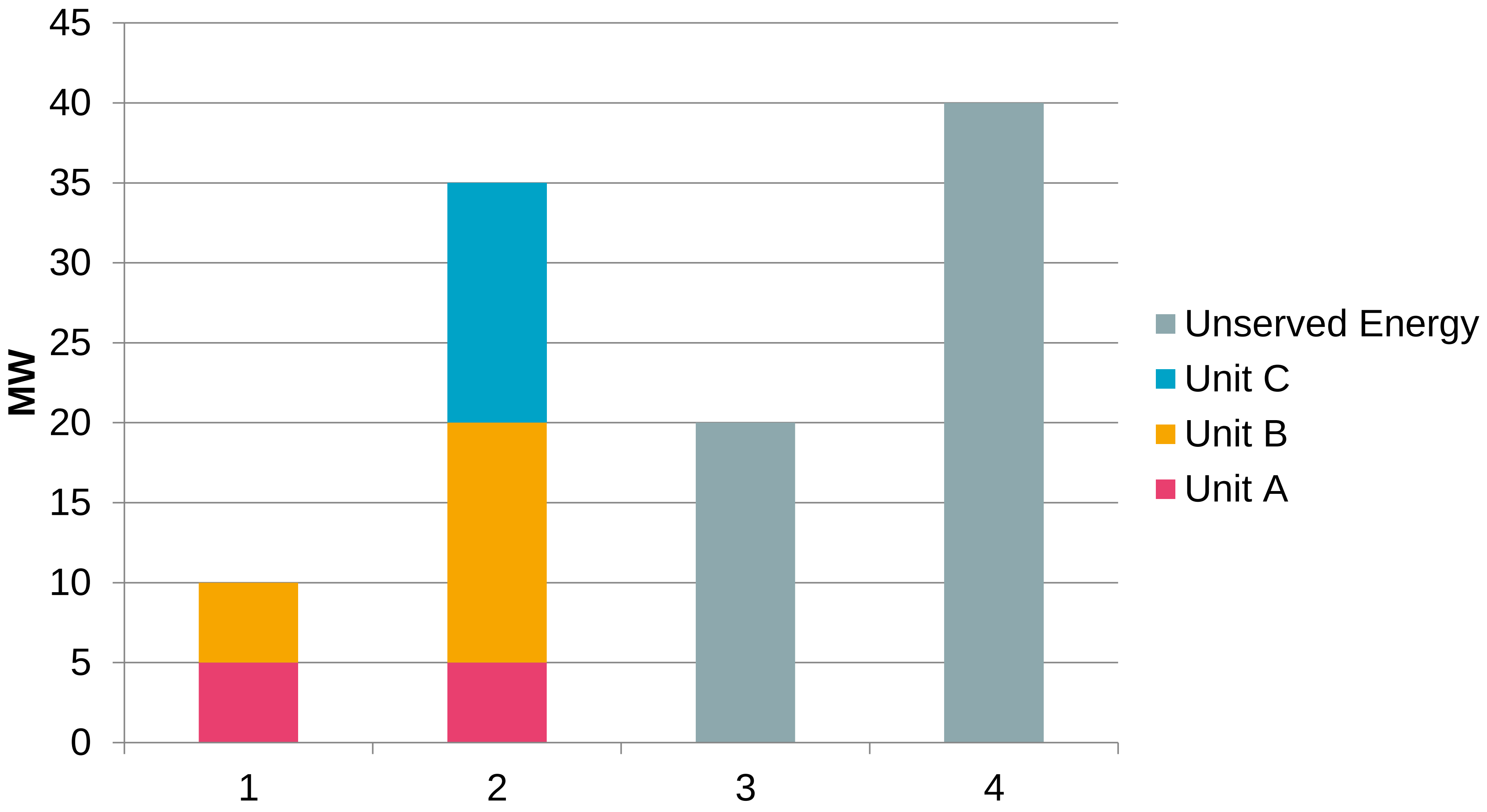
UEM Storage Algorithms

Algorithm 1: Meet first outage



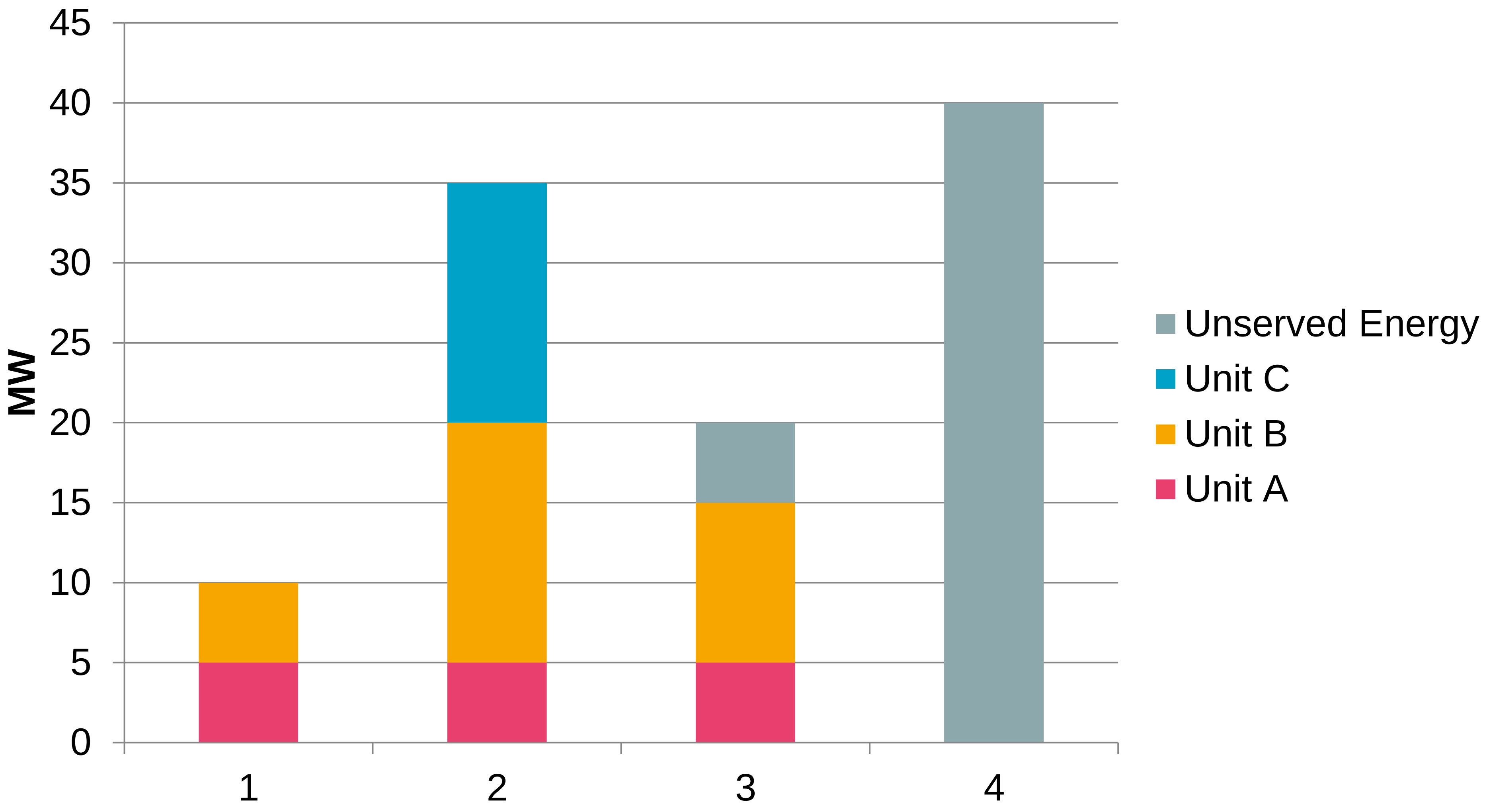
UEM Storage Algorithms

Algorithm 1: Meet first outage



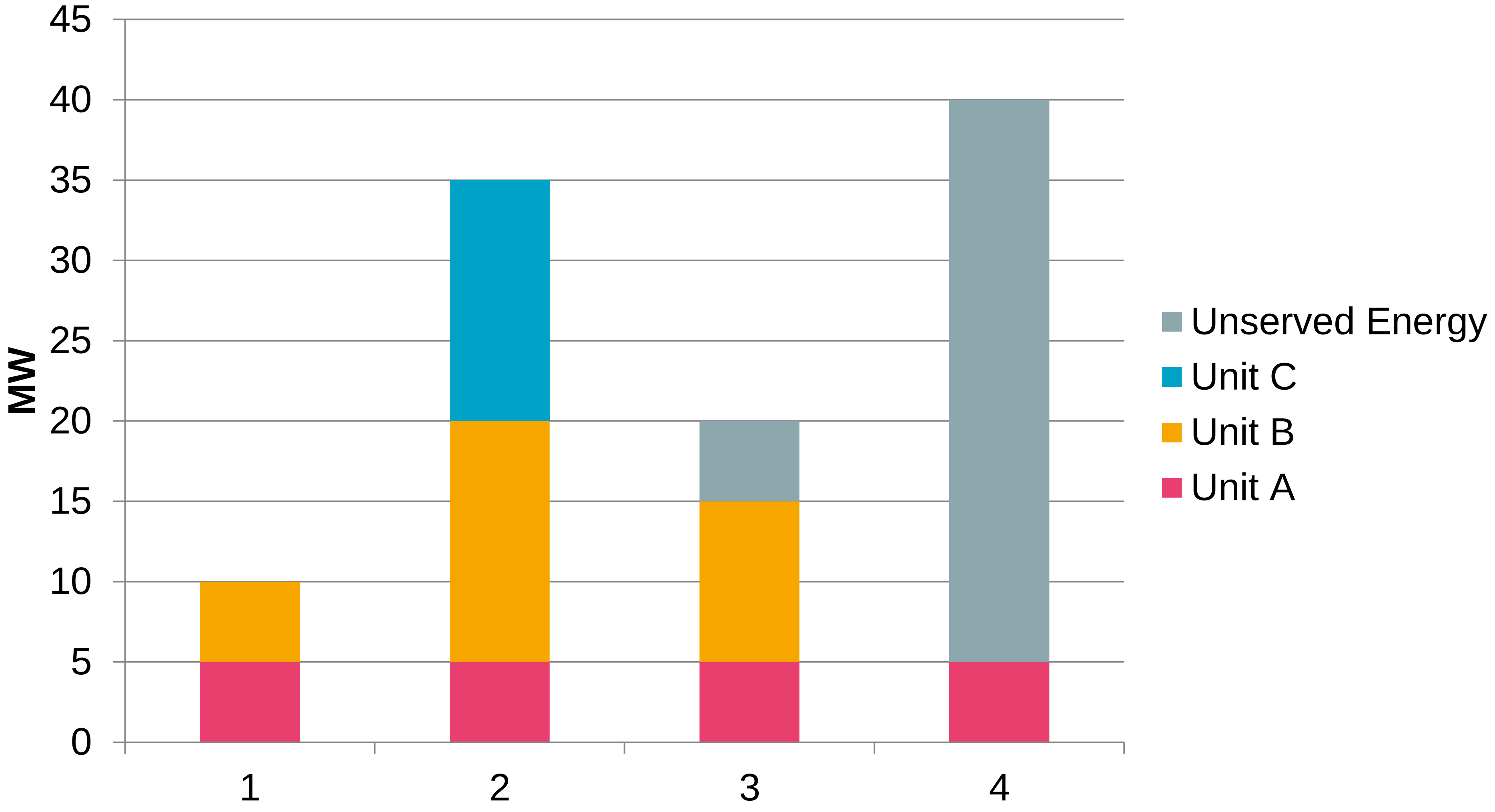
UEM Storage Algorithms

Algorithm 1: Meet first outage



UEM Storage Algorithms

Algorithm 1: Meet first outage



UEM Storage Algorithms

Algorithm 1: Meet first outage - Result

How this result is achieved is as follows:

1. Looking at the first period, we need to find 5MWh (10MW of output for half an hour). The first unit to use is Unit A as it has the longest duration. In this period it can dispatch 5MW which is accepted. From this we still need to find 5MW. This is received from unit B as this has the largest output capacity of the remaining plants (all of which have the same duration).

2. In the second period, all plants still have energy to dispatch, this time we need 35 MW. Again we use unit A first due to its duration. Unit B can then dispatch at its maximum capacity. The remaining capacity is filled exactly by Unit C.

3. In period 3, units A & B still have remaining MWh capacity. Unit A runs at full capacity, however unit B only has 5MWh remaining, so outputs at 10MW.

4. In period 4, only unit A has remaining MWh capacity so outputs at full output capacity to use up the rest of its energy.

UEM Storage Algorithms

Algorithm 2: Mimic baseload generation

In this scenario, each storage unit spreads their capacity equally between the periods with energy unserved. The steps in the algorithm are as follows:

Sort storage units in order of descending duration

↓

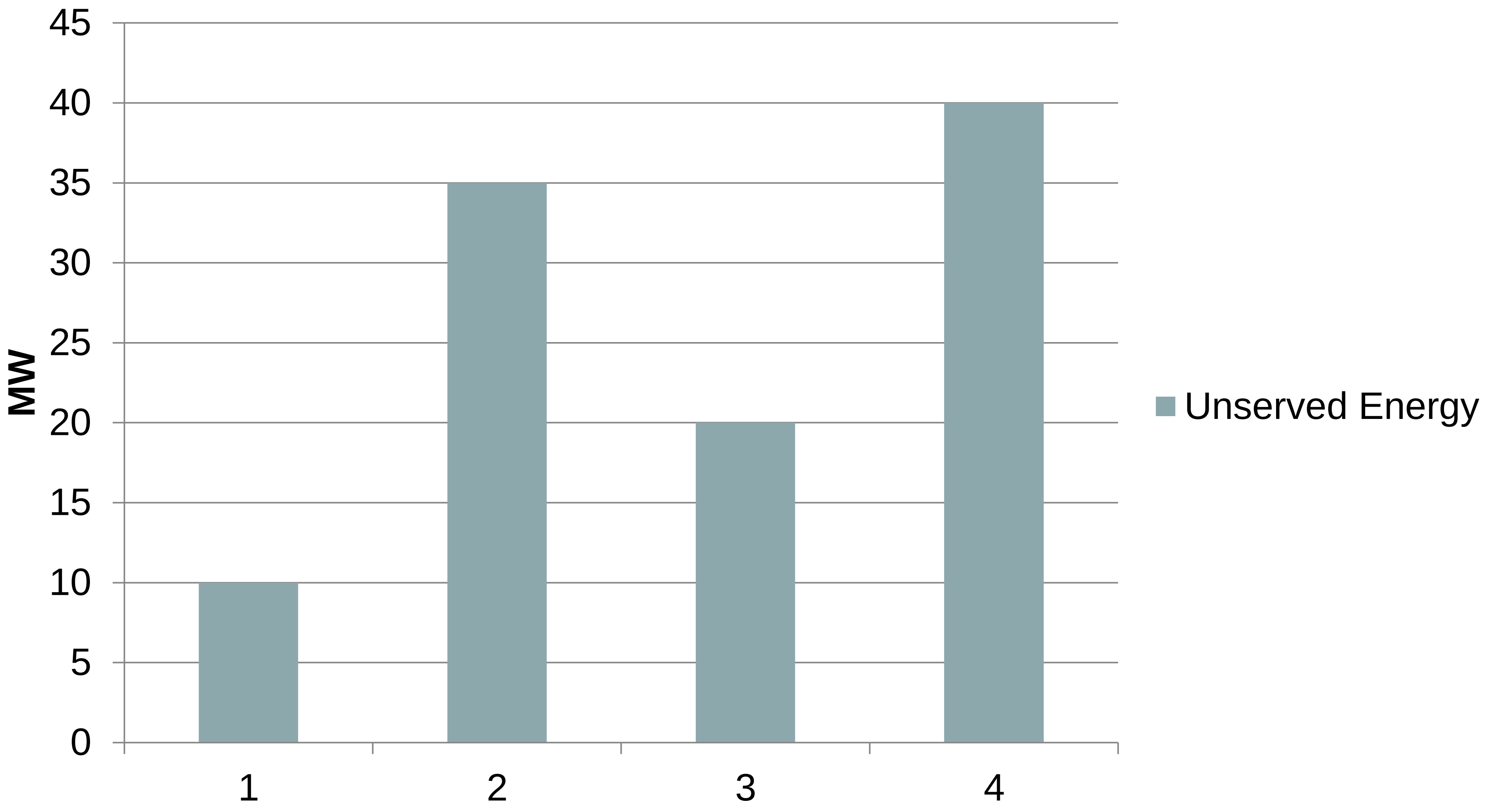
Sort periods in order of ascending unserved energy
(no ramping constraints on storage so periods can be reordered without loss of generality)

↓

For each period (i =1 .. N)
For each storage plant
"Spread output over remaining periods"
The capacity to use is the minimum of:
- Storage capacity / (N – i)
- Remaining unserved energy in the period
- Output capacity of the plant
- End when all plant are depleted or unserved energy is met.

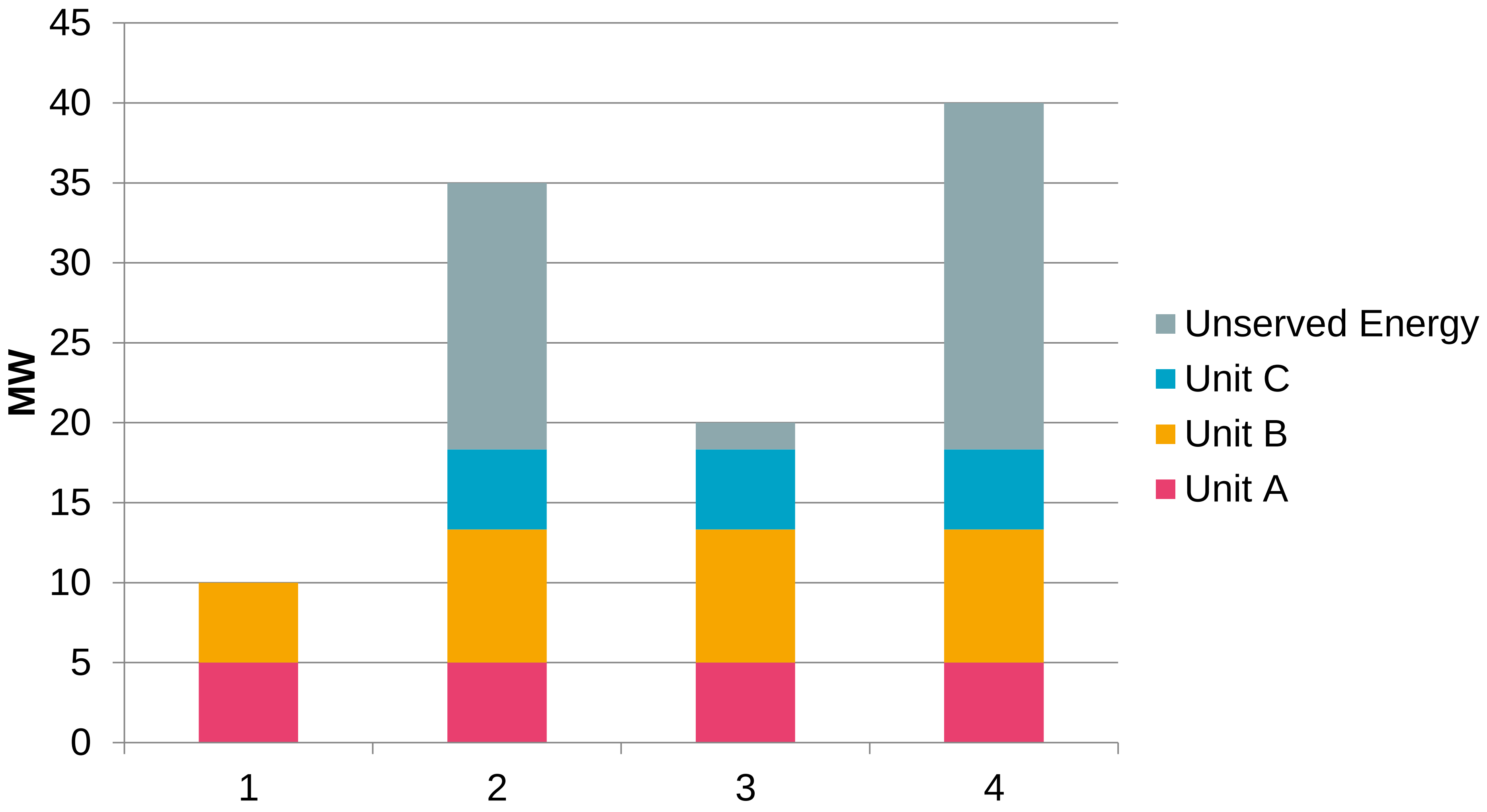
UEM Storage Algorithms

Algorithm 2: Mimic baseload generation



UEM Storage Algorithms

Algorithm 2: Mimic baseload generation



UEM Storage Algorithms

Algorithm 3: Minimise LOLE

In this scenario, the storage units are used to reduce LOLE as much as possible. The steps for this algorithm are identical to those for algorithm 1, with an additional first step.

Sort periods in order of ascending amount of energy unserved (as opposed to chronologically)

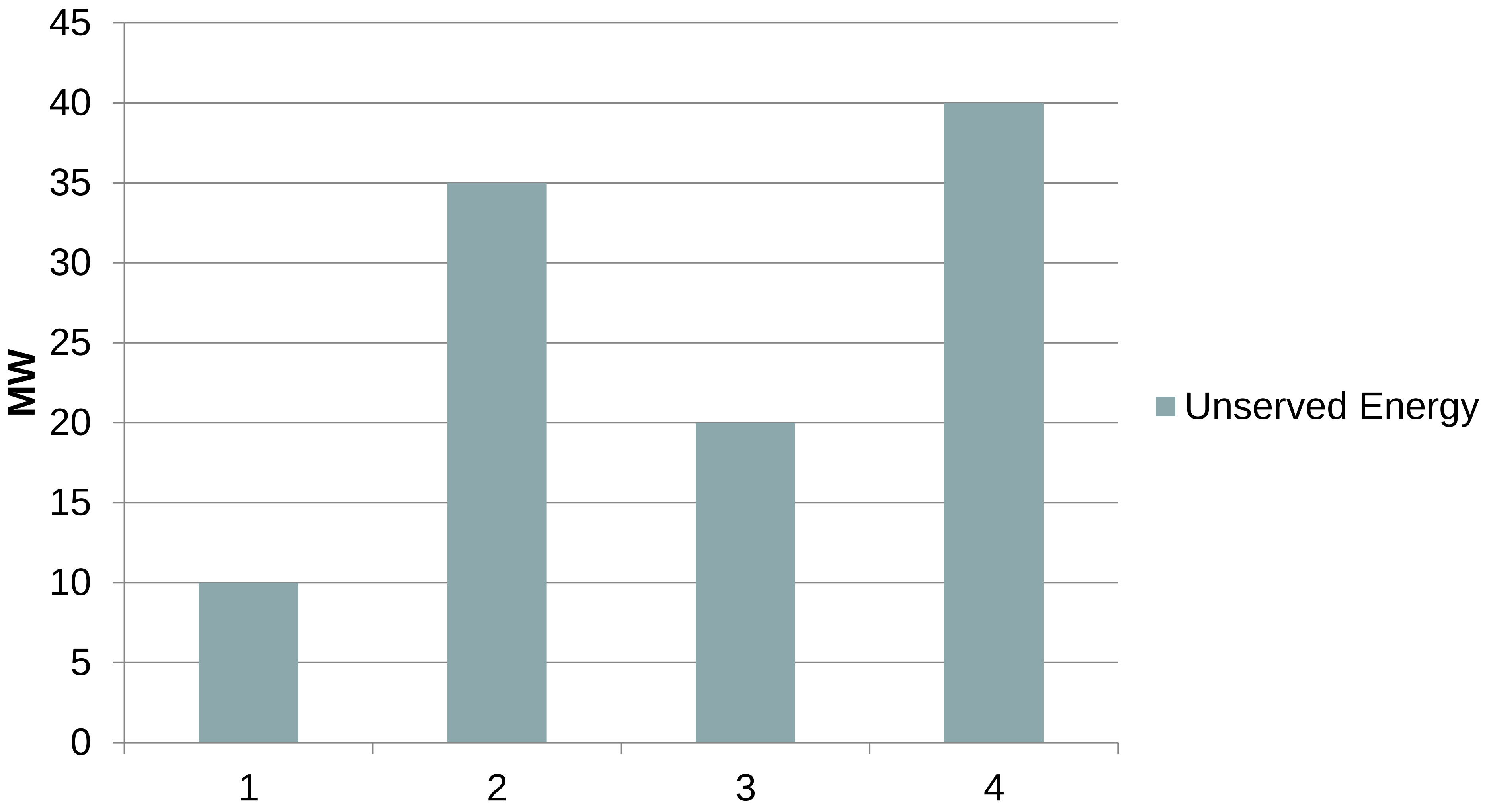
↓

Run Algorithm 1

This works because minimising LOLE is equivalent to serving the periods with lowest energy unserved first.

UEM Storage Algorithms

Algorithm 3: Minimise LOLE



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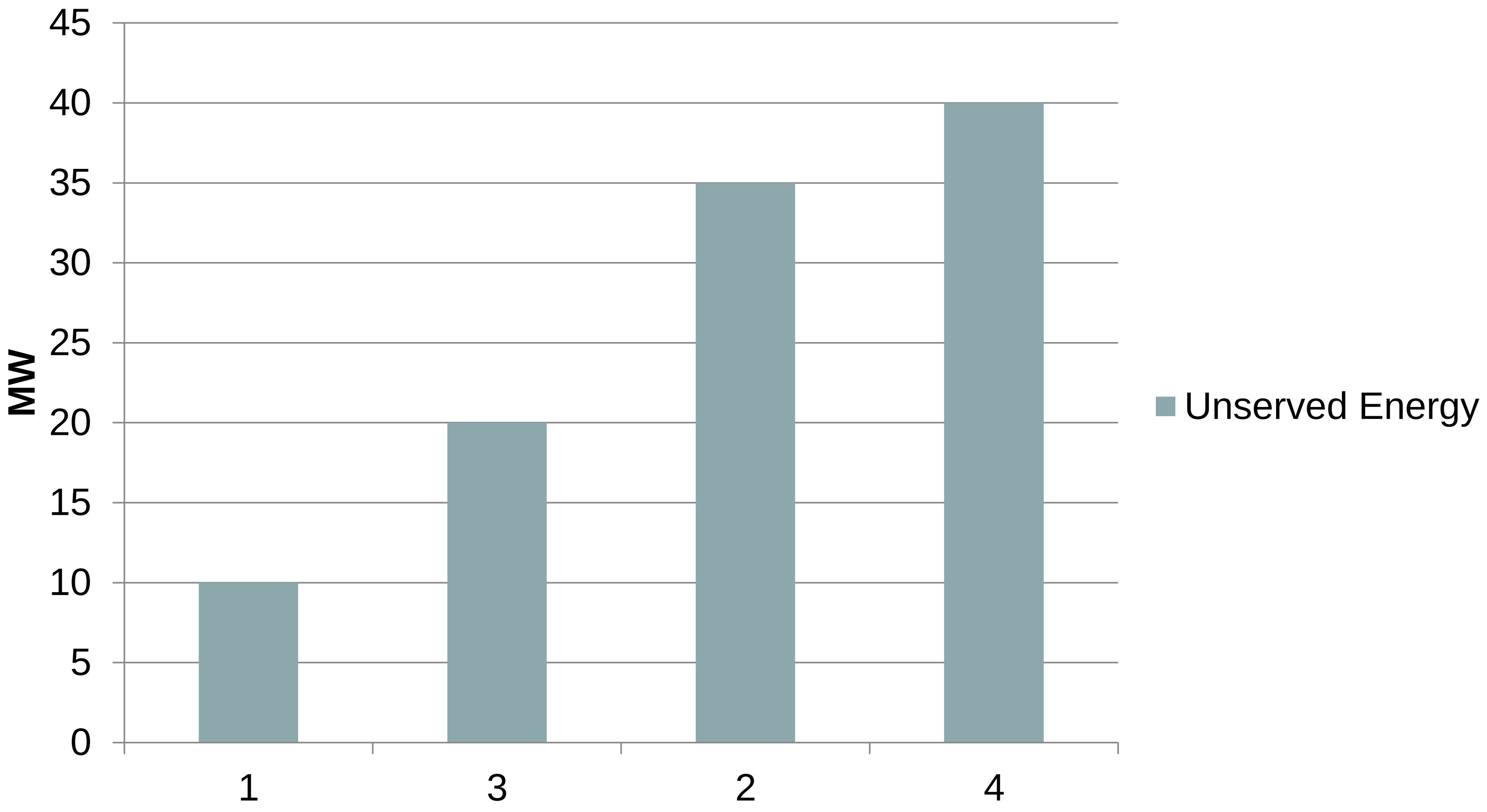
Algorithm 3: Minimise LOLE



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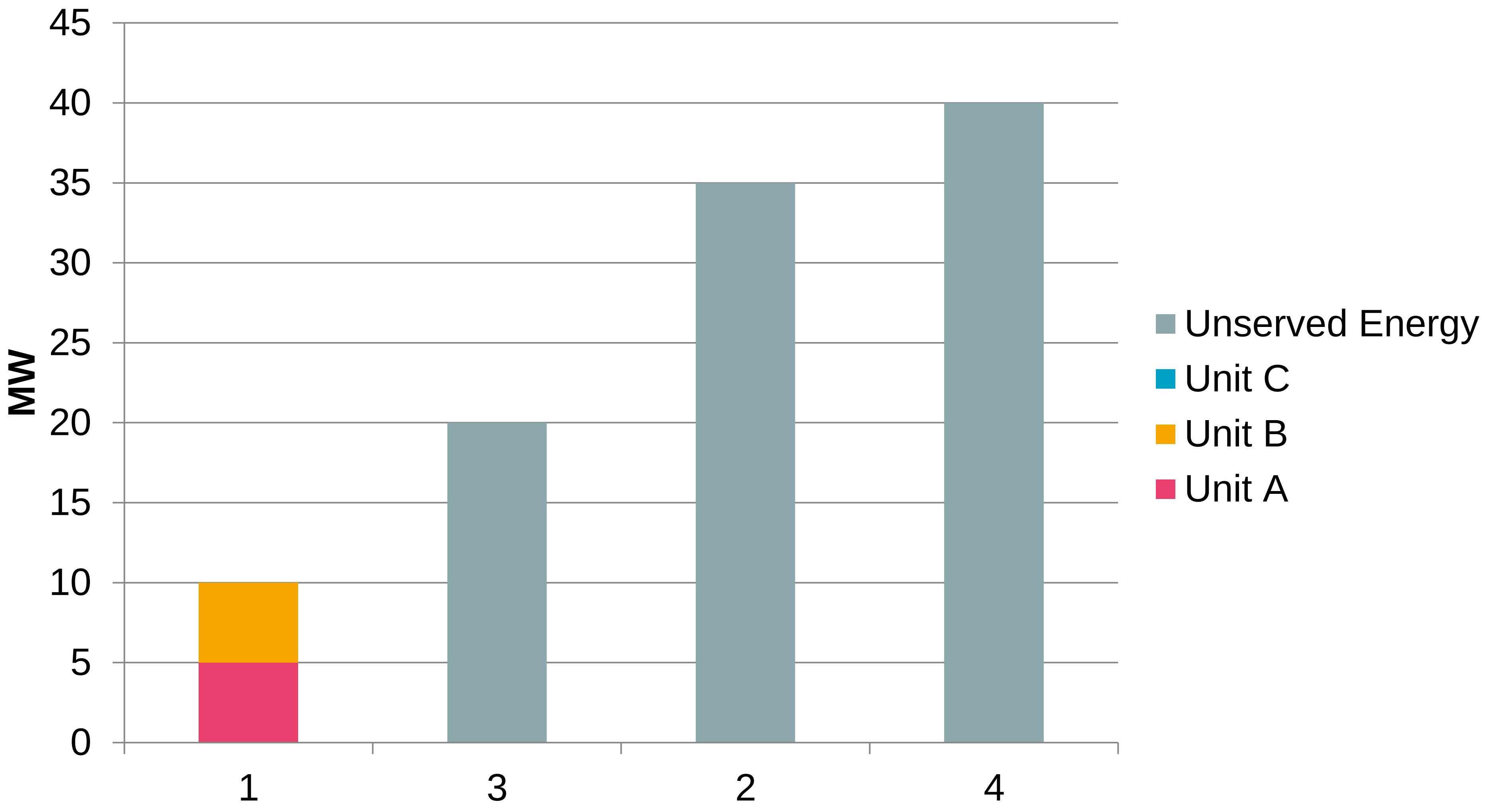
Algorithm 3: Minimise LOLE



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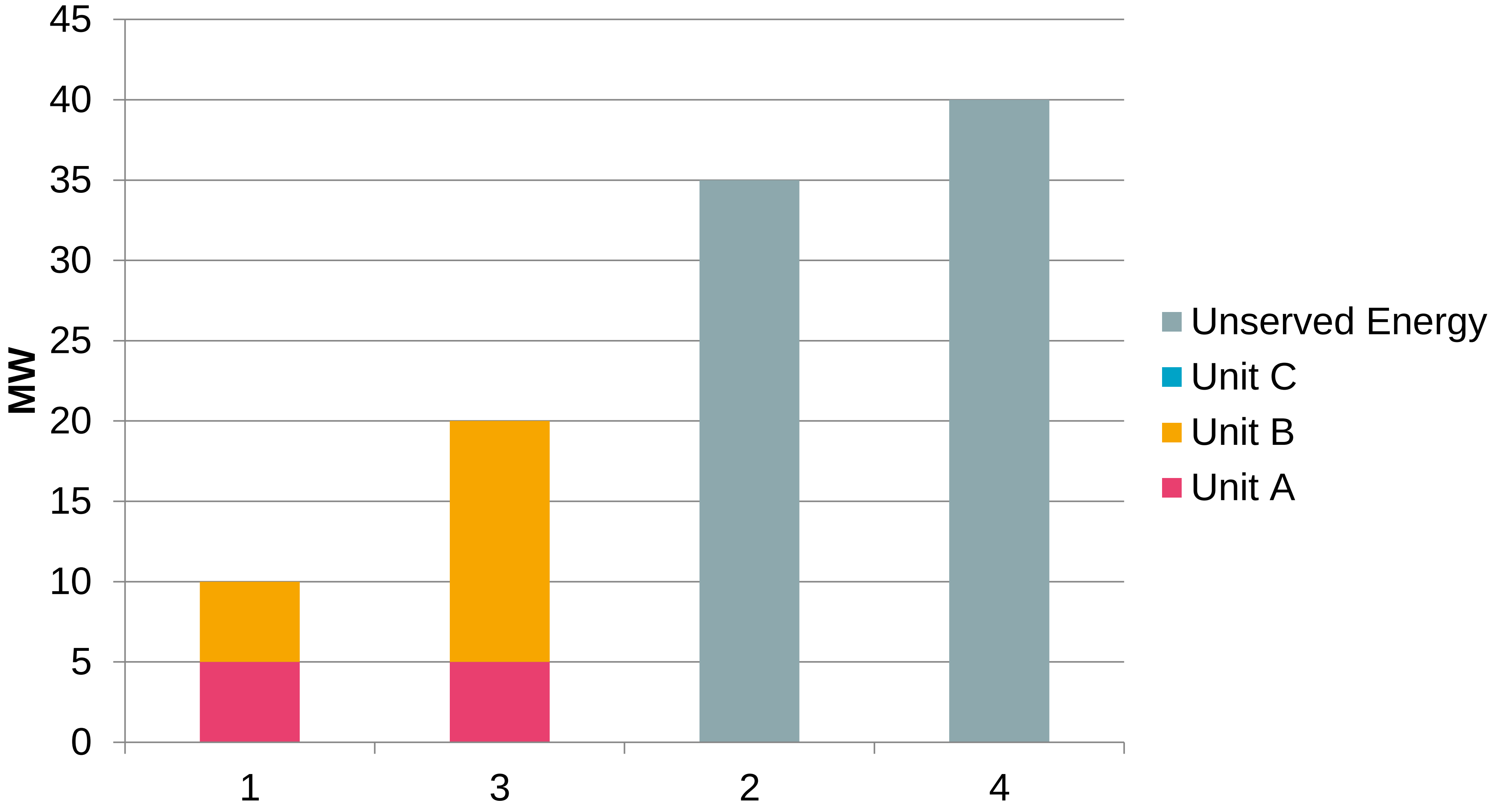
Algorithm 3: Minimise LOLE



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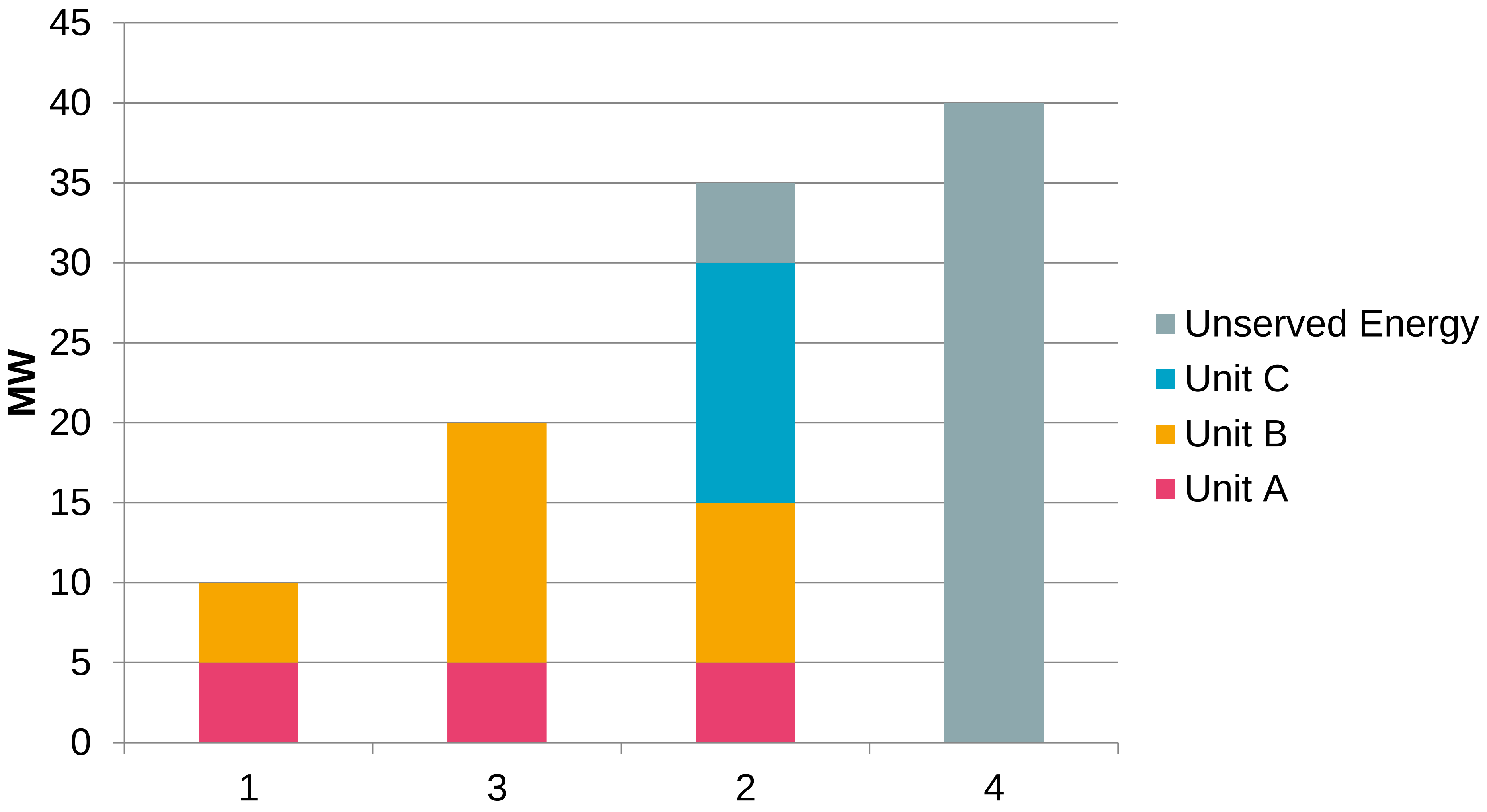
Algorithm 3: Minimise LOLE



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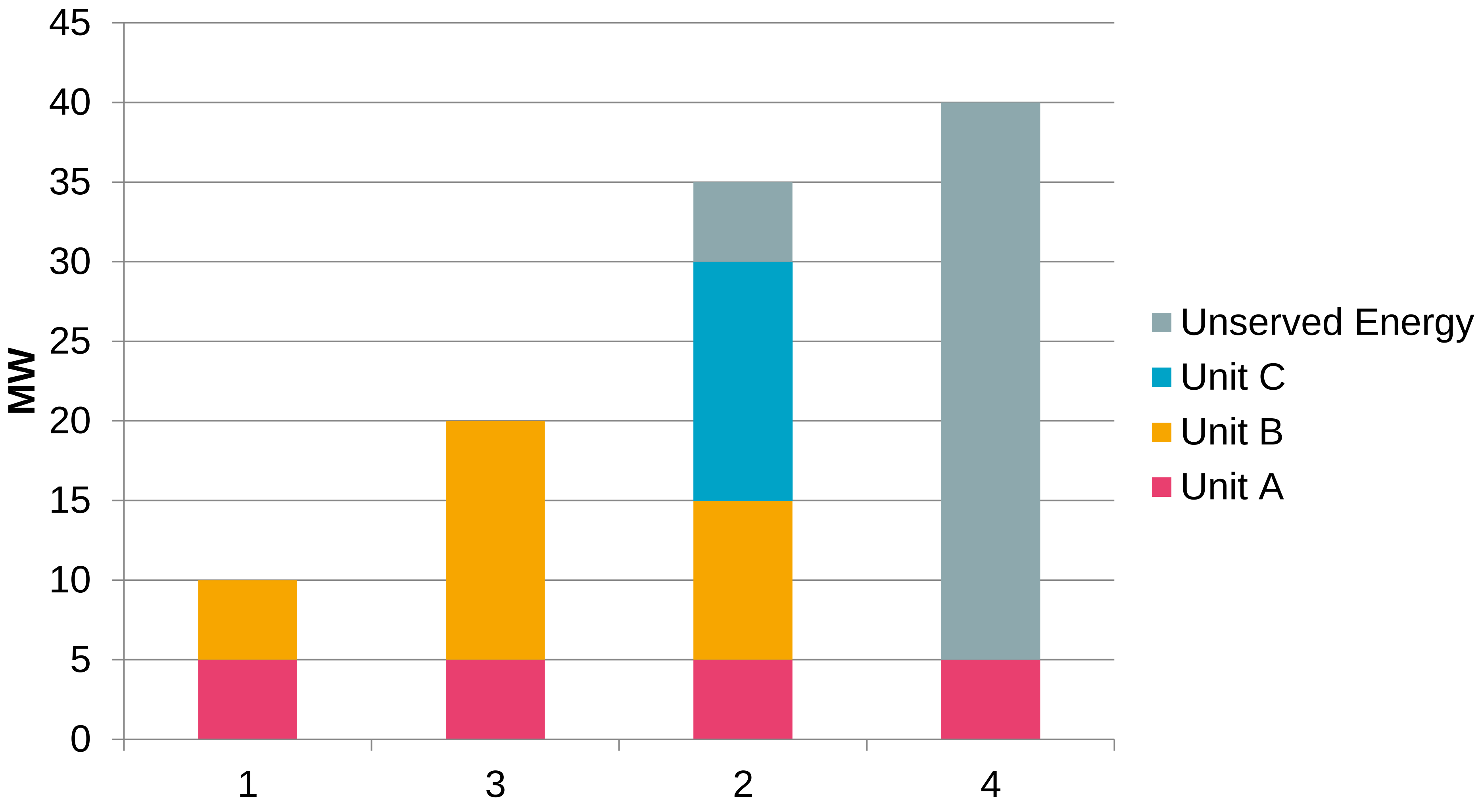
Algorithm 3: Minimise LOLE



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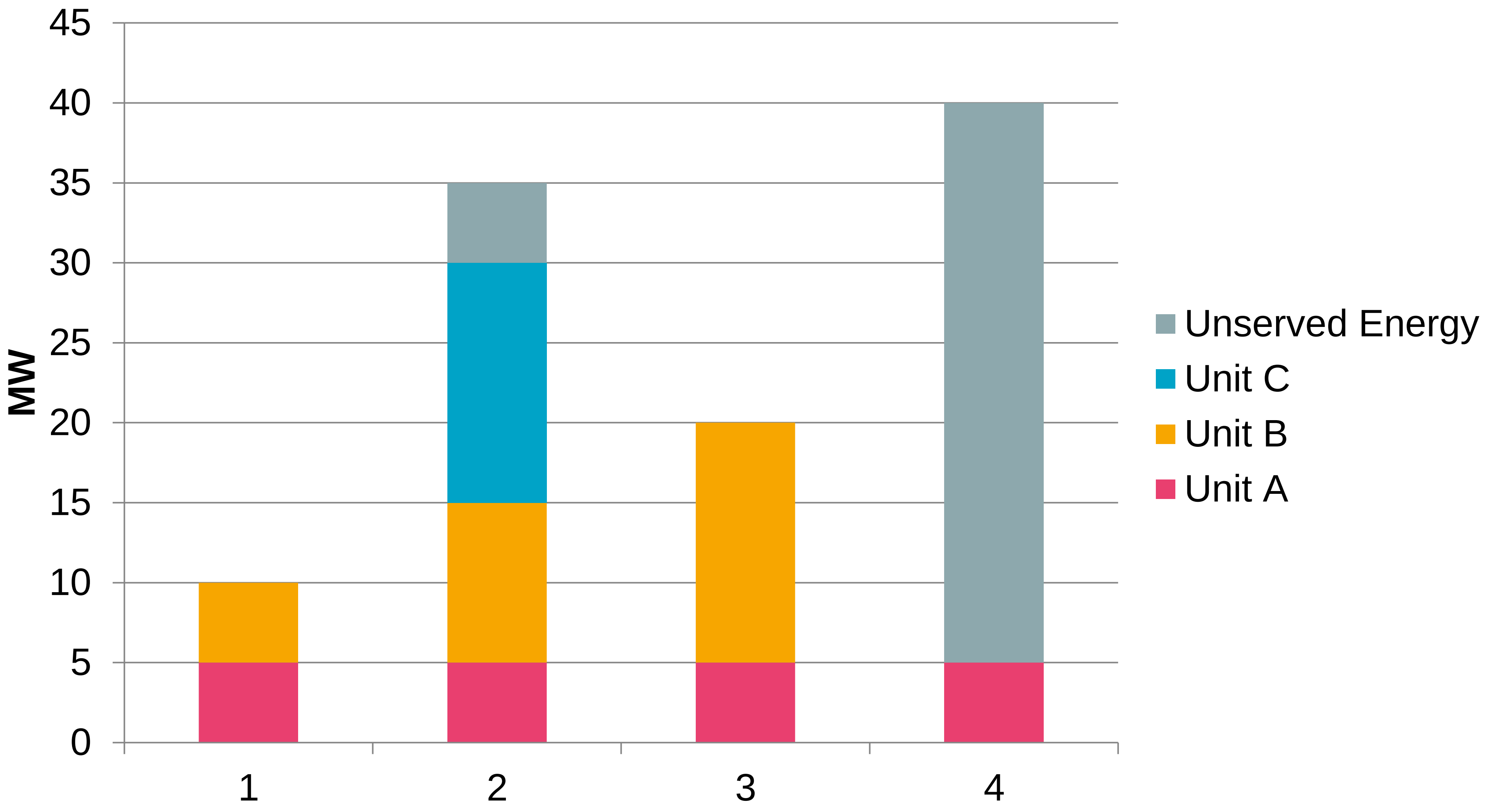
Algorithm 3: Minimise LOLE



UEM Storage Algorithms

Algorithm 4: Minimise shortfall

In this scenario, the storage units are mobilised so as to minimise the maximum amount of energy unserved in any period.

Sort storage units in order of descending duration

↓

Sort periods in order of descending amount of energy unserved (as opposed to chronologically)

↓

For each storage plant

"Spread output over periods with most energy unserved in which it is still possible to produce"

The capacity to use is the minimum of:

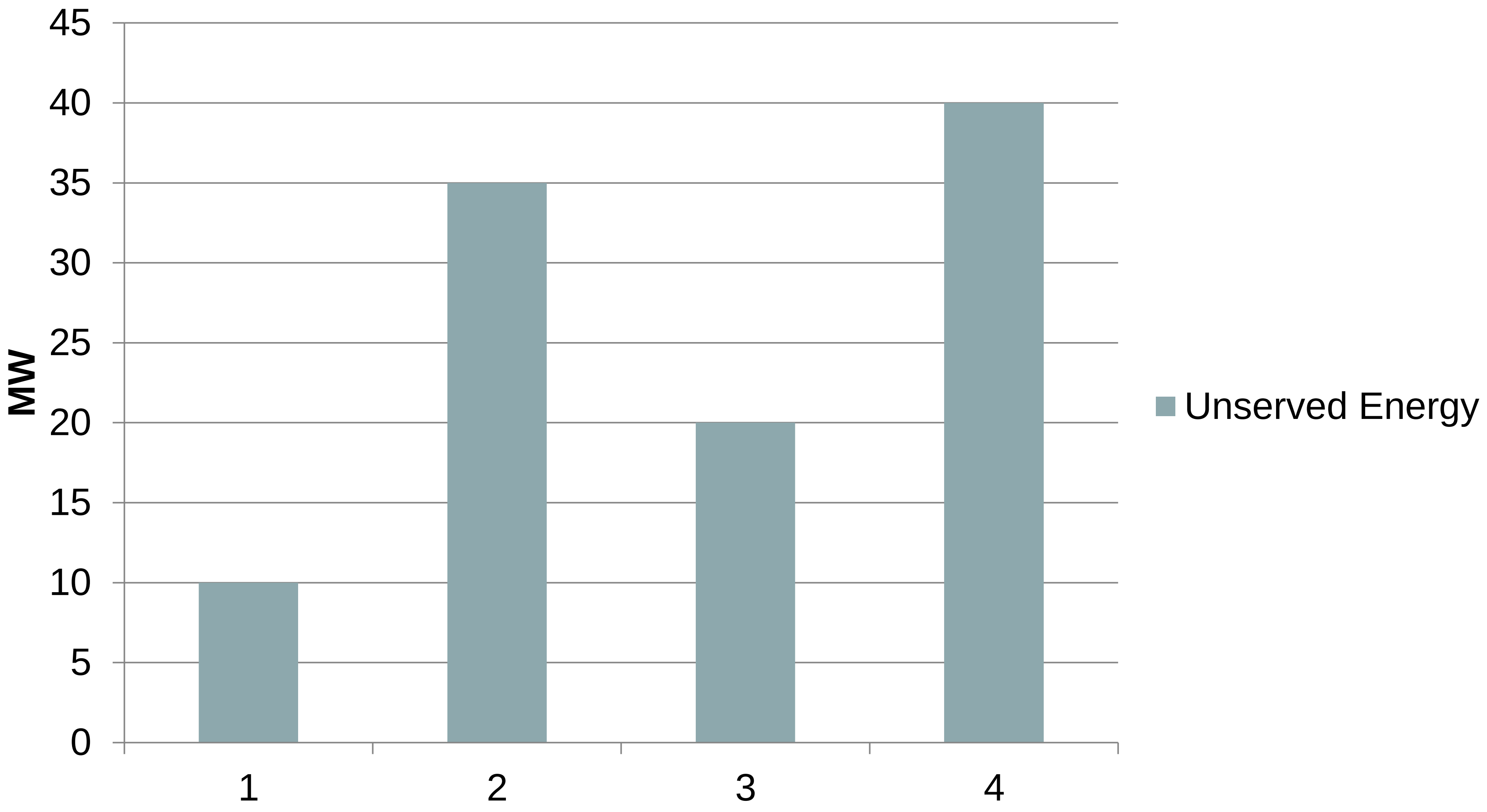
- Difference between largest and second largest level of energy unserved
- Minimum remaining output capacity of the plant in any applicable period
- Remaining storage capacity / number of applicable periods

Repeat until plant is depleted or all unserved energy is met

- End when all plant are depleted or all unserved energy is met.

UEM Storage Algorithms

Algorithm 4: Minimise shortfall



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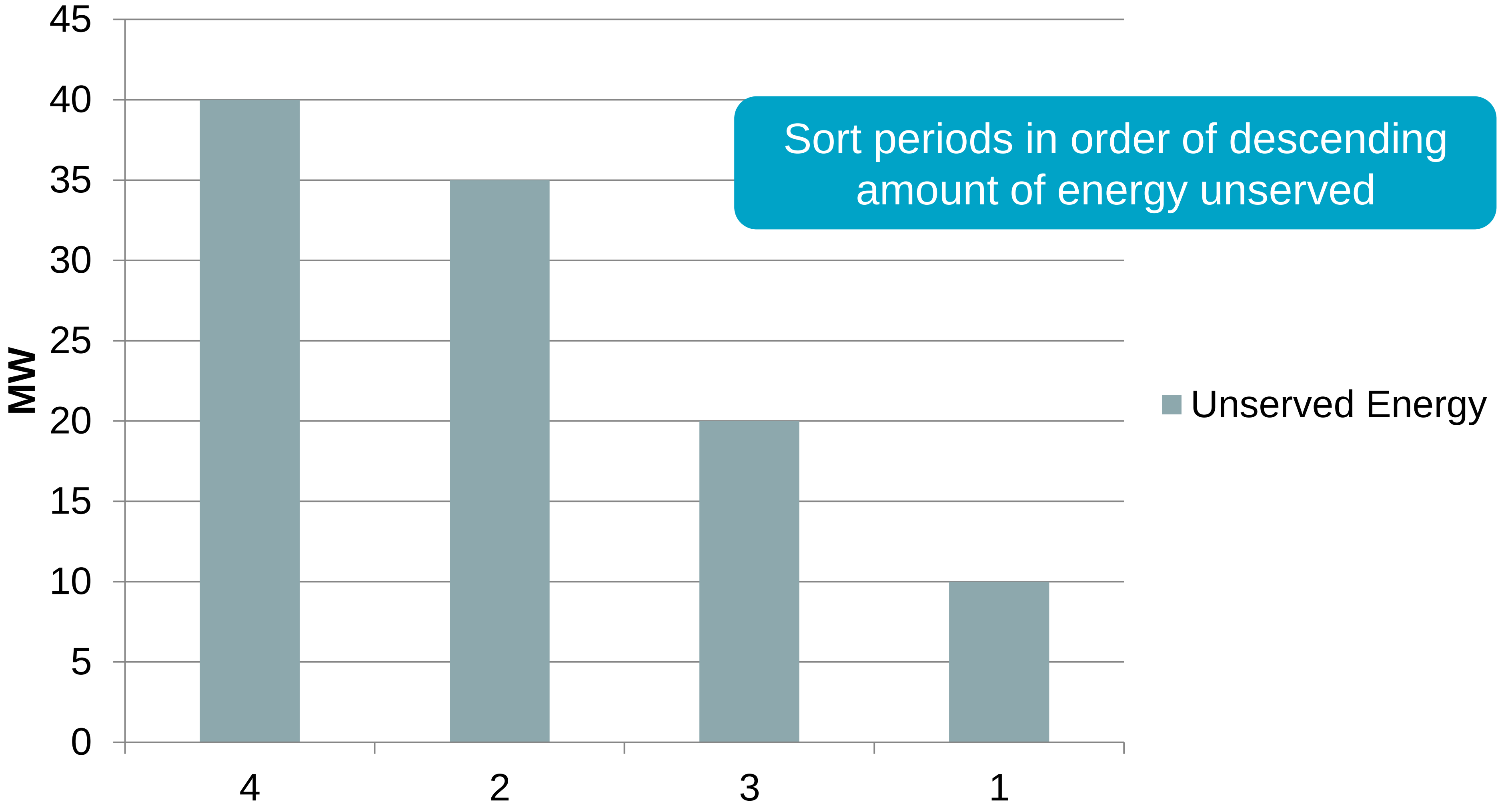
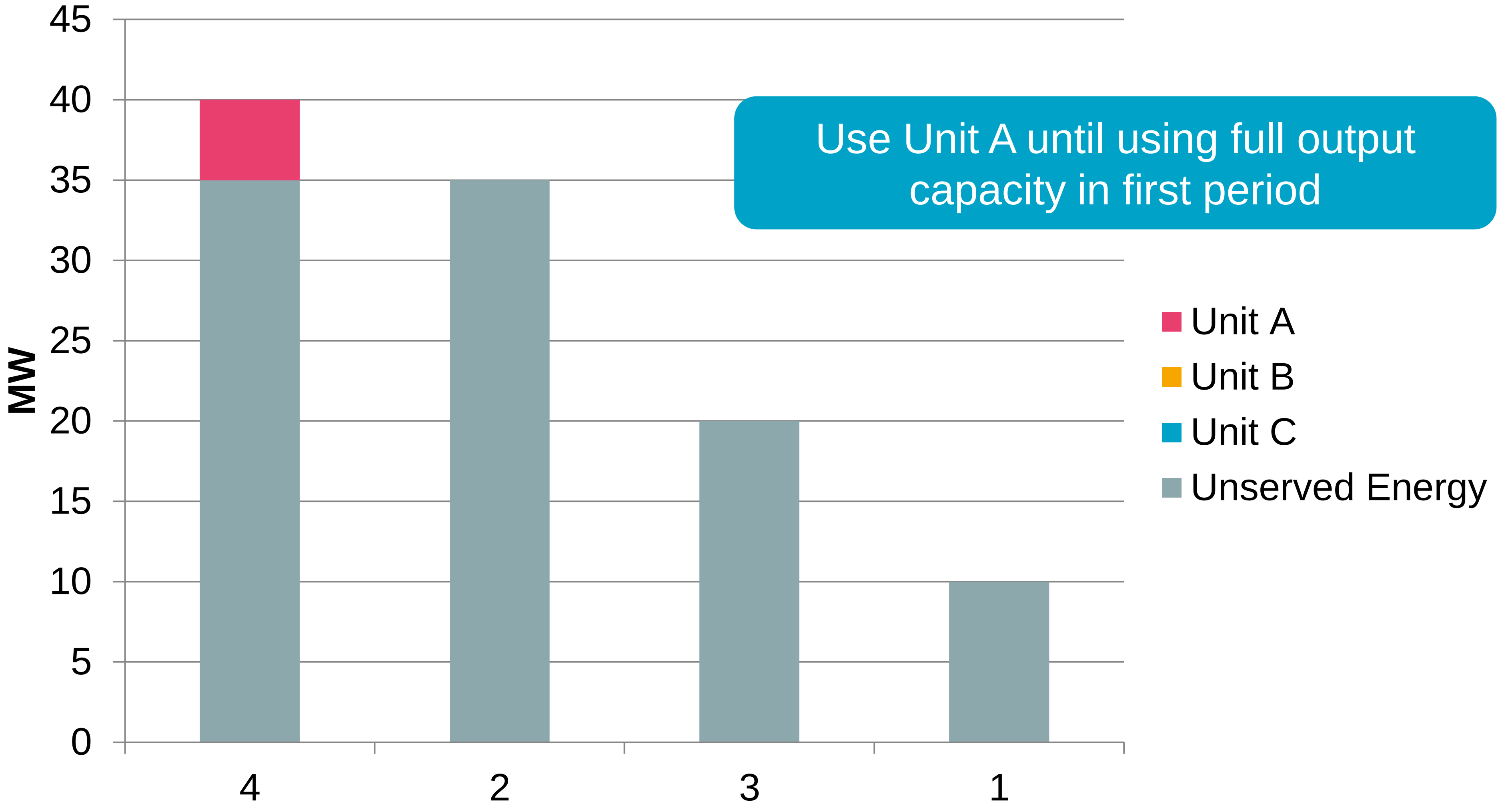
Algorithm 4: Minimise shortfall



Sort periods in order of descending amount of energy unserved

UEM Storage Algorithms

Algorithm 4: Minimise shortfall



Use Unit A until using full output capacity in first period

This also corresponds to reducing the remaining energy unserved in period 4 to the same level as period 2, so if Unit A had a higher output capacity it would then start to split across both periods

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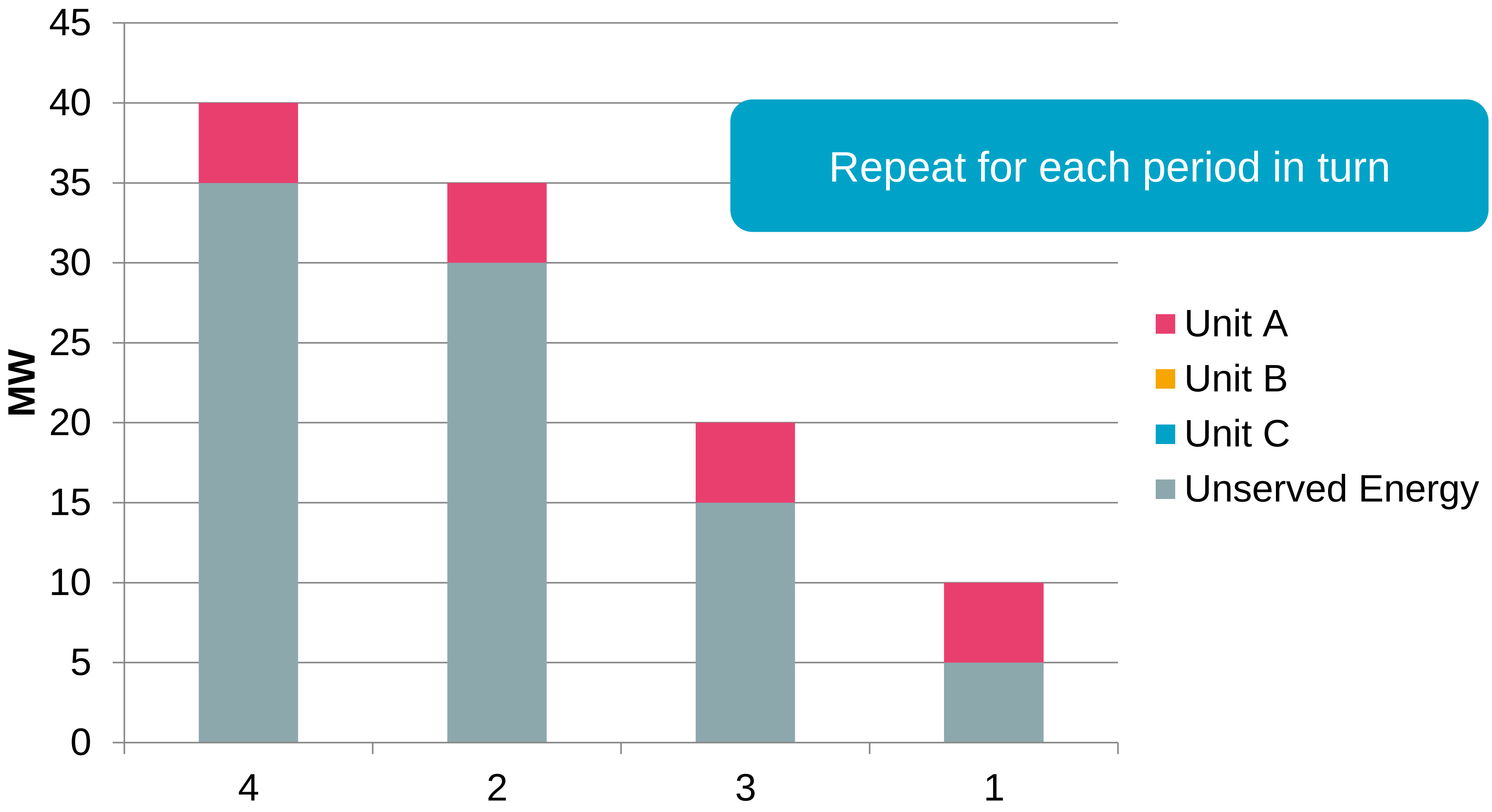
Algorithm 4: Minimise shortfall



Repeat for each period in turn

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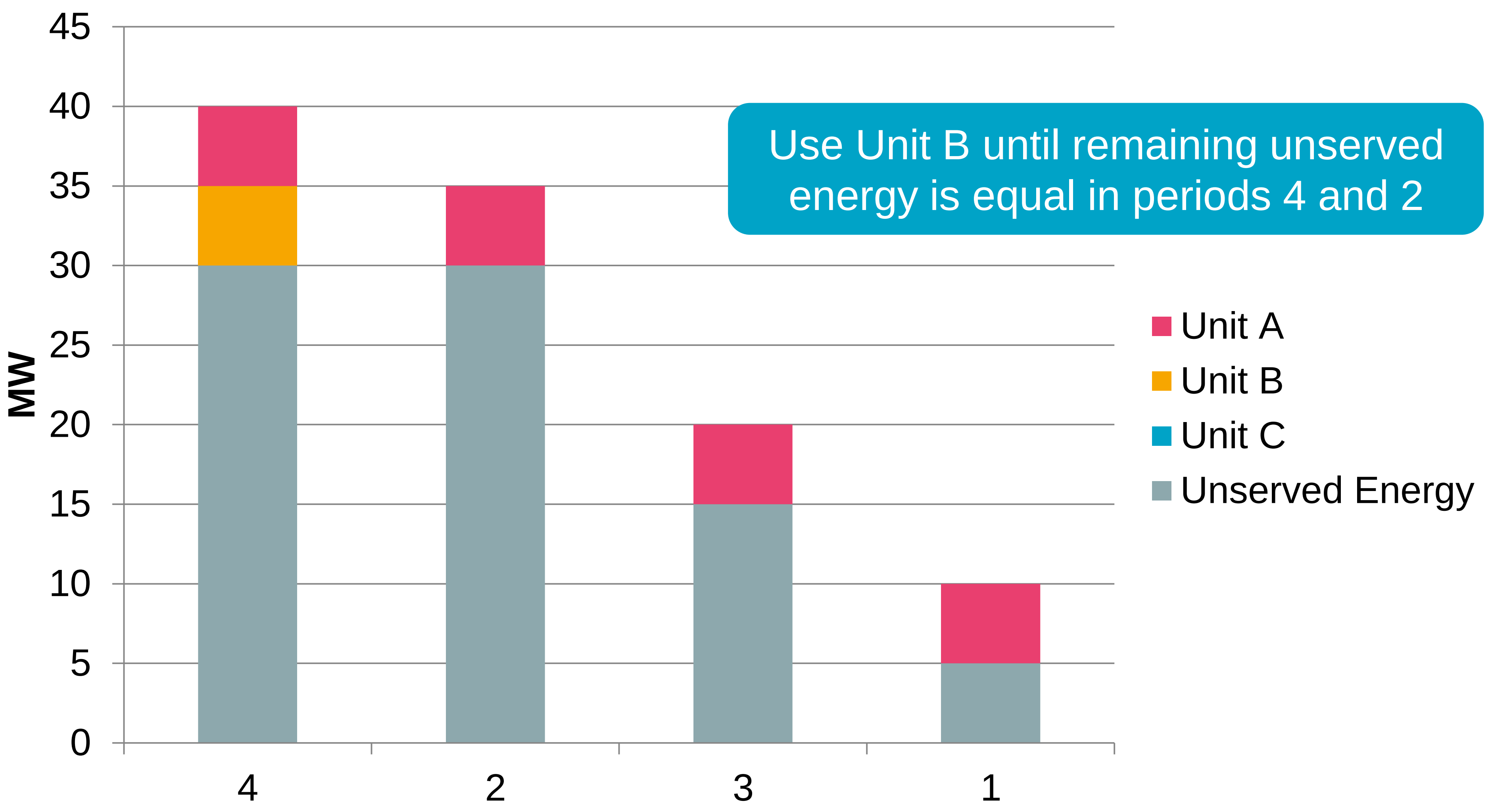
Algorithm 4: Minimise shortfall



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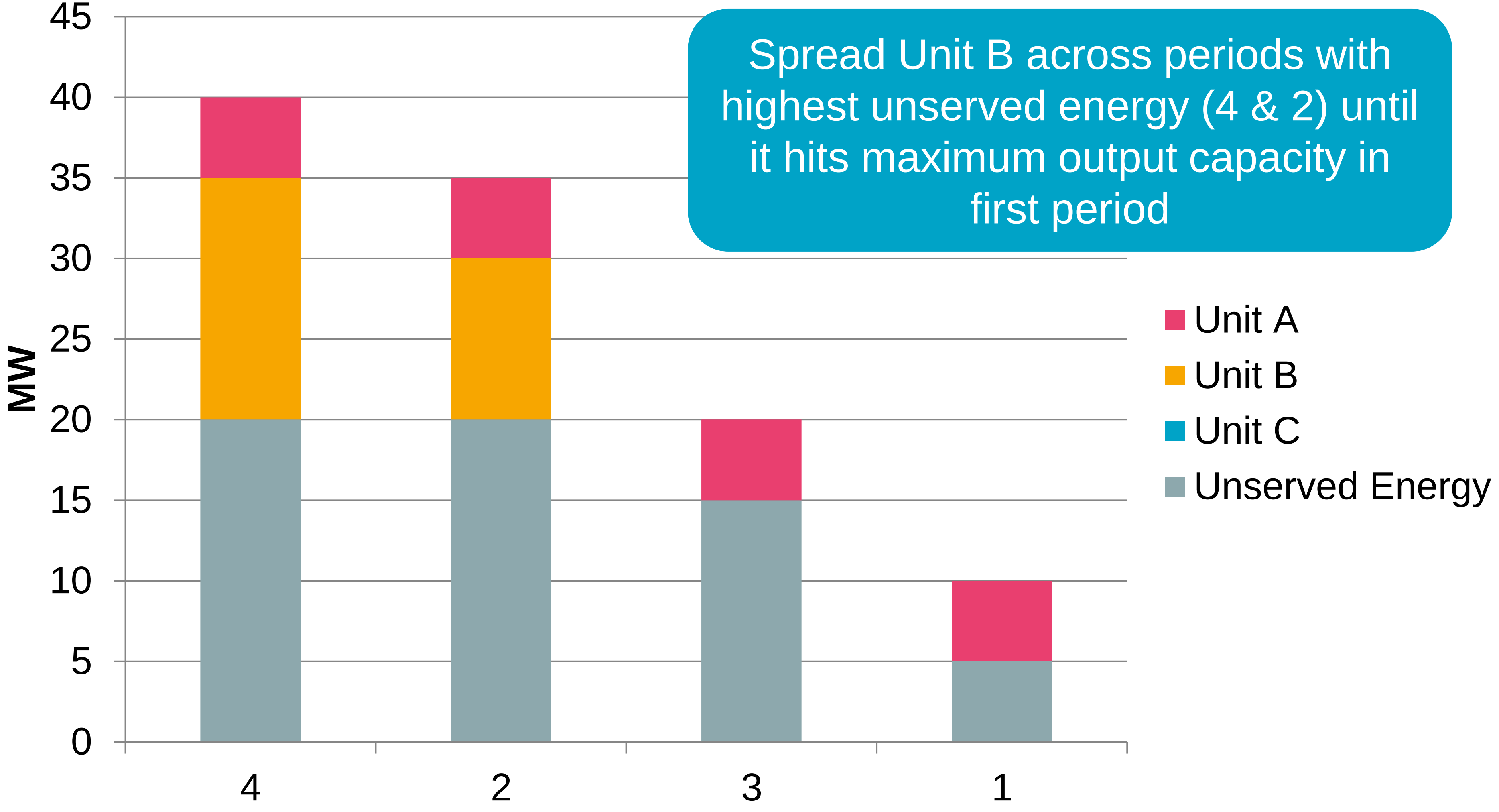
Algorithm 4: Minimise shortfall



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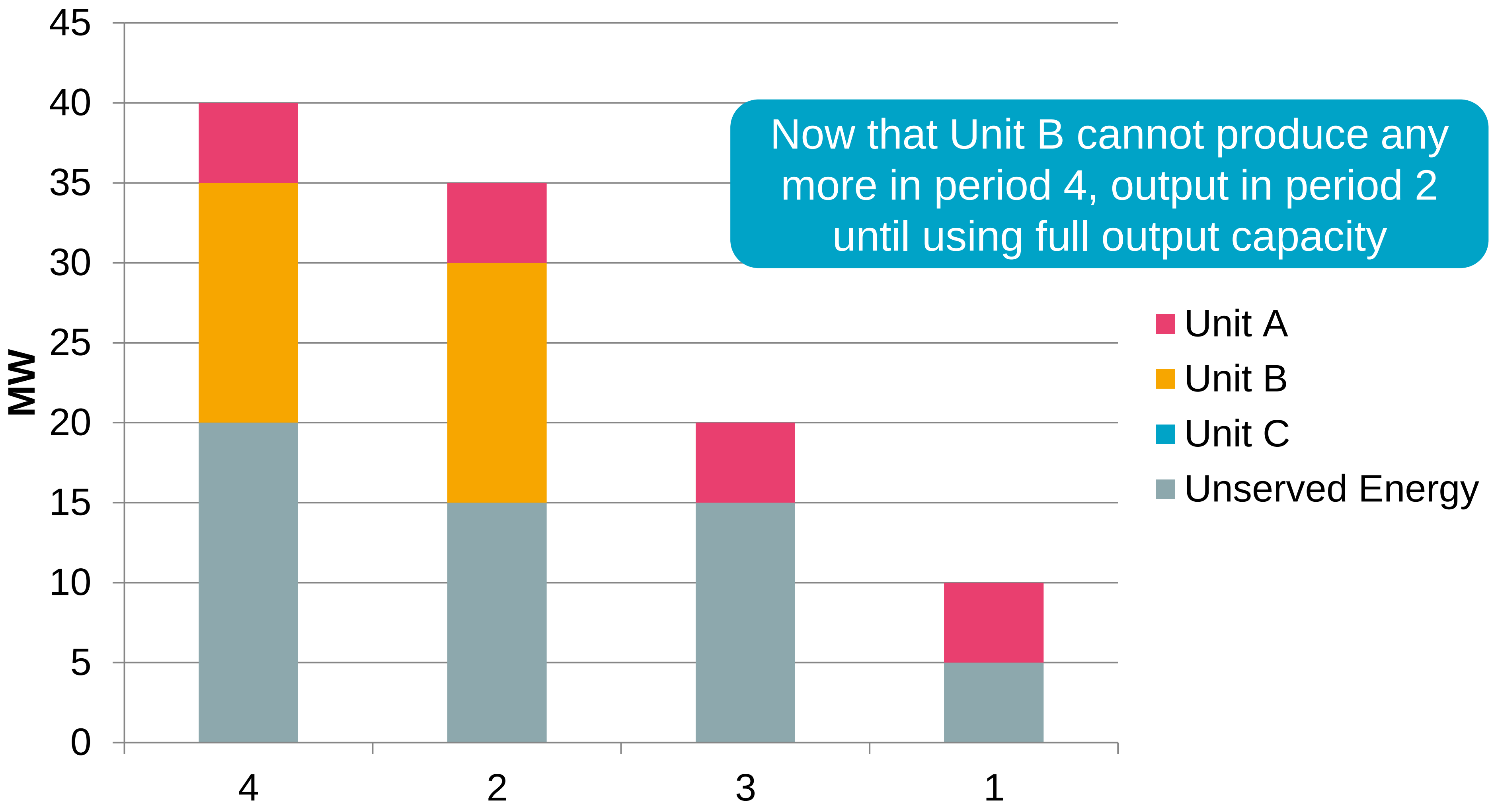
Algorithm 4: Minimise shortfall



Now that Unit B cannot produce any more in period 4, output in period 2 until using full output capacity

This also corresponds to reducing the remaining energy unserved in period 2 to the same level as period 3, so if Unit B had a higher output capacity it would then split across both periods

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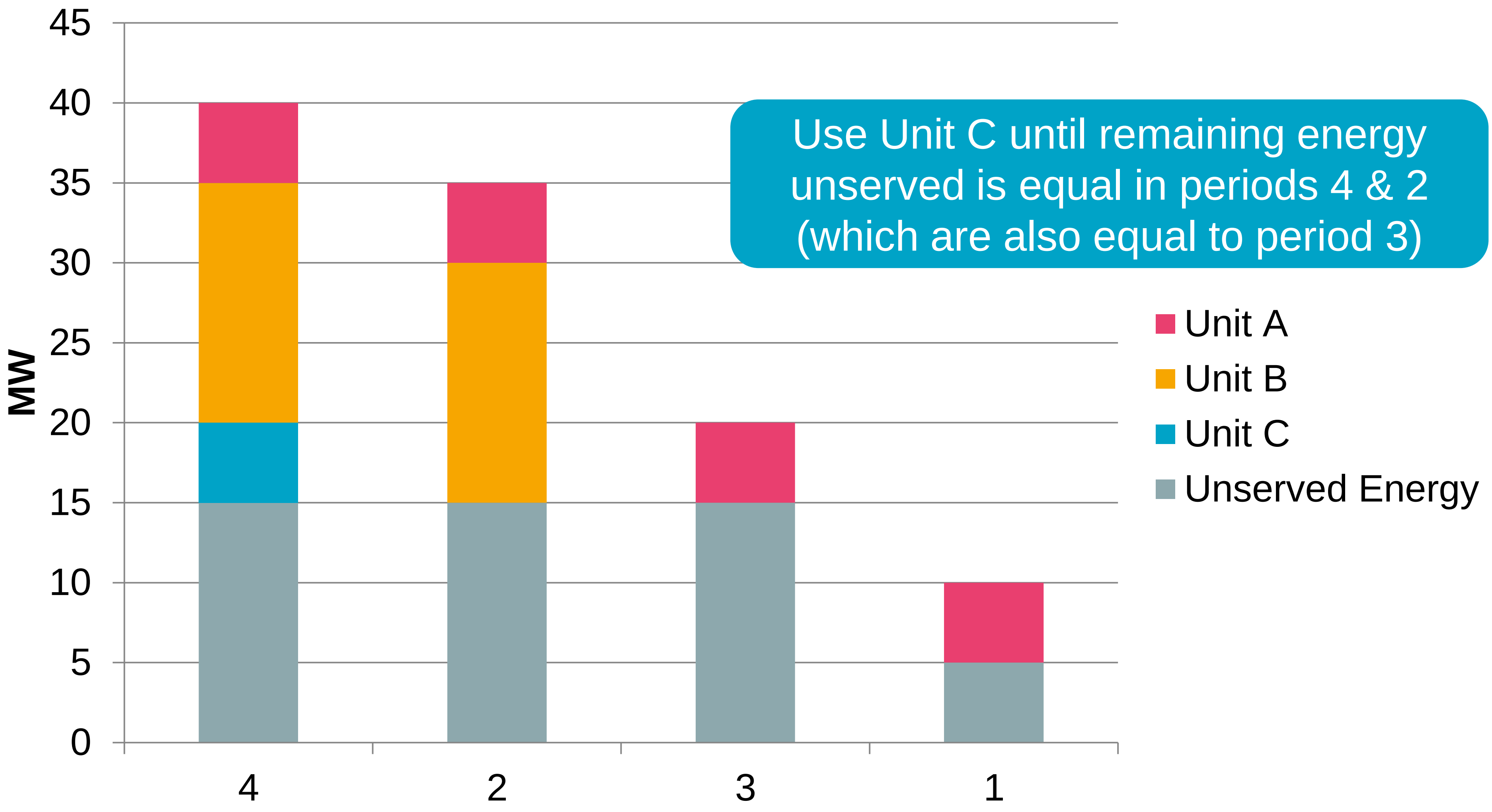
Algorithm 4: Minimise shortfall



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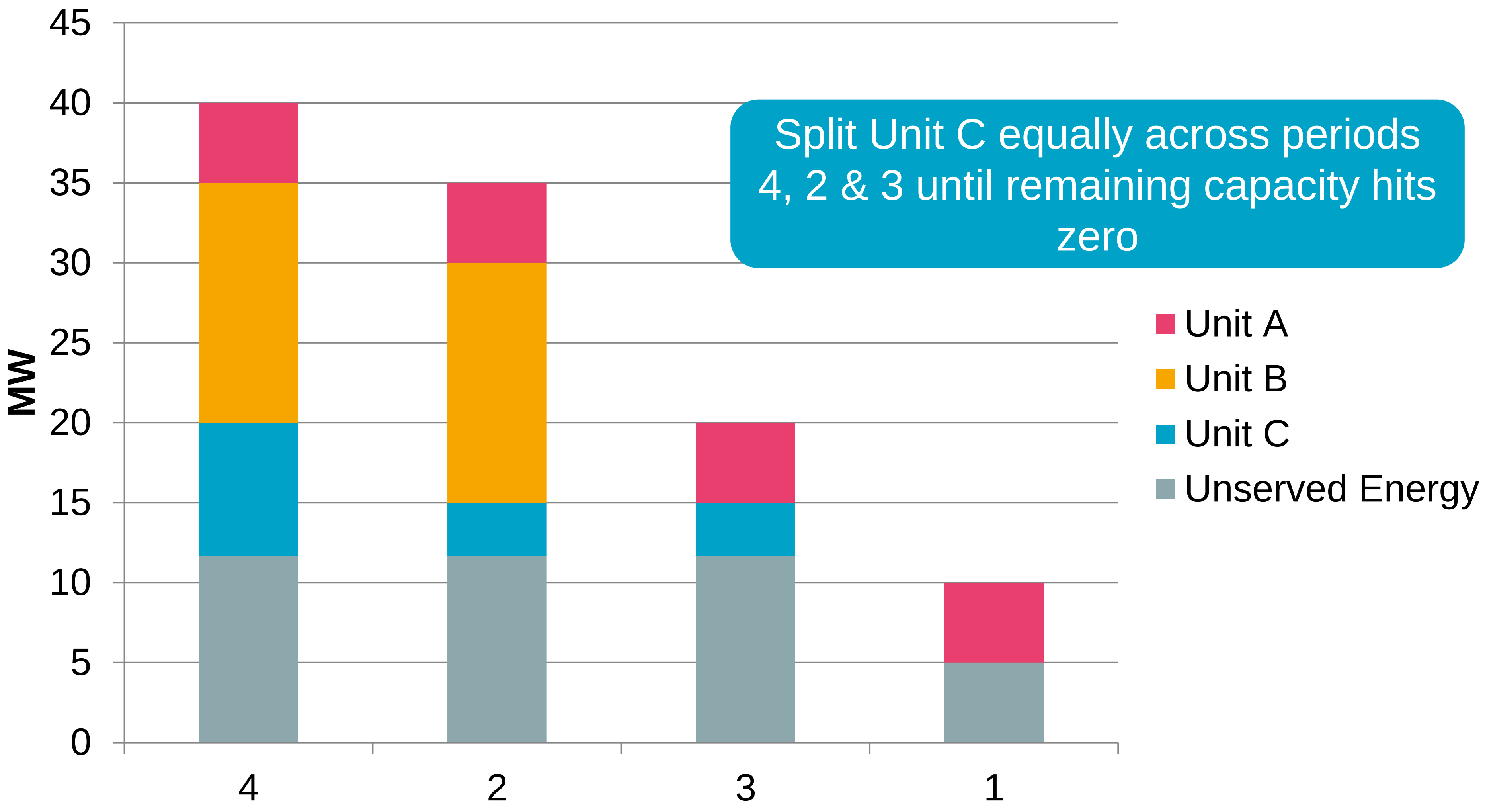
Algorithm 4: Minimise shortfall



Approach to calculating EFCs and related metrics

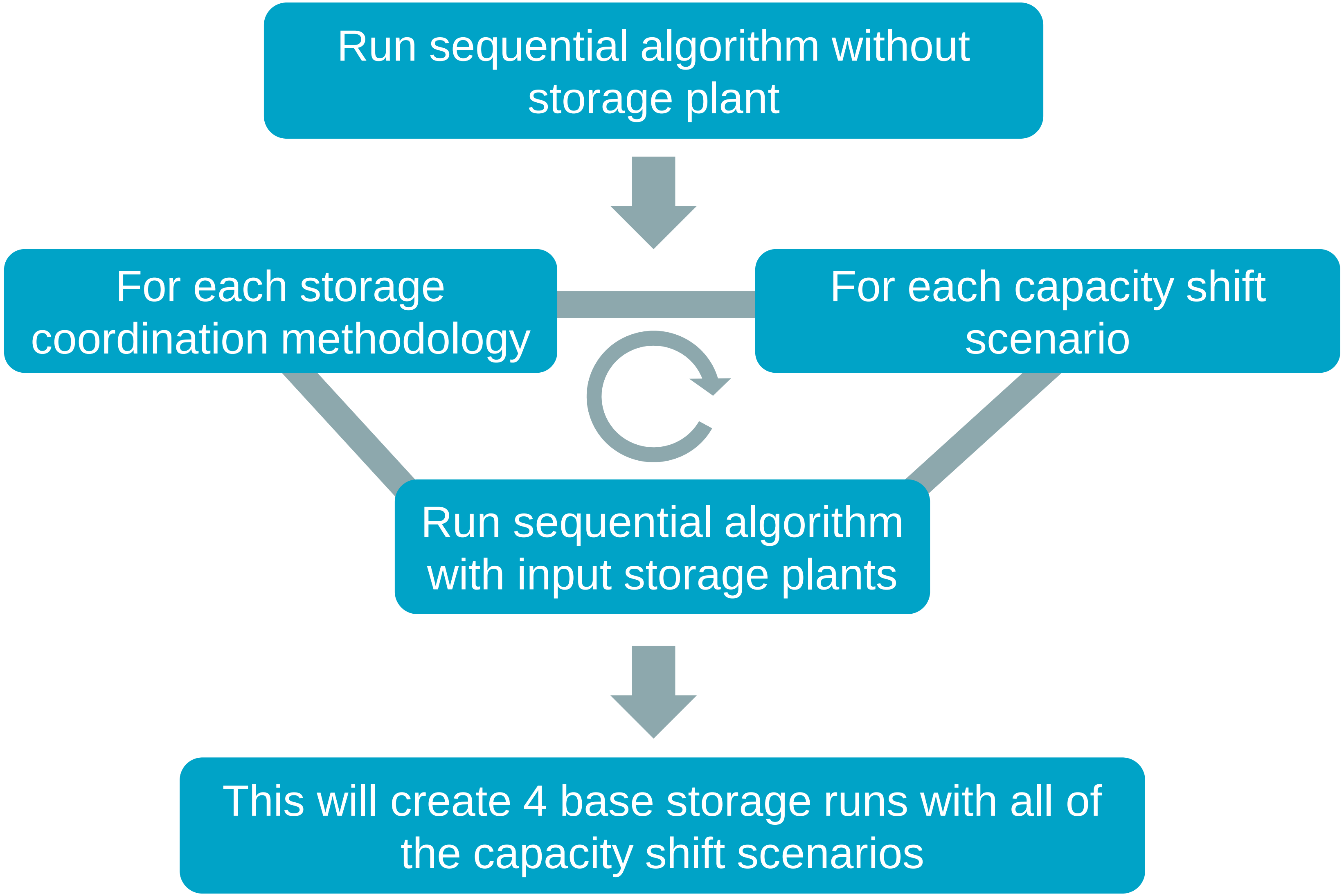
Calculating EFCs

Overview

- The algorithms above give us 4 approaches to arrive at different unserved energy metrics. This can then be used to calculate EFC and related metrics.
- For this analysis we are attempting to calculate marginal equivalent firm capacity (EFC) percentages as potential Capacity Market derating factors. These will vary for different types storage capacity / output capacity ratios.
- The marginal EFCs should be taken from a base point with a fleet giving a LOLE of 3 hours.

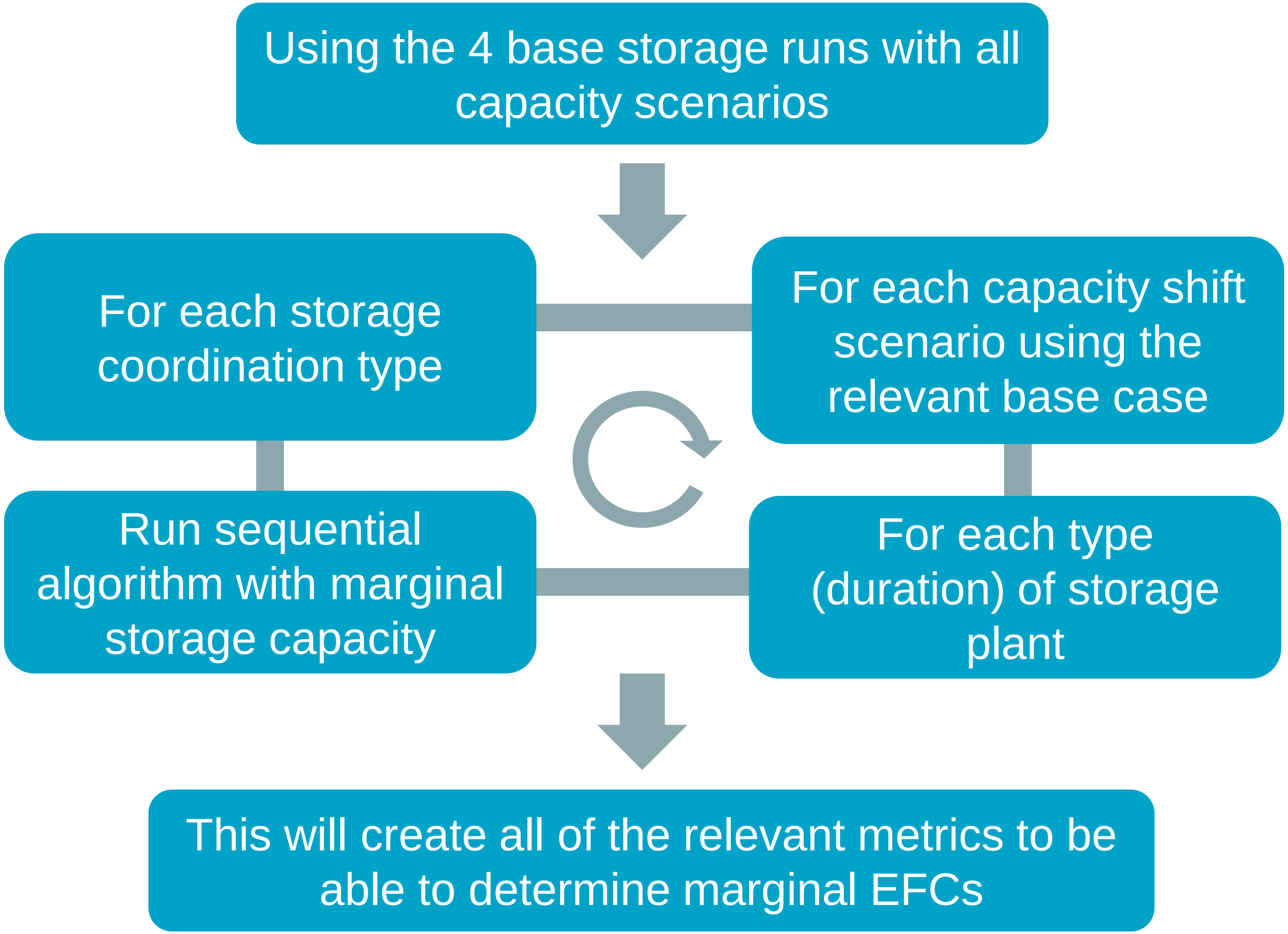
Stages – per simulation

Methodology



Stages – per simulation

Methodology



Calculating EFCs

Methodology

To calculate the EFC on an EEU basis the following calculation performed.

1. Determine the MW capacity shift that produces a LOLE of 3 in the relevant coordination base case (linearly interpolate to find exact capacity shift); record interpolated EEU value
2. For each storage type, from the same MW capacity shift, find the outturn EEU. Interpolate again if required.
3. In the relevant coordination base case, find the firm MW capacity shift that gives the same EEU as in the marginal case.
4. The EFC percentage for each storage type is then:

$$\frac{Firm\ capacity\ shift\ from\ 3\ -\ firm\ capacity\ shift\ from\ 1}{Chosen\ marginal\ capacity}$$

N.B. Marginal capacity amounts will be an user defined option

Calculating EFCs

Example

In the example below co-ordination 1 is used to identify the shift that gives a LOLE of 3 (interpolation will be required in all stages in practice).

LOLE Table									
		With base storage				With base storage + 100MW of storage type 1			
Shift	No storage	Coordination 1	Coordination 2	Coordination 3	Coordination 4	Coordination 1	Coordination 2	Coordination 3	Coordination 4
-2000									
-1950									
-1900									
-1850									
-1800									
-1750									
-1700									
-1650									
-1600									
-1550	6.00	3.00	3.10	2.90	3.20	2.80	2.70	2.60	2.90
-1500									
-1450									
-1400									
-1350									
-1300									
-1250									
-1200									
-1150									
-1100									
-1050									
-1000									
-950									

Calculating EFCs

Example

The table below shows the equivalent EEU for the defined shift scenario, and the reduction for adding 100MW of a given storage type.

We can then determine the shift that gives the same EEU (shown in blue).

The EFC percentage for storage type 1 in this example is:

$$50\% = (1550 - 1500) / 100MW$$

EEU Table

		With base storage				With base storage + 100MW of storage type 1			
Shift	No storage	Coordination 1	Coordination 2	Coordination 3	Coordination 4	Coordination 1	Coordination 2	Coordination 3	Coordination 4
-2000									
-1950									
-1900									
-1850									
-1800									
-1750									
-1700									
-1650									
-1600									
-1550	35000	10000	10000	10000	10000	9333	9333	9333	9333
-1500	33400	9333	9333	9333	9333	9100	9100	9100	9100
-1450									
-1400									
-1350									
-1300									
-1250									
-1200									
-1150									
-1100									
-1050									
-1000									
-950									

Calculating EFCs

Summary

- This approach also allows
  - EFC calculations based on LOLE as well as EEU
  - Any approach to defining what methodology defines a LOLE 3

  Based on a single run.
- The output template would show all EFCs directly, based on a EEU or LOLE method.
- We don't anticipate that this will extend the run time by a significant amount due to the low frequency of events. However, this will depend on the following inputs:
  - Number of MW capacity shift scenarios (this is defined how close the base run is to a LOLE of 3 and how much interpolation is view as acceptable)
  - Number of storage types (durations)

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LCP's Energy Analytics practice has been at the heart of Electricity Market Reform (EMR) analysis since the first design proposals. We provide analytic and consulting services that support the industry in understanding the impacts of these significant reforms to the GB power market. We also provide some of the key tools in the industry, including the Dynamic Dispatch Model that is used by BEIS and National Grid for analysis such as the final EMR delivery plan and the setting of the capacity requirement for the annual GB capacity auctions. More widely we support our clients to understand how these fundamental changes to the market will affect portfolio profitability and risk over the medium to long term. We provide a range of services including asset valuation, impact analysis and strategic advice.

If you would like any assistance or further information, please contact Tom Porter, tom.porter@lcp.uk.com, who heads up our Energy Analytics practice.

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