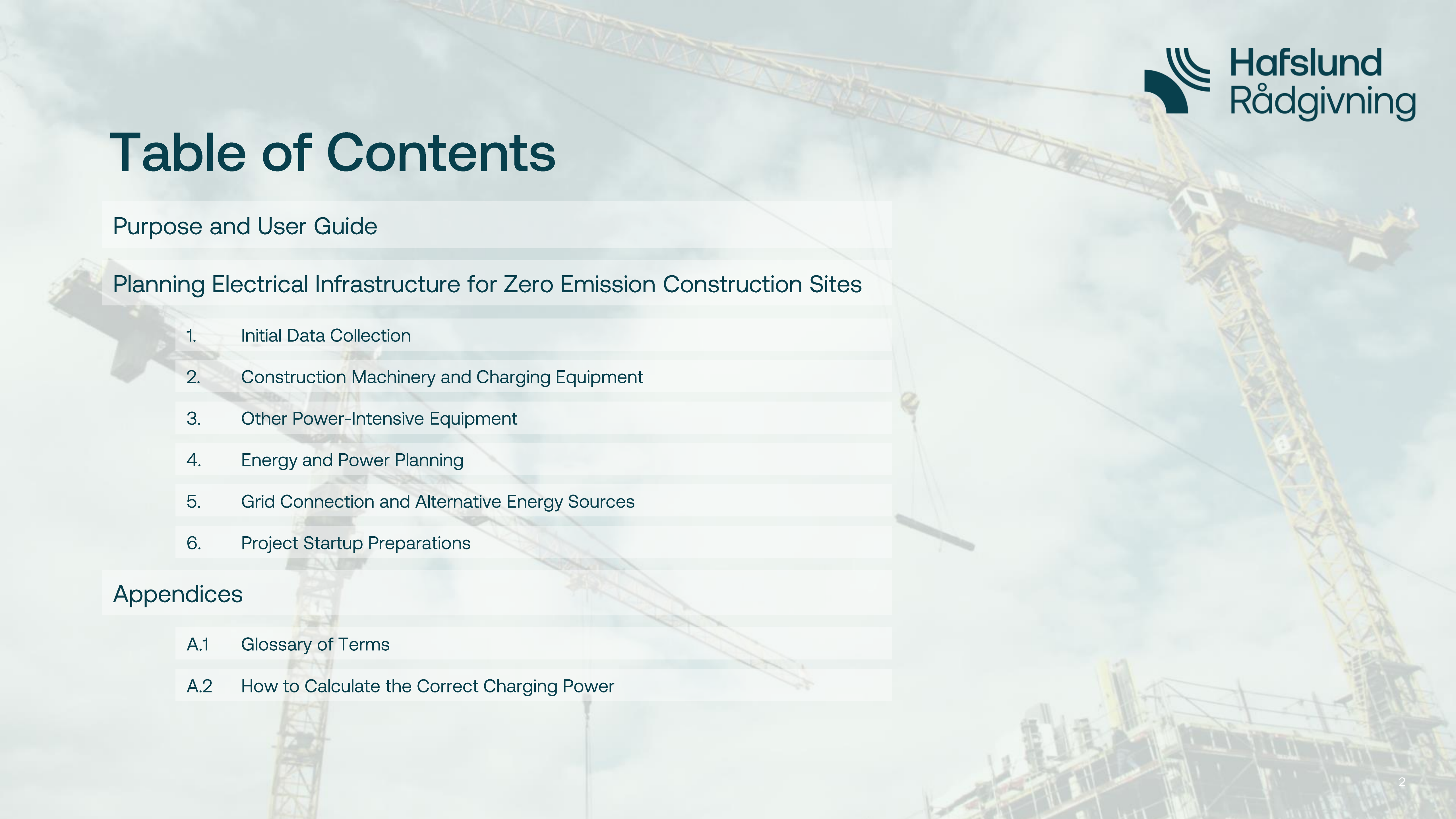
Hafslund
Rådgivning

Guideline for Zero Emission Construction Sites

- Building construction



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Purpose and User Guideline

Guideline for ZEMCON

This guideline informs contractors planning and designing electrical infrastructure for zero-emission construction sites, focusing on charging infrastructure for construction machinery. It is intended as a practical tool to support the dimensioning process for electrical infrastructure and supplement existing project planning routines and knowledge among contractors.

Client	✓ Designs and sets requirements for project execution ✓ Estimates power demand, requests grid capacity information from the grid operator, and includes this in the tender specifications*
Contractor	✓ Plan electrical infrastructure and operations ✓ Procures equipment for electrical implementation ✓ Engages a certified electrical contractor for grid connection
Grid Operator	✓ Responds to inquiries regarding available grid capacity and connection. Can also provide advice on power reduction solutions. ✓ Handles orders and allocates grid capacity

Market Need
There is a growing need for a clear and user-friendly guideline for contractors establishing charging infrastructure for zero-emission construction projects.

Target Audience
Contractors who need to strengthen their knowledge of zero-emission construction sites.

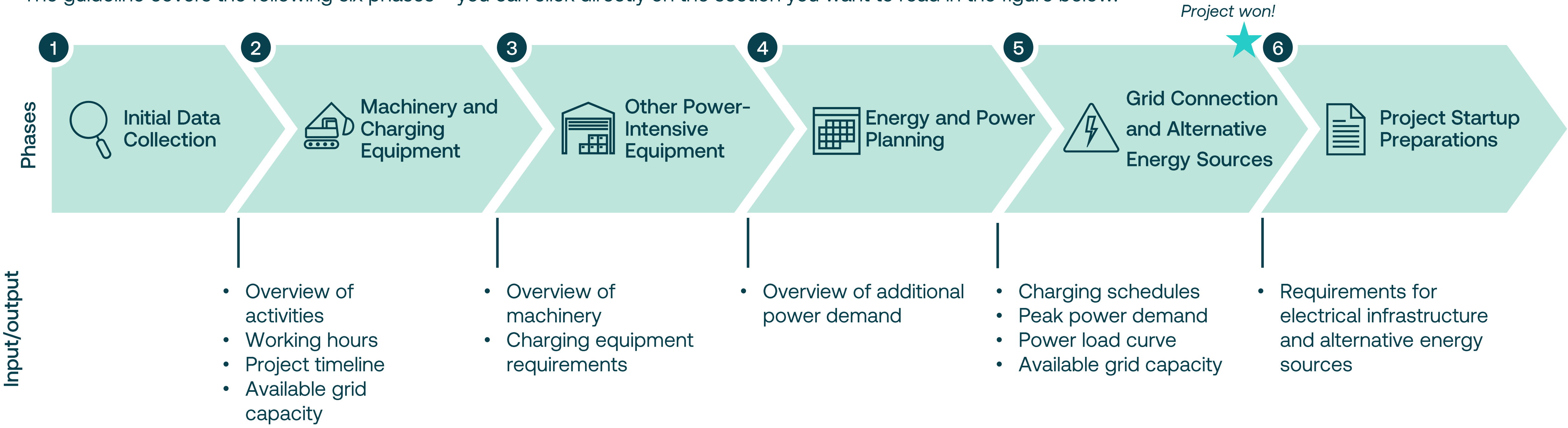
Scope
- ✓ Electrical infrastructure for charging machinery within the construction site
- ✓ Dimensioning of electrical infrastructure also includes power supply for site-related needs such as modular site offices, equipment containers, electric vehicles etc.

**The client does not always provide information on available grid capacity in the tender documents or estimate the power demand. In such cases, the contractor is responsible.*

Planning Electrical Infrastructure for ZEMCON

This guideline is divided into six phases, each representing a key part of planning electrical infrastructure for a ZEMCON. Every phase requires specific input, resulting in an output used in the next phase. In addition to these six phases, intermediate activities naturally occur in the bidding process and project startup. Planning electrical infrastructure for ZEMCON is also an iterative process, where some phases may need to be repeated to achieve the optimal setup. The guideline includes various terms related to electricity and power. Explanations of these terms can be found in Appendix A.1.

The guideline covers the following six phases – you can click directly on the section you want to read in the figure below.



- Overview of activities
- Working hours
- Project timeline
- Available grid capacity

- Overview of machinery
- Charging equipment requirements

- Overview of additional power demand

- Charging schedules
- Peak power demand
- Power load curve
- Available grid capacity

- Requirements for electrical infrastructure and alternative energy sources

Examples | **Applying the Guideline in Practice**

Each phase includes examples with calculations demonstrating the guideline's application.

Optimization
The guideline includes dedicated sections with recommendations on optimizing equipment and activities to lower costs and enhance efficiency.

1. Initial Data Collection

The purpose of this phase is to gather the necessary information to begin planning the electrical infrastructure for the construction project.

By the end of this phase, you will have a complete overview of the key data required to proceed with the remaining phases.

1. Initial Data Collection

Key Information for Planning ZEMCON

Essential information must be collected before planning electrical infrastructure at the construction site. The client typically provides much of this in the project tender or obtains it as part of the contractor's standard procedures.

Required Information Includes:

- Project location and potential site setup areas
- Project duration
- Project start date
- Working hours and break schedules
- Overview of work processes and required machinery
- Overview of additional energy-consuming elements such as site huts, heating, tower cranes, and vehicle charging
- Available grid capacity*

*Not all clients disclose available grid capacity. You can request this information directly from the grid operator. The process is outlined in this chapter.

Example | **Building Construction in an Urban Area**

A sports arena will be built, along with an expanded parking area, a pedestrian walkway, and a widened road with sidewalks. The building's energy supply will come from geothermal energy, requiring the drilling of 12 energy wells.

Project duration:	12 months, starting in Aug.
Working hours:	Mon-Wed 07:00–19:00, Thur 07:00–14:00
Breaks:	1-hour lunch at 11, 1-hour dinner at 16 (Mon-Wed)

The available grid capacity is unknown.

The project requires 2 excavators (8T), 2 excavators (25T), a demolition machine (30T), a dumper (20T), a roller, a vibrating plate, a telescopic handler (8T), a tower crane (20T), a drilling rig, a compressor, a construction heater, a scissor lift, a boom lift, and a small wheel loader. Additionally, site huts with 16 units and charging facilities for 3 electric vehicles.

If the available grid capacity is not given by the tender

Requesting Information on Grid Capacity

The grid operator must be contacted if the available grid capacity is not specified in the tender. Different grid operators may have varying procedures for handling such inquiries. For example, Elvia, the grid operator in the Oslo region, provides a form for requesting grid capacity information.

The grid operator requires basic project information along with an estimate of the project's maximum power demand, which indicates the highest level of electricity consumption expected during peak usage

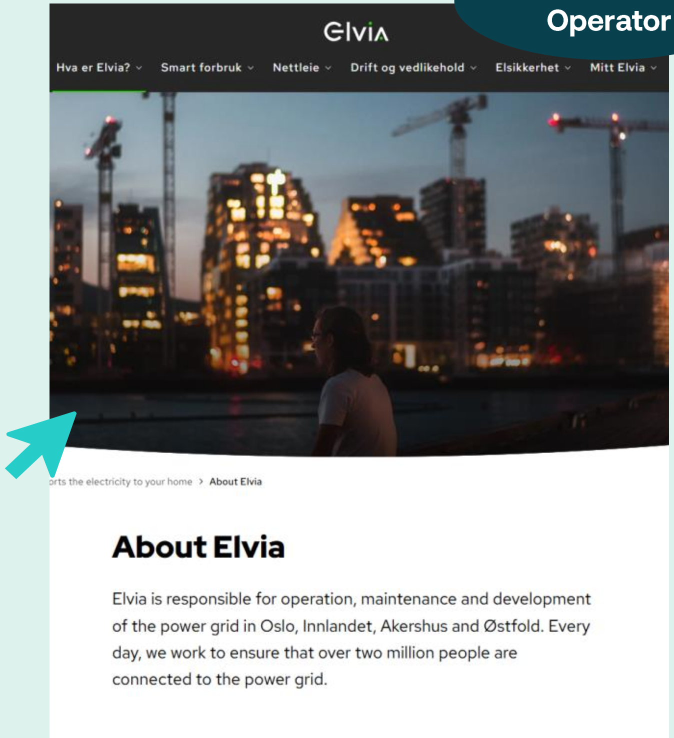
To estimate the maximum power demand, follow these steps:

1. Identify the period of the project when power demand will be at its highest.
2. Assess the total power required for machinery and other energy-intensive processes, such as site huts, charging infrastructure for transport, tower cranes, heating, etc.

> ⚠ Processing time for grid connection requests can take **several weeks**. It is crucial to start this process as early as possible.

Available Grid Capacity ?

Ask the Grid Operator



About Elvia

Elvia is responsible for operation, maintenance and development of the power grid in Oslo, Innlandet, Akershus and Østfold. Every day, we work to ensure that over two million people are connected to the power grid.

If the available grid capacity is not given by the tender

Identify the Most Power-Intensive Phase of the Project

When estimating power demand, it is essential to determine which phase of the project will have the highest energy consumption. This peak demand will be the basis for grid capacity requests submitted to the grid operator.

Key questions for assessing project phases:

- **Does the project involve particularly power-intensive processes?**
  Some early-stage groundwork activities require significant power. If such activities are included, they should be factored into the peak demand estimate.
- **During which season will the project take place?**
  If construction occurs in winter, power demand may increase due to increased heating needs for site huts. Additionally, battery-powered machinery generally consumes more energy in colder temperatures.
- **Which processes will run simultaneously, and how will they affect total power demand?**
  - Cable-powered machines maintain steady consumption during operation.
  - Battery-powered machines require more power during charging, especially in breaks.
  - If multiple cable-powered machines operate while several battery-powered machines fast-charge, total power demand will increase.
  - Additional power-consuming equipment such as heating for site huts, drilling rigs, and charging for heavy-duty vehicles can further impact peak power demand.

By evaluating these factors together, you can determine which project phase will likely have the highest power demand.

Example | **Defining the Peak Power Demand Period**

Context: The project experiences peak equipment usage in both winter and summer. The geothermal drilling rig will operate for three weeks in summer alongside other machines.

Peak Power Demand Period: During winter, the site hut will have the highest power demand due to increased heating needs. Several large machines will also require simultaneous charging.

During the drilling rig operation, multiple machines will need to charge simultaneously. Despite being a summer period, this phase may still be the most power-intensive due to the high energy demand for drilling rigs.

1. Initial Data Collection

If the available grid capacity is not given by the tender

Estimating Maximum Power Demand

An overall estimate of the project's peak power demand is required to request available grid capacity. This typically corresponds to the phase with the most large construction machines in use or during activities such as drilling. Additional power needs must also be considered, including electricity for site huts, charging of heavy-duty vehicle, and heating.

This estimation process often involves simplifications and relies on experience, while more detailed calculations are done later. If power demand is uncertain, use the upper limits from the table below as a rough guideline.

Machinery	Power Demand Fast Charging	Power Demand Slow Charging	Power Demand Cable
Small (8-16t)	40 kW	20 kW	22 kW (32 A)
Medium (17-23t)	150 – 200 kW	40 kW	86 kW (125A)
Large (>23t)	150 – 300 kW	40 kW	207 kW (300A)

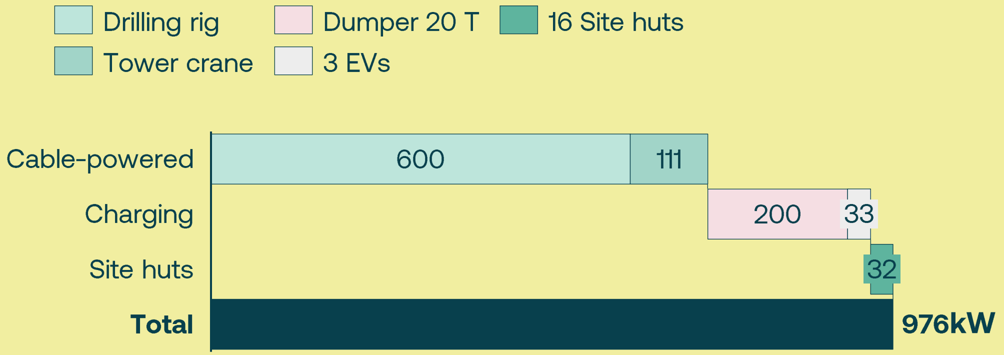
Other Power-Intensive equipment*	Power Demand	Unit
Geothermal drilling rig	400-600 kW	Per unit
Fast charging, heavy-duty vehicle	150-300 kW	Per unit
Tower crane (160A)	111 kW	Per unit
Ground thawing	30 kW	Per 100 m2
Standard EV charging	11 kW	Per charger
Site huts	3 kW (2kW summer)	Per hut

Example | **Estimating Maximum Power Demand**

Context: During peak power demand, the drilling rig, compressor, large and small excavators, dumper, ground thawing, tower crane, and vibratory plate are used. 16 site cabins must also be heated and 3 electric vehicles charged.

Estimated Power Demand: Excavators require fast charging during breaks, while the telehandler equipment charges normally. The dumper is fast-charged three times daily, not necessarily during breaks. EVs charge during the day, the vibratory plate charges sporadically, and other equipment runs on cables. The site huts have a stable load, with peak demand occurring when the drilling rig and compressor operate simultaneously.

Note! Estimates for different project phases can be made if the power demand is uncertain.



Estimated power demand to be shared with grid operator

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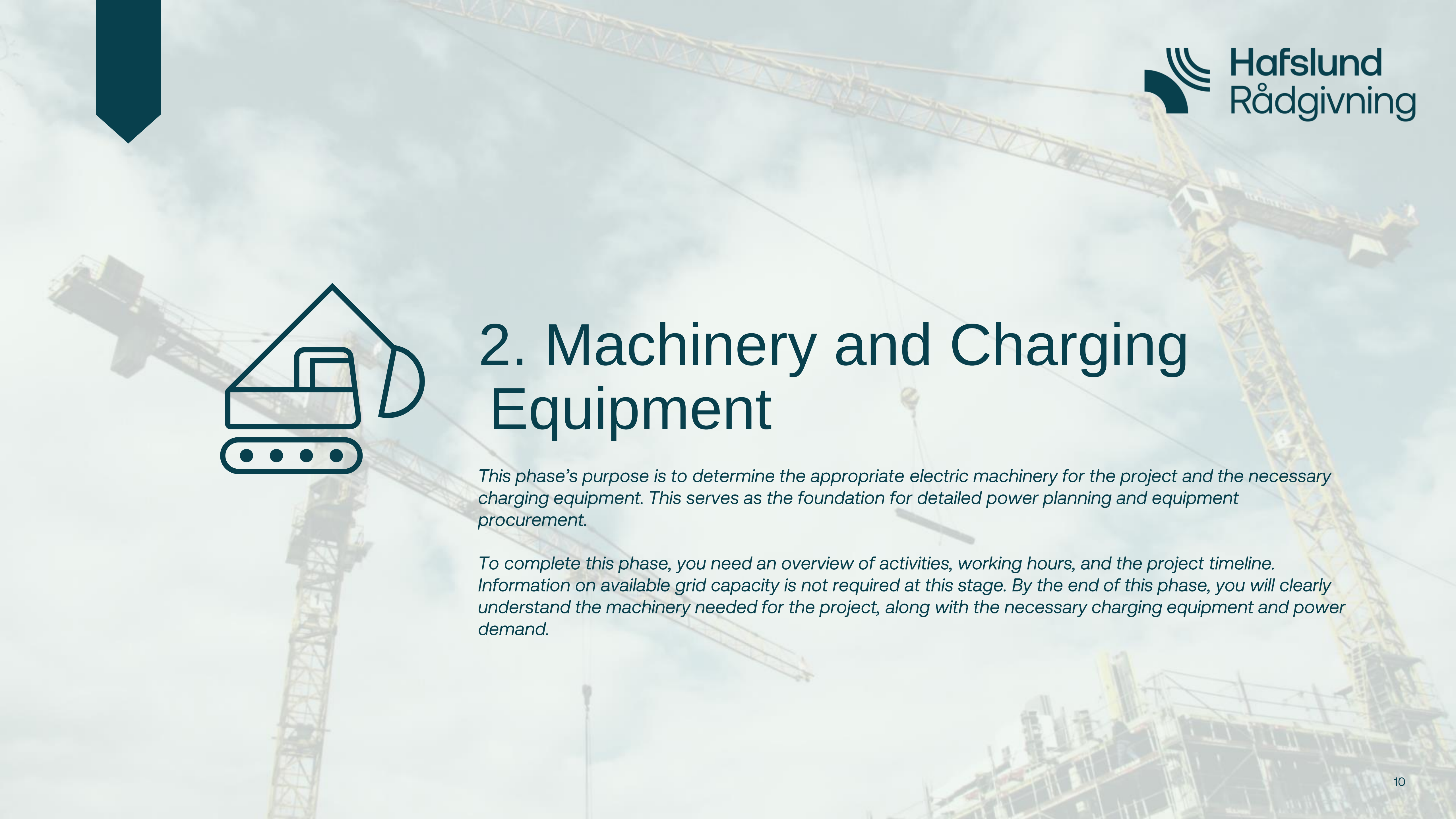
*Examples of equipment with high power demand



2. Machinery and Charging Equipment

This phase's purpose is to determine the appropriate electric machinery for the project and the necessary charging equipment. This serves as the foundation for detailed power planning and equipment procurement.

To complete this phase, you need an overview of activities, working hours, and the project timeline. Information on available grid capacity is not required at this stage. By the end of this phase, you will clearly understand the machinery needed for the project, along with the necessary charging equipment and power demand.

Choosing the Right Electric Machinery

The choice of machinery depends on the project's tasks. Electric machines come in battery-powered, cable-powered, or hybrid models. Hybrid models can be adapted to project needs, while cable-powered machines often have smaller batteries to reduce startup power surges.

Electric machines can be bought or rented, but availability is limited, and delivery times can be extended. Order well in advance to avoid delays.

Key Specifications for Battery-Powered Machines:

- Expected runtime (varies with workload and temperature)
- Battery capacity (kWh)
- Charging method
- Maximum charging power (kW)

This information is found in data sheets or by contacting suppliers. Some machines have high startup power, which must be considered to avoid overloading electrical systems.

Battery-Powered Machines

⚡ Charges during breaks and overnight. Some allow battery swapping.

⚒ Uses fast chargers at the site or mobile chargers near the work area, with overnight charging as an option. Extra batteries may be needed.

👍 Flexible, can operate away from power sources.

⚠ Charging should be planned based on battery size and distance to charging points.

Photo credit: Anleggsmaskiner

Cable-Powered Machines

⚡ Connects to power nearby through a cabinet or a mobile battery with CEE/industrial outlets.

⚒ Uses power cabinets, mobile batteries, or dedicated cable infrastructure with optional automated cable winding.

👍 Reliable, continuous operation while plugged in.

⚠ Cable infrastructure is expensive over long distances. Be aware of high startup currents and a need for strong circuit breaker (C/D fuses).

Photo credit: Rental Group

Understanding Data Sheets for Electric Construction Machinery

Selecting the right machine requires understanding key specifications. Below are key terms commonly found in data sheets.

Photo: Nasta

ZERON ZE135 electric excavator

Machine Weight: 15 700 kg
Motor Driveline: 74 kW / 100 hk
Power Source: Battery
Battery Capacity: 200 kWh
Indicative Runtime: Up to 6 hours
Charging: CCS2 200 kW / 44 kW-400V/63A

Power Source: Indicates whether the machine runs on battery, cable, or both.

The ZERON ZE135 is battery-powered.

Battery Capacity: Shows stored energy (kWh) when fully charged.

The ZERON ZE135 can fully charge at 200 kW in one hour.

Charging: Charging method and maximum power.

The ZERON ZE135 can fast charge at 200 kW using a CCS2 charger or charge at 44 kW via a 63A CEE connection to a 400V power cabinet.

Runtime: Estimates how long the machine runs before charging. Cold weather and heavy workloads reduce runtime.

The ZERON ZE135 operates up to six hours per charge and must recharge after one cycle.

Example | **Choosing Machinery**

Context: The project requires various types of machines (see the first example page). The construction work occurs in a defined area with a 200m stretch.

Machine selection: The project is relatively stationary, allowing the use of both cable- and battery-powered machines, with most running on batteries. The dumper has been replaced by an electric tipper for the required functionality. Below are the selected machines:

CAT 320 Z-Line, 25T (Battery)
Battery: 300 kWh
Runtime: 5-6h (heavy work)
Charging: CCS 190 kW, CEE 44 kW (63 A)

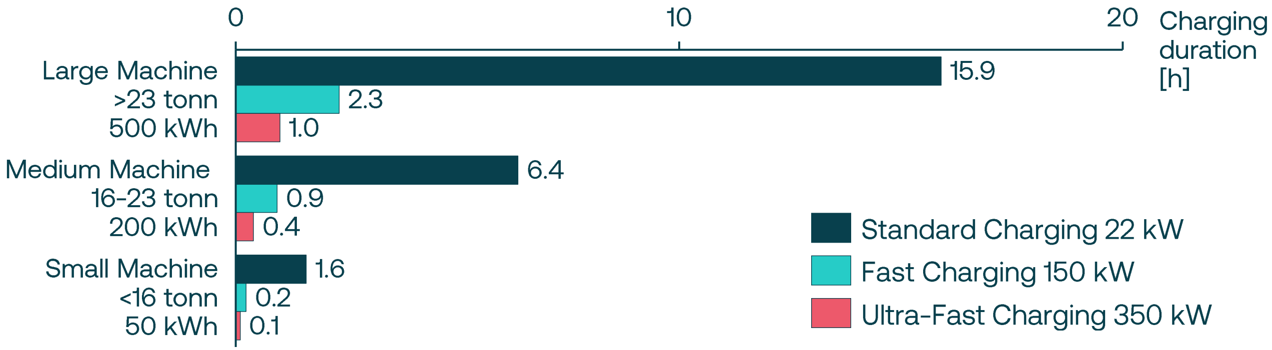
ZERON ZE85, 8T (Battery)
Battery: 100 kWh
Runtime: 3 h (heavy work)
Charging: CCS 150 kW, CEE 63 A

Scania 29T (Battery)
Battery: 300 kWh
Runtime: 4h
Charging: CCS 130 kW

Differences Between Chargers

The type of charging equipment on-site affects how quickly and how often machines can be charged. The choice depends on grid capacity, the machine's charging capability, and the work schedule. Lower charging power reduces battery strain and limits grid load, so charging should be as slow as practical for the project.

The graph below shows charging times for different power levels and machine sizes. Charging for transport vehicles is covered in the next phase of the guideline.



In addition to different charging power levels, machines use different types of connectors. Electric machines are designed for specific charging standards, which determine compatibility.

CEE is used for AC charging and connects directly to a power cabinet.

Type 2 is a charging standard for AC charging (slow charging)

CCS is a charging standard for DC charging (fast and ultra-fast charging)

Slow Charger

<50 kW

Uses low power, resulting in longer charging times.

Best suited for overnight charging.

Photo credit: Satema

Fast Charger

50-300 kW

Delivers more power, allowing for quicker charging. Typically charges in about an hour, depending on battery size and charger output.

Ideal for charging during breaks.

Photo credit: Atlas Copco

Ultra-Fast Charger

>300 kW

Provides 300 kW or more, enabling rapid turnaround for large machines. Few machines support such high-power levels, therefore always check compatibility before choosing this option.

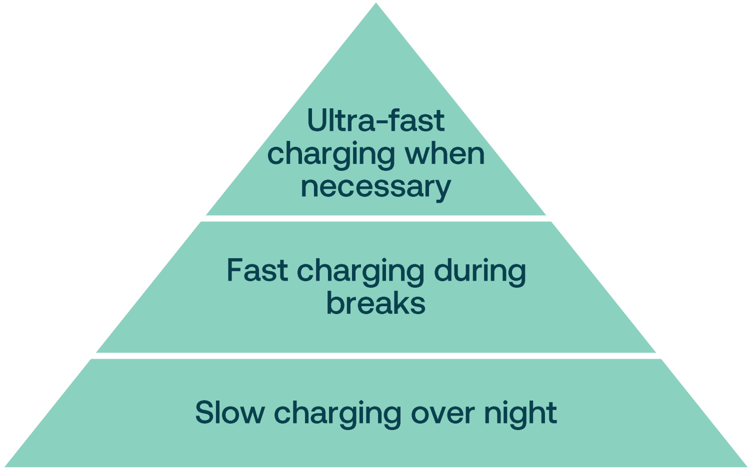
Ideal for charging during breaks.

Photo credit: Kverneland Energi

Choosing the Right Charger

To optimize time, reduce electricity costs, and extend battery life, a combination of charging solutions is recommended:

- **Slow Charging**: Most charging should be done at low power, as it takes longer but is gentler on the battery. Longer breaks, such as overnight, are ideal for this method.
- **Fast Charging**: Many machines can run for 4–6 hours before needing to charge. Fast charging is often necessary to keep operations running smoothly. By charging during breaks, machines have enough energy for a full workday
- **Ultra-Fast Charging**: Large machines with high energy demands may require very high-power charging during breaks to maintain uptime. This method delivers the most power in the shortest time.



Optimizing | **Charger Use**

Efficient charger use lowers both infrastructure and energy costs. Key strategies include:

- **Minimizing reliance on fast and ultra-fast chargers** to reduce energy costs and grid demand. Slow charging is usually cheaper to rent.
- **Charging as much as possible overnight**, when electricity rates are lower. Prices are often highest in the morning and early evening.
- **Choosing chargers with smart charging capabilities**, allowing automated scheduling for optimal efficiency.

Example | **Choosing chargers for a project**

Context: Workdays last 12 hours, and the machine fleet described in the equipment selection example must be charged. Three EVs also need charging on-site, but this can be planned for a later phase.

Charging Strategy:

- Cable-powered machines do not require chargers; they run directly from a power source using CEE connections.
- All machines need overnight charging with CEE cable.
- The battery-powered excavator needs to be charged twice per shift for continuous operation. It can use fast charging at up to 190 kW via CCS.
- The tipper charges 3 times daily outside breaks, with fast charging up to 130 kW.
- The telehandler charges during breaks via a 63A CEE connection (44 kW).

Calculating Charging Power for Electric Machinery

Once machines and charging equipment are selected, the required charging power and charging time can be calculated. This is essential for estimating total power demand on-site and ensuring an optimal workflow.

To determine the appropriate charging power for construction machines, consider the following factors:
- Machine energy consumption per hour
- Work session duration
- Maximum charging power (for both fast and slow charging)
- Battery capacity
- Duration of breaks and overnight charging

Formulas for calculating the required charging power for fast and slow charging are available in Appendix A.2.

⚠ Adjusting charging power requires control over the energy intake of the machine or the output of the charger. If this is not possible, use the machine's maximum charging power as the baseline for both fast and slow charging.

Example | **Calculating Charging Power**

Context: The project requires charging multiple machines during working hours, while all battery-powered machines also need overnight charging.

Calculating charging Power: Example for the excavator:

Energy consumption per hour (from data sheet) → $\frac{300}{6} = 50\ kWh/time$

Energy used before lunch (4h) → $50 \times 4 = 200\ kWh$

Energy replenished during lunch (1h fast charge at 190 kW) → $190 \times 1 = 190\ kWh$

Remaining energy after lunch → $300 - 200 + 190 = 290\ kWh$

Remaining energy after dinner (4h work + 1 h break) → $290 - 4 \times 50 + 190 = 280\ kWh$

Remaining energy before overnight charging (2h work) → $280\ - 50 \times 2 = 180\ kWh$

Required charging power for overnight charging (12h available) → $\frac{300-180}{12} = 10\ kW$

The same method is used for the other battery-powered machines.

3. Other Power-Intensive Equipment

The purpose of this phase is to map out additional power demands beyond construction machinery and chargers. This provides the basis for estimating the total energy requirements on-site.

To complete this phase, you need an overview of other activities taking place on-site and the number of energy-consuming installations such as site huts, drilling equipment, and ground thawing equipment. By the end of this phase, you will have a complete overview of the total power demand at the construction site.

Other Power-Intensive Equipment to Consider

Power use on-site is affected by more than just construction machinery. Other equipment, such as heating for site huts, cable-powered tools like drilling rigs, and charging stations for electric vehicles, also contribute to total demand. Smaller loads from lighting and storage units are usually minor and don't significantly impact power planning.

For accurate and efficient planning, it's important to map out when and how power is used. Some equipment, like site huts, has a steady power demand throughout the project, while cable-powered tools such as drilling rigs have high demand during working hours.

Photo credit: Heatwork

Heating Systems – Typically have a constant power demand.
Examples: Heating for site huts, heating for buildings, construction drying and ground thawing equipment.

Photo credit: Haug contractor

Cable-Powered Equipment – Can significantly impact peak demand.
Examples: Tower crane, drilling rigs and compressors.

Photo credit: Volvo

Vehicle Charging – Affects peak demand depending on charging type.
Examples: Fast charging for heavy duty vehicles (HDV), slow charging for EVs.

Optimizing | **Other power-intensive equipment**

Alternative Heating – Using heat pumps, district heating and geothermal energy can reduce power use for heating. District and geothermal heating are particularly useful for construction drying and heating if planned. A heat pump with an efficiency factor of 3 provides 3 kWh of heat for every 1 kWh of electricity used.

Smart Scheduling – Reducing power use from site huts and charging during peak hours helps balance demand.

Off-Site Charging – Charging transport vehicles and EVs at public stations reduces demand on-site.

General Assessment of Additional Power Demand

The table below outlines estimated power demand for various equipment types based on experience. These values can be used to calculate total site power needs. If exact values are needed, they can be found in equipment data sheets or by contacting suppliers.

Heating	Power Demand	Unit
Electrical heating	0,04 kW	Per m2
Construction dryers	5-6 kW	Per 100 m2
Ground thawing	30 kW	Per 100 m2
Site huts	3 kW (2 kW summer)	Per unit

Power-Intensive Cable-Powered Equipment	Power Demand	Unit
Tower cranes	110 kW	Per unit
Geothermal drilling rig	400 - 600 kW	Per unit

Charging for Vehicles	Power Demand	Unit
Slow chargers for EVs	11 kW	Per unit
Fast chargers for HDV	150 – 300 kW	Per unit

Example | **Calculating Additional Power Demand**

Context: The project includes a 16-module site facility, charging for 3 EVs, a tower crane, various lifts, and a drilling rig for 12 energy wells. It also requires 200 m^2 of construction drying and 100 m^2 of ground thawing.

Estimated Additional Power Demand: Power demand varies throughout the project. Heating for the site huts and EV charging are required continuously. At the same time, peak loads occur when the drilling rig and tower crane operate together, during simultaneous ground thawing and material transport charging, and when lifts, heating, and construction drying run concurrently.

Power demand estimate:
Site huts: 1kW x 16 = 16 kW (heat pumps, insulated)
EV charging: 3 x 11 kW = 33 kW (simultaneous)
Drilling rig and compressor: 600 kW
Tower crane: 111 kW

4. Energy and Power Planning

The purpose of this phase is to establish an overview of the energy and power demand of a construction site over a full workday. This forms the basis for grid connection requirements and potential alternative energy sources.

To complete this phase, you need an overview of the construction machinery and charging equipment required, as well as other power-intensive equipment. By the end of this phase, you will have a clear understanding of how much energy and power will be used, when, where, and how throughout the workday.

Energy and Power Planning for ZEMCON

Energy and power demand for a construction site is planned by mapping out daily consumption. A well-structured energy and power plan makes it easier to assess total demand, maintain continuous operations, ensure efficient energy use, and reduce peak loads.

The plan should be based on the project's most energy-intensive workday, which defines the dimensioning power demand. Identifying the phase with the highest energy use is crucial, as this will typically be when multiple machines operate simultaneously, heavy-duty work is carried out, or winter conditions increase heating needs.

To develop an accurate energy and power plan, the project must define which machines will be used, what charging equipment is required, and which other energy-consuming equipment and processes will contribute to total demand.

Tips for energy and power planning:

- During winter, all machines should be fully charged overnight to prevent power loss from cold temperatures.
- If it's difficult to determine the most power-intensive phase of the project, plans can be made for multiple periods and then compared.

Example | **Identifying the Peak Power Demand Period**

Context: The project experiences peak equipment usage in both winter and summer. The geothermal drilling rig will operate for three weeks in summer alongside other machines.

Peak Power Demand Period: During winter, the site hut will have the highest power demand due to increased heating needs. Several large machines will also require simultaneous charging.

During the drilling rig operation, multiple machines will need to charge simultaneously. Despite being a summer period, this phase may still be the most power-intensive due to the high energy demand for drilling rigs.

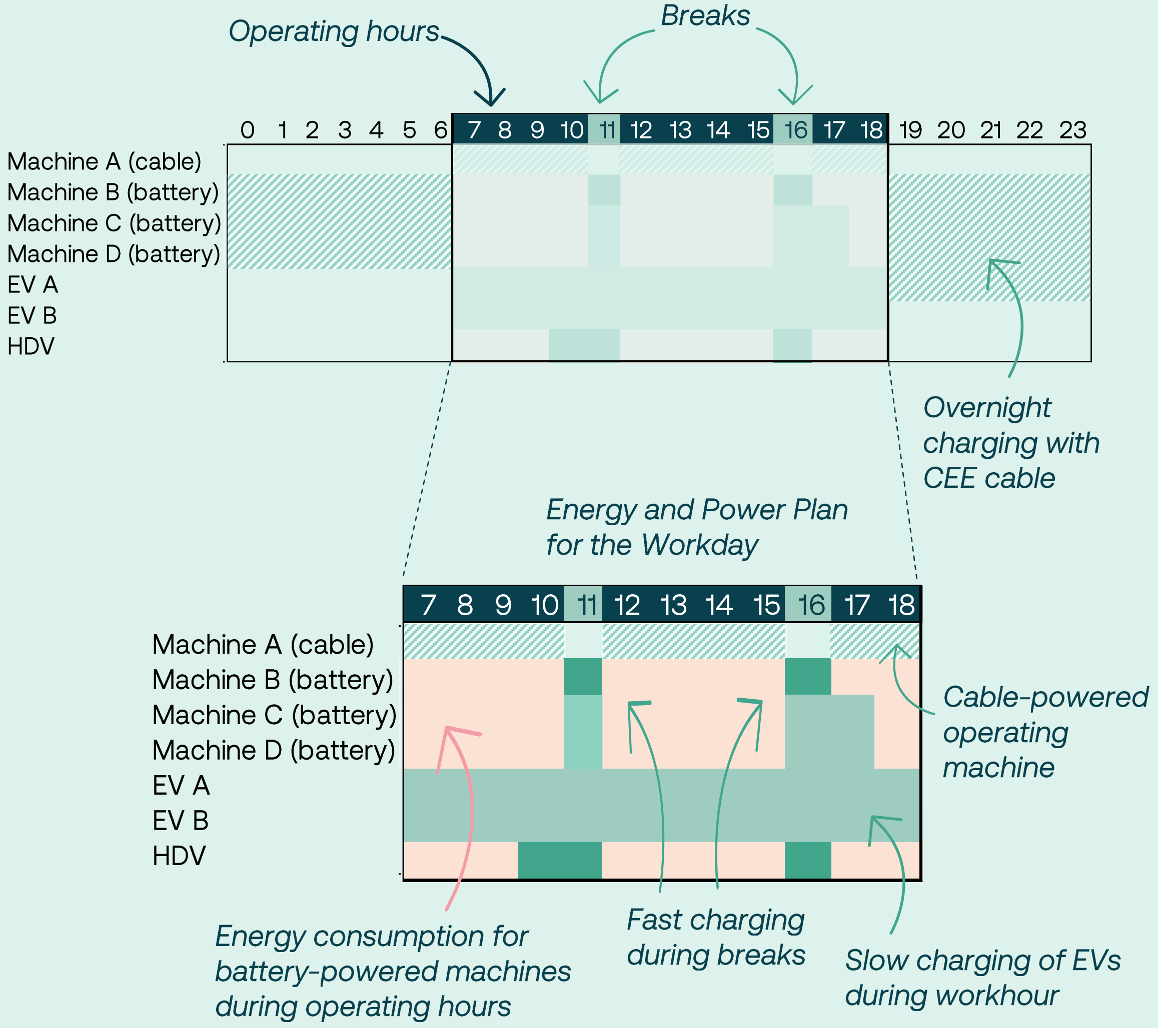
Developing an Energy and Power Plan

After identifying the project's most power-intensive phase, the next step is to create a structured energy and power plan. This ensures efficient energy use, stable operations, and reduced peak loads.

1. **Map Out the Work Schedule**
   Create an overview of the workday, including start and end times and scheduled breaks. Structure the plan by the hour or half-hour, depending on the level of detail needed.
2. **Register Operating Time and Power Consumption per Machine**
   Define the estimated operating hours for each machine and determine its power consumption.
3. **Plan Charging Time and Required Power per Machine**
   To plan charging sessions, use data on battery capacity, maximum charging power, and expected energy demand. Start by allocating charging during breaks and outside of working hours. Charging during breaks is often the peak power demand, while slow charging overnight ensures machines are fully charged before the next workday.
4. **Include Additional Power Demand**
   Account for other power-intensive equipment, such as heating for site huts and vehicle charging. Estimate the energy required at different times of the day.
5. **Sum Up and Validate Power Demand**
   Total the expected power demand for each time slot and ensure it does not exceed available grid capacity. Consider optimizing demand, redistributing loads, or integrating alternative energy sources if specific periods exceed available grid power. Further details on these solutions can be found in Part 5: Grid Connection and Alternative Energy Sources.

Energy and Power Plan for a Workday

This plan illustrates how energy and power consumption are managed for a typical workday. Power and energy use are distributed hourly during the daytime, with slow charging occurring overnight.



Example | Energy and Power Plan

The drilling rig phase is identified as the project's most power-intensive period. To better understand demand, a power plan will be developed for a full operational day in this phase.

1. Map Out the Work Schedule

Workdays last up to 12 hours (7 AM–7 PM) with one-hour breaks at 11 AM (lunch) and 4 PM (dinner), resulting in two 4-hour shifts and one 2-hour shift.

2. Register Operating Time and Power Consumption per Machine

Excavators and the telehandler operate continuously, pausing only for breaks. The tipper truck runs for 3 hours before charging.

CAT 320 Z-Line, 25T (Battery)
Power consumption per hour: 50 kW

ZERON ZE85, 8.75T (Battery)
Power consumption per hour: 23 kW

Scania 29T (Battery)
Power consumption per hour: 68 kW

Snorkel Telehandler (Battery)
Power consumption per hour: 6 kW

3. Plan Charging Time and Required Power per Machine

Charging calculations are based on the methodology outlined in the previous phase.

CAT 320 Z-Line, 25T (Battery)
Fast charging during breaks (1h): 190 kW
Slow charging overnight (12h): 10 kW

ZERON ZE85, 8.75T (Battery)
Fast charging during breaks (1h): 150 kW
Slow charging overnight (12h): 4,5 kW

Volvo L25, 5T (Battery)
Fast charging every 3h: 130 kW

Snorkel Telehandler (Battery)
Slow charging during breaks (1h): 44 kW
Slow charging overnight (12h): 4 kW

Eksempelet fortsetter på neste side →

Example | Energy and Power Plan

4. Include Additional Power Demand

During peak demand, power is drawn from site huts, EV charging, the drilling rig, and the tower crane. Site huts' power demand peaks during work hours, then drops 50% after. EVs charge only during work hours, while the rig and crane run on cable.

5. Sum Up and Validate Power Demand

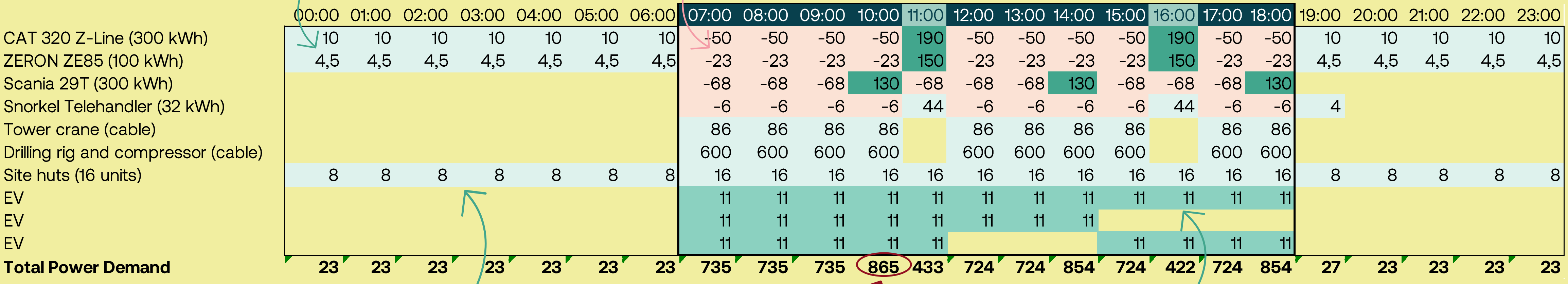
The power demand calculation shows that peak consumption occurs during breaks, with a maximum demand of **865 kW**. Addressing peak demand within the available grid capacity and exploring optimization measures or alternative energy sources will be the focus of the next example.

Machines are slow-charged overnight to ensure full battery by work start

Estimated power use at full operation

Fast charging of machines during breaks to ensure maximum uptime

Time	**Charging**
Operation	CEE-cable
Break	Type2
	CCS



	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
CAT 320 Z-Line (300 kWh)	10	10	10	10	10	10	10	-50	-50	-50	-50	190	-50	-50	-50	-50	190	-50	-50	10	10	10	10	10
ZERON ZE85 (100 kWh)	4,5	4,5	4,5	4,5	4,5	4,5	4,5	-23	-23	-23	-23	150	-23	-23	-23	-23	150	-23	-23	4,5	4,5	4,5	4,5	4,5
Scania 29T (300 kWh)								-68	-68	-68	130	-68	-68	-68	130	-68	-68	-68	130					
Snorkel Telehandler (32 kWh)								-6	-6	-6	-6	44	-6	-6	-6	-6	44	-6	-6	4				
Tower crane (cable)								86	86	86	86		86	86	86	86		86	86					
Drilling rig and compressor (cable)								600	600	600	600		600	600	600	600		600	600					
Site huts (16 units)	8	8	8	8	8	8	8	16	16	16	16	16	16	16	16	16	16	16	16	8	8	8	8	8
EV								11	11	11	11	11	11	11	11	11	11	11	11					
EV								11	11	11	11	11	11	11	11									
EV								11	11	11	11	11				11	11	11	11					
Total Power Demand	23	23	23	23	23	23	23	735	735	735	865	433	724	724	854	724	422	724	854	27	23	23	23	23

Reducing heating demand for site huts at night by 50%

Peak Power Demand

EV charging demand varies during the day

5. Grid Connection and Alternative Energy Sources

The purpose of this phase is to determine the appropriate grid connection for the project and assess the need for alternative energy sources and further optimization measures.

To complete this phase, you need an overview of the site's energy and power demand throughout a workday and the available grid capacity. After this phase, you will know the required grid connection and whether alternative energy sources are needed on-site.

Choosing the Right Grid Connection

The required grid connection depends on available capacity, voltage levels, and connection points. Multiple substations may sometimes be combined to meet the power demand. Capacity is usually provided in kVA, which can be simplified to kW but is a more technical and precise phrasing considering the three-phase system.

Voltage Levels

Grid capacity is specified for low-voltage (LV) or high-voltage (HV) networks. The different voltage levels may vary across countries.

- LV networks typically offer 400V or 230V. Most machinery and charging equipment require 400V. If only 230V is available, a phase converter is required.
- HV connections always need a transformer to 400V, making substations necessary in most cases.

Power Demand and Available Grid Capacity

The required grid connection depends on available capacity, voltage levels, and connection point placement. If the power demand exceeds 500 kW, a temporary or permanent substation is typically required, connected directly to the high-voltage grid. Temporary substations are commonly used in electric projects as a cost-effective solution, whereas the grid operator owns permanent substations after completion.

Power cabinets may be adequate for power demand below 500 kW if the low-voltage grid has sufficient capacity. They can be connected directly to an existing low-voltage substation.

Substation

>500 kVA

Standard sizes: 500 kVA, 1000 kVA, 1600 kVA or 2000 kVA.
Choose based on power demand and the available grid capacity. Determine whether a permanent or temporary substation is necessary.

⚠ Requires grid concession

Photo credit: Møre Trafo, Norsk Transformator

Power Cabinet

< 500 kVA

Power cabinets can be connected to existing LV substations. An electrical contractor must install them, and the grid operator is responsible for installing a meter.

On construction sites, it is common to use a combination of multiple power cabinets, often connected in series.

Photo credit: Satema

Considering Alternative Energy Sources

Alternative energy sources may be needed for projects with limited grid capacity, high peak power demand, or machinery operating long distances from the grid. Standard solutions for ZEMCONs include battery systems. Some piloting projects have also tested using hydrogen fuel cells and solar panels.

Batteries are well suited for supplementing power supply and covering short-term peak demand, up to 500 kW. They come as battery containers or mobile battery trailers with high power output and fast charging capabilities. Mobile battery trailers are handy for charging machinery away from fixed power sources, such as road construction projects. However, batteries are heavy, have limited energy density, and lose efficiency in cold temperatures. Battery trailers require certification for transport and vehicles capable of towing over 3.5 tons.

Hydrogen fuel cells provide electricity through hydrogen combustion, which is emission-free when using renewable hydrogen. They can power machinery through direct connections or supply electricity to chargers. However, hydrogen fuel cell technology remains costly and underdeveloped, with limited suppliers and hydrogen storage and distribution challenges. Additional safety measures and space requirements make implementation complex.

Solar panels can supplement power for site cabins, containers, and small chargers, but their contribution is limited to low-energy needs and depends on good sunlight conditions.

Battery Container

👍 Covers high power demand over short periods during

⚠ Efficiency drops in low temperatures, requires recharging

Photo credit: Atlas Copco,

Battery Trailer

👍 Powers machinery operating away from the main power source

⚠ Efficiency drops in low temperatures, requires recharging, needs ADR certification, and a towing vehicle over 3.5 tons. High inrush current requires strong circuit breaker (C/D) for CEE connection

Photo credit: Hafslund

Hydrogen Fuel Cell

👍 Provides power without grid connection

⚠ Low efficiency, limited hydrogen suppliers, space-consuming, underdeveloped technology, and costly

Photo credit: NAPOP

Solar Panels

👍 Covers small daytime energy needs (typically for site huts, containers, and small chargers)

⚠ Limited to low power demand, performance depends on good sunlight conditions

Photo credit: Kverneland Energi

Example | **Setup for Grid Connection and Power Optimization**

Context: The project had no pre-defined available grid capacity, and the grid operator has now processed the request. They provide the following information for the area:

«Thank you for your inquiry. The following estimates of available capacity are based on current conditions and cannot be reserved.
See the attached map for nearby substations and connection options:
NS123: 400V, with an available capacity of approximately 200 kW.»

The estimated maximum power demand is 865 kW.

Grid connection and staging area:
The substation's location is ideal for power supply and a staging area near the sports arena's parking lot, minimizing the distance to chargers. However, its capacity is insufficient to meet power demand, requiring alternative energy sources, a temporary substation, and/or optimization measures to secure adequate power.

The example continues on the next page →

Example | **Setup for Grid Connection and Power Optimization**

Evaluation of Alternative Energy Sources and Power Optimization:

The tower crane and drilling rig require a steady 686 kW during work hours. Current battery solutions make covering this demand for several hours difficult, making a temporary substation necessary. As the drilling rig exceeds 500 kW, a 1000 kVA substation is required.

Power demand will also exceed 200 kW for much of the project, mainly due to fast charging. Assessments based on equipment distribution and rough calculations suggest installing a temporary substation at startup is necessary.

A heat pump has an efficiency factor of 3, and well-insulated site huts can reduce heating power demand from 3 kW to 1 kW per site hut, resulting in a total reduction of 32 kW. This adjustment has already been accounted for in the power calculations presented in the energy and power plan example.

Another optimization measure is to lower charging power or limit the current during overnight charging to reduce power consumption and lower energy costs. This adjustment has already been accounted for in the power calculations presented in the energy and power plan example.

Temporary substation, 1000 kVA
Due to high power demand over extended periods and limited grid capacity in the area, a high-voltage grid connection is required.

⚠ A grid concession application must be submitted once the project is awarded..

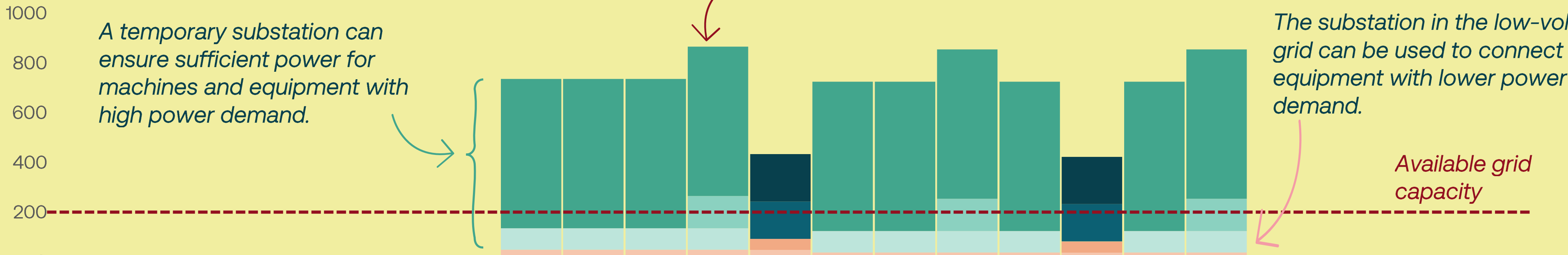
Heat Pump
Power reduction: 2 kW per site hut

Charging Power Adjustment
Reduces power demand during overnight charging.

The example continues on the next page →

Example | **Setup for Grid Connection and Power Optimization**

Balancing Power Demand with Available Grid Capacity:
The available grid capacity in the low-voltage network is insufficient to meet the total power demand. Therefore, a temporary substation will be installed.



Peak Power Demand

A temporary substation can ensure sufficient power for machines and equipment with high power demand.

The substation in the low-voltage grid can be used to connect equipment with lower power demand.

Available grid capacity

	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Total Power Demand	23	23	23	23	23	23	23	735	735	735	865	433	724	724	854	724	422	724	854	27	23	23	23	23
■ CAT 320 Z-Line (300 kWh)	10	10	10	10	10	10	10					190					190			10	10	10	10	10
■ ZERON ZE85 (100 kWh)	4,5	4,5	4,5	4,5	4,5	4,5	4,5					150					150			4,5	4,5	4,5	4,5	4,5
■ Drilling rig and compressor (cable)								600	600	600	600		600	600	600	600	0	600	600					
■ Scania 29T (300 kWh)											130				130				130					
■ Tower crane (cable)								86	86	86	86		86	86	86	86	0	86	86					
■ Snorkel Telehandler (32 kWh)												44					44			4				
■ EVs (3 stk)								33	33	33	33	33	22	22	22	22	22	22	22					
■ Site huts (16 units)	8	8	8	8	8	8	8	16	16	16	16	16	16	16	16	16	16	16	16	8	8	8	8	8

The example continues on the next page →

Example | **Setup for Grid Connection and Power Optimization**

Updating the energy and power plan:
A temporary substation of 1000 kVA can accommodate the maximum power demand of 865 kW. However, the low-voltage substation is also utilized for connections to allow for flexible infrastructure placement. The energy and power plan is adjusted based on different connections to the temporary substation (1000 kVA) and the low-voltage substation (200 kVA). Equipment with high power demand is connected to the temporary substation, while lower-power equipment is connected to the low-voltage grid.

Time	***Charging***
Operation	CEE-cable
Break	Type2
	CCS

Machine and equipment setuop for temporary substation, 1000 kVA

	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
CAT 320 Z-Line (300 kWh)	10	10	10	10	10	10	10	-50	-50	-50	-50	190	-50	-50	-50	-50	190	-50	-50	10	10	10	10	10
ZERON ZE85 (100 kWh)	4,5	4,5	4,5	4,5	4,5	4,5	4,5	-23	-23	-23	-23	150	-23	-23	-23	-23	150	-23	-23	4,5	4,5	4,5	4,5	4,5
Scania 29T (300 kWh)								-68	-68	-68	130	-68	-68	-68	130	-68	-68	-68	130					
Tower crane (cable)								86	86	86	86		86	86	86	86		86	86					
Drilling rig and compressor (cable)								600	600	600	600		600	600	600	600		600	600					
Total Power Demand	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**686**	**686**	**686**	**816**	**340**	**686**	**686**	**816**	**686**	**340**	**686**	**816**	**15**	**15**	**15**	**15**	**15**

Peak Power Demand

Machine and equipment setuop for low-voltage substation, 200 kVA

	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Snorkel Telehandler (32 kWh)								-6	-6	-6	-6	44	-6	-6	-6	-6	44	-6	-6	4				
Site huts (16 units)	8	8	8	8	8	8	8	16	16	16	16	16	16	16	16	16	16	16	16	8	8	8	8	8
EV								11	11	11	11	11	11	11	11	11	11	11	11					
EV								11	11	11	11	11	11	11	11									
EV								11	11	11	11	11				11	11	11	11					
Total Power Demand	**8**	**8**	**8**	**8**	**8**	**8**	**8**	**49**	**49**	**49**	**49**	**93**	**38**	**38**	**38**	**38**	**82**	**38**	**38**	**12**	**8**	**8**	**8**	**8**

Peak Power Demand

The example continues on the next page →

Example | **Setup for Grid Connection and Power Optimization**

Based on the power demand and available grid capacity, the appropriate grid connection is to use power cabinets connected to the temporary substation and the nearest substation (400 V). The selection of suitable power cabinets is based on the available grid capacity at the substation and calculations of the corresponding current.

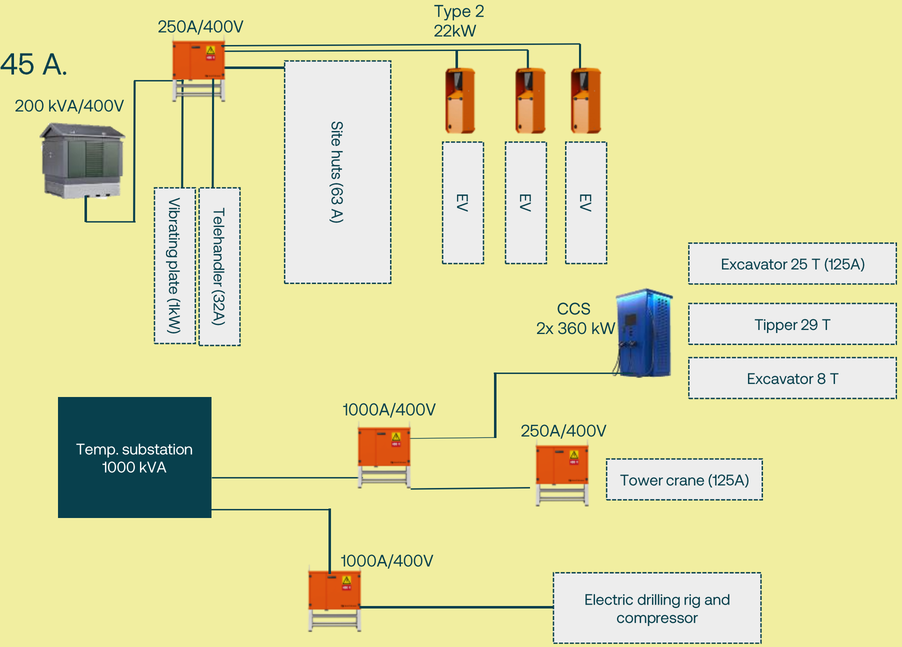
NS123 has 200 kVA available, corresponding to a maximum current output of 289 A.
The temporary substation has 1000 kVA available, corresponding to a maximum current output of 1,445 A.

Considering the charging requirements for construction machinery and equipment, the proposed dimensions for the power cabinet are as follows:

Power Cabinet 250A/400V
Connected to NS123
Circuit breakers: 63 A (Site huts), 32A (EV charger), 63 A (2x EV chargers), 32 A (Telescopic handler), small circuit breaker for the vibrating plate

2x Power Cabinet 1000A/400V
Connected to temporary substation
Circuit breakers: circuit breakers for drilling rig and compressor, fast chargers and 250A power cabinet

Power Cabinet 250A/400V – optional
Connected to power cabinet 1000 A/400 V
Circuit breakers: 125 A (Tower crane)
Comment: Not necessary, but it may be practical to have a separate power cabinet for the cable-powered tower crane close to the working area



6. Project Startup Preparations

This phase's purpose is to make the final preparations before the project starts and after it has been awarded.

Preparations After Project Award and Before Project Start

For fully or partially electric construction projects, securing the power supply as soon as possible after winning the project is crucial.

Below is a list of power-specific preparations that must be completed before project startup:

- Establish an agreement with an electrical contractor
- Determine whether a construction power concession is required
- Apply for a construction power concession if needed
- Order/rent construction machinery and charging equipment
- Enter into a temporary grid connection agreement
- Coordinate with the electrical contractor for the setup of a temporary power system

The following pages guide you through determining if a construction power concession is necessary and how to apply.

When a Grid Concession is Required and Who Can Apply

When?

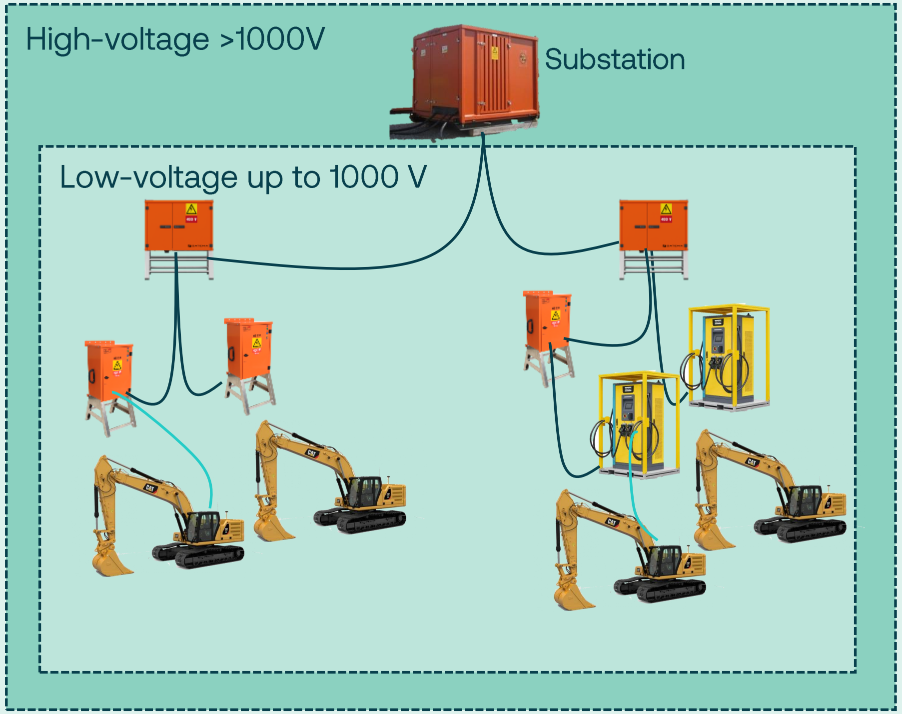
A grid concession is necessary for construction projects that require a temporary substation to accommodate power demands. A temporary installation can range from a few months to several years, with a typical maximum duration of five years. Substations are connected to the high-voltage grid, and a concession is always required to build, own, and operate this grid. In Norway, this means that qualified personnel approved by the Norwegian Water Resources and Energy Directorate (NVE) must establish and operate the facility.

Who?

Once the project is awarded, the construction and electrical contractors responsible for operating the high-voltage installation can be granted a grid concession. In Norway, there are competency requirements according to the regulations for electrical companies and qualification requirements for work related to electrical installations and equipment (FEK). The company must also be registered in the Business Register at the Norwegian Directorate for Civil Protection (DSB).

Processing for concession applications can take **several months**. Therefore, it is important to start this process immediately after signing the contract!

Grid concession is required for connection to high-voltage grid



Applying for Grid Concession

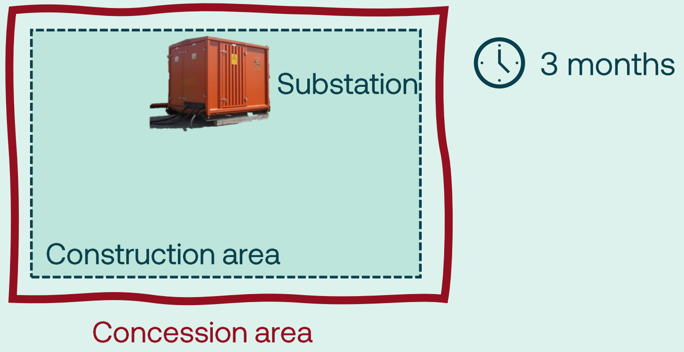
The Norwegian Water Resources and Energy Directorate (NVE) is responsible for processing and granting grid concession applications in Norway. NVE has developed a digital guide on how to apply.

NVE offers two application alternatives:

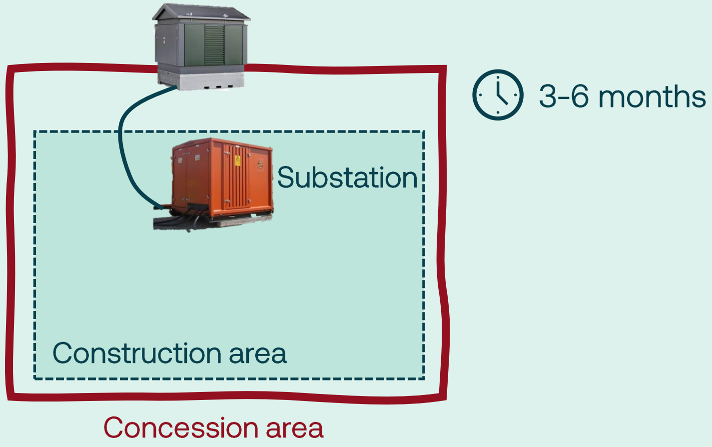
1. Application for a grid concession for installations within a defined construction area.
2. Application for a grid concession for installations within a defined construction area, including the power line leading to the site.

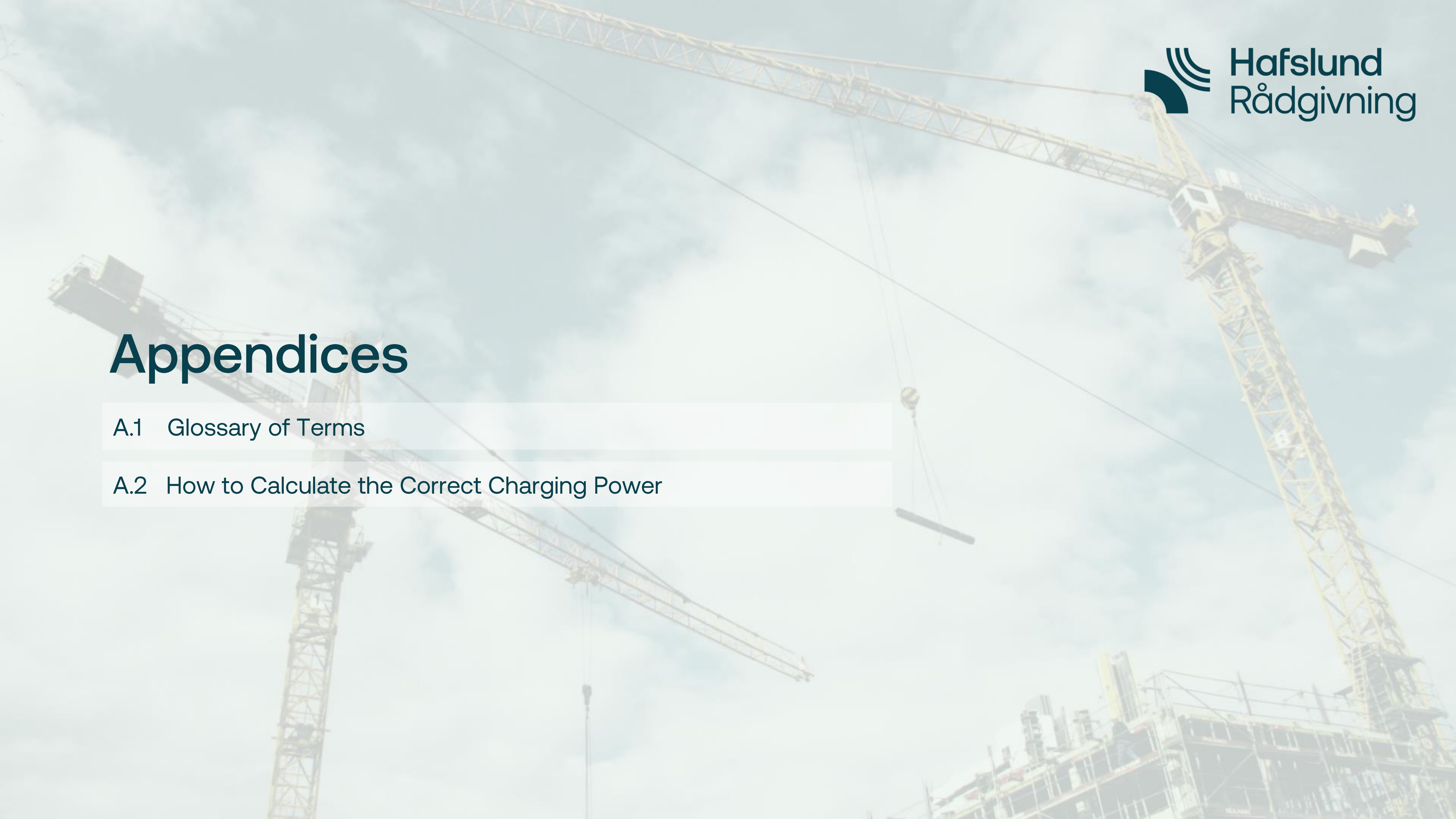
The installation of power lines to the construction site is relevant only for temporary cable connections. It does not pertain to establishing a permanent power supply in the area. NVE has strict requirements for such installations, resulting in a comprehensive application process with long waiting times. It is essential to confirm with the grid operator whether they will be responsible for installing the power line to the substation.

1 **Grid concession for a defined construction area**



2 **Grid concession for a defined construction area, including the power line leading to the site**





Appendices

Glossary of Terms for ZEMCON

Current is measured in amperes (A) and represents the amount of electric charge passing through a conductor per second. On construction sites, current values refer to power cabinets, circuit breakers, and cables.

Voltage is measured in volts (V) and represents the difference in electrical potential between two points. On construction sites, main power supplies typically operate at 230 V and 400 V, and equipment and cables must be compatible with the grid voltage. The terms low voltage and high voltage are used in connection with grid connections and are defined as follows:

- **Low-voltage grid**: Voltages up to 1,000 V AC. Low-voltage connections apply to direct connections to transformers, which typically provide 230 V or 400 V.
- **High-voltage grid:** Voltages above 1,000 V AC. Used for grid connections requiring high power loads and requiring specific permits for connection.

Power is measured in kilowatts (kW) and indicates how quickly energy is used or transferred. Higher power means higher energy consumption simultaneously. Power is typically used to define charging speed and to size electrical infrastructure. Power is calculated using the formula:

$$Power\ (kW) = Voltage\ (V) \times Current(A) \times 1{,}73$$

where 1,73 is a constant factor used for three-phase systems (always applicable on construction sites)

Energy is measured in kilowatt-hours (kWh) and represents total energy consumption over time. One kWh corresponds to using one kilowatt of power for one hour. Energy is used, for example, to specify battery capacity, estimate energy costs, and assess potential emission reductions. Energy is calculated using the formula:

$$Energy\ (kWh) = Power(kW) \times time\ (h)$$

Example | **Current, voltage, power and energy**

Scenario 1: You have a circuit with a 63 A circuit breaker and a voltage of 400 V. You want to determine the maximum power this circuit can deliver.

Power calculation: $400\ V \times 63\ A \times 1{,}73 = \mathbf{43{,}6\ kW}$

Scenario 2: You have a machine with a battery capacity of 100 kWh. You are using a 20 kW charger and want to determine the charging time to fully charge the battery.

Energy calculation: Charging time is calculated by rearranging the energy formula: $\frac{100\ kWh}{20\ kW} = \mathbf{5\ h}$

Scenario 3: Your machine requires 22 kW of charging power and is connected to a system with 400 V voltage. You want to determine the appropriate circuit breaker size for the power cabinet.

Current calculation: $400\ V \times 1{,}73 \div 22\ kW = \mathbf{31{,}8\ A}$. Circuit breakers comes in standard sizes, typically 32 A, 40 A, 50 A etc. To ensure a safety margin, 40 A is recommended.

How do you calculate the correct charging power for the machines?

Once the construction machines and their corresponding charging equipment have been selected, the required charging power and charging schedule for the machines can be calculated. This is essential for determining the total power demand on the construction site and ensuring the workday is planned as efficiently as possible.

The datasheets for the selected machines contain information on their battery capacity and operating time. This information is used to calculate how much energy each machine consumes during operation:

$$(1) Hourly\ consumption\ (\frac{kWh}{h}) = \frac{Battery\ capacity\ (kWh)}{Operating\ time\ (h)}$$

In addition, an overview of when the workday starts and ends and when breaks occur is used to calculate how much energy the machines consume per work shift:

$$(2)\ Energy\ consumption\ per\ shift(kWh) = Hourly\ consumption\ \left(\frac{kWh}{h}\right) \times Shift\ duration\ (h)$$

For example, if charging is planned during lunch breaks, the shift duration refers to the time from the start of the workday until lunch.

The limiting factor for fast charging is usually the maximum charging power the machine can receive. The datasheet information and the charging session duration are used to calculate the energy supplied to the battery:

$$(3)\ Charged\ energy(kWh) = Charging\ power(kW) \times Duration(h)$$

After the charging session, the available energy in the battery is calculated as follows:

$$(4) Available\ energy\ (kWh) = Battery\ capacity - Energy\ cons.per\ shitft + Charged\ energy$$

Using equations (2), (3), and (4), this calculation is repeated for each shift until the next fast-charging session. The necessary charging power for overnight charging is then determined as follows:

$$(5) Necessary\ charging\ power(kW) = \frac{Battery\ capacity\ - Remaining\ energy\ (kWh)}{Duration\ (h)}$$

This calculation indicates the required charging power for overnight charging of the machines. The result should be rounded up to the nearest available charging power.

Example | **Charging Power Calculation**

Context: The Bygata project requires charging for one 300 kWh excavator (6h operation) and two 40 kWh wheel loaders (8h operation), with charging during lunch, dinner, and overnight.

Charging power: Calculations for the excavator:

Using the information from the datasheet→ $Hourly\ consumption = \frac{300}{6} = 50\ kWh/h$

Before lunch, operating time is 4h→ $Energy\ cons.per\ shift = 50 \times 4 = 200\ kWh$

Charging power 190 kW, lunch break for 1h → $Charged\ energy = 190 \times 1 = 190\ kWh$

Remaining energy → $300 - 200 + 190 = 290\ kWh$

Next shift last for 4h, dinner break for 1h. After fast charging the remaining energy in the machine is→ $290 - 200 + 190 = 280\ kWh$

The next shift last for 2h → $Energy\ cons.per\ shift\ = 50 \times 2 = 100\ kWh$

Remaining energy before overnight charging → $280 - 100 = 180\ kWh$

Overnight charging lasts for 12h → $Necessary\ charging\ power\ = \frac{300-180}{12} = 10\ kW$

The same calculations apply to the other battery-powered machines.

Hafslund
Rådgivning