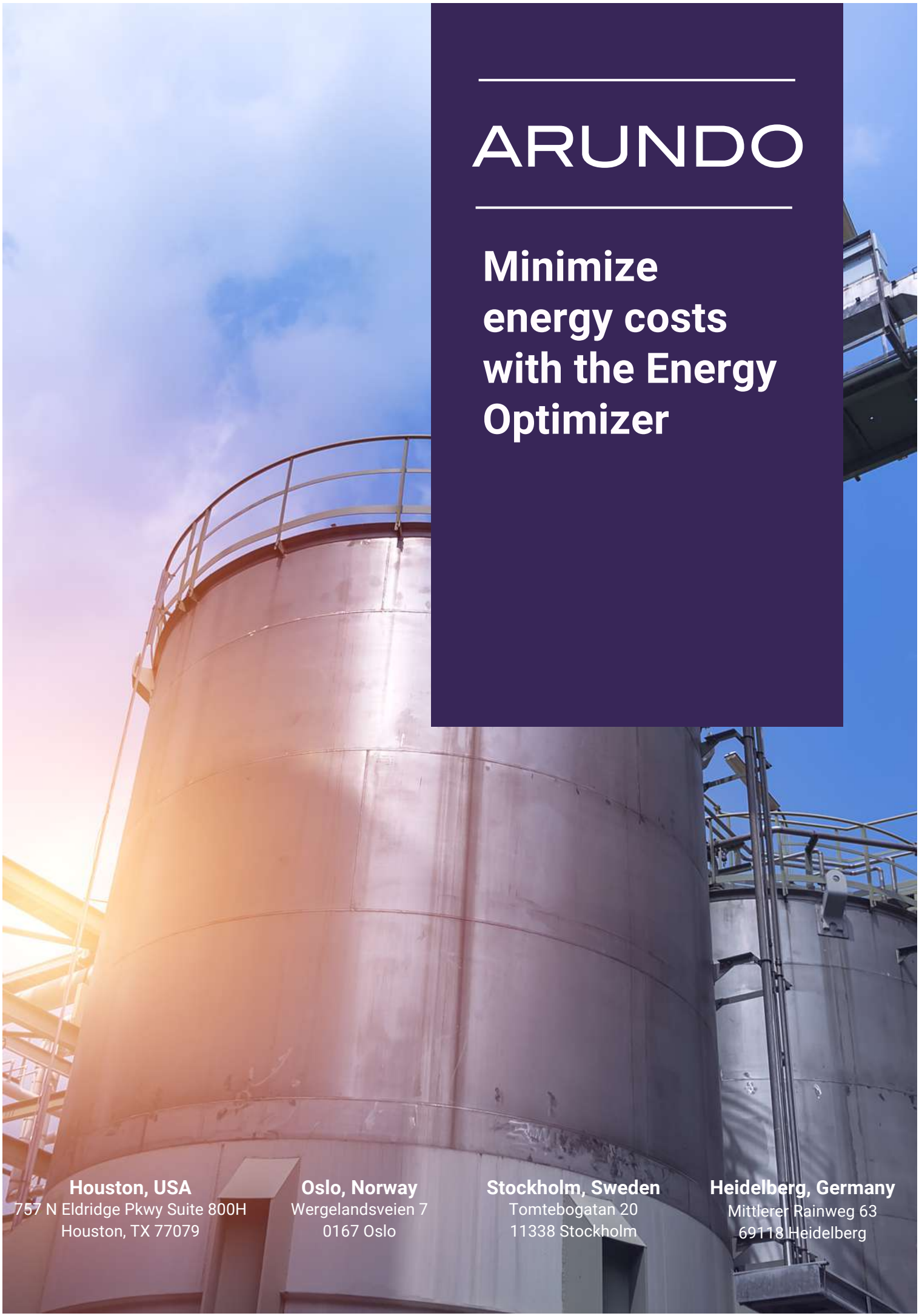


ARUNDO

Minimize energy costs with the Energy Optimizer

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INTRODUCTION: KEY TAKEAWAYS - EXEC SUMMARY

As recent geopolitical events and the transition away from fossil and nuclear fuels have led to higher and increasingly volatile energy prices in Europe, reducing energy costs is now a top priority for all affected industrial companies.

This is not only limited to running machinery at optimal efficiency, but also adjusting production to take advantage of spot price variations. This naturally gives direct savings for electricity purchased on the spot market and creates the opportunity to sell back during peak hours for fixed-price contracts. In addition, reducing consumption at peak demand has environmental and societal benefits: CO_2 emissions are reduced as the fossil-fuel component of the energy mix is the highest at peak demand, and reducing peak demand is an important contributor to grid stability.

To face these challenges, Arundo has developed the **Energy Optimizer**, a cloud-based application combining mathematical optimization and machine-learning-based electricity price forecasts to plan production for the lowest possible energy costs. The application is used by a global leader in the chemical industry, who uses it on a daily basis in their chlor-alkali process at several different sites.

In this article, we show illustrative results for a generic industrial plant which can modulate their process. The realizable electricity cost savings potential is on the order of 3-5%, with an absolute potential of 15%, limited by spare production capacity, electricity prices, forecast accuracy, and how often and by how much the electrolyzers can be adjusted during operation.

WHY IS THIS IMPORTANT NOW?

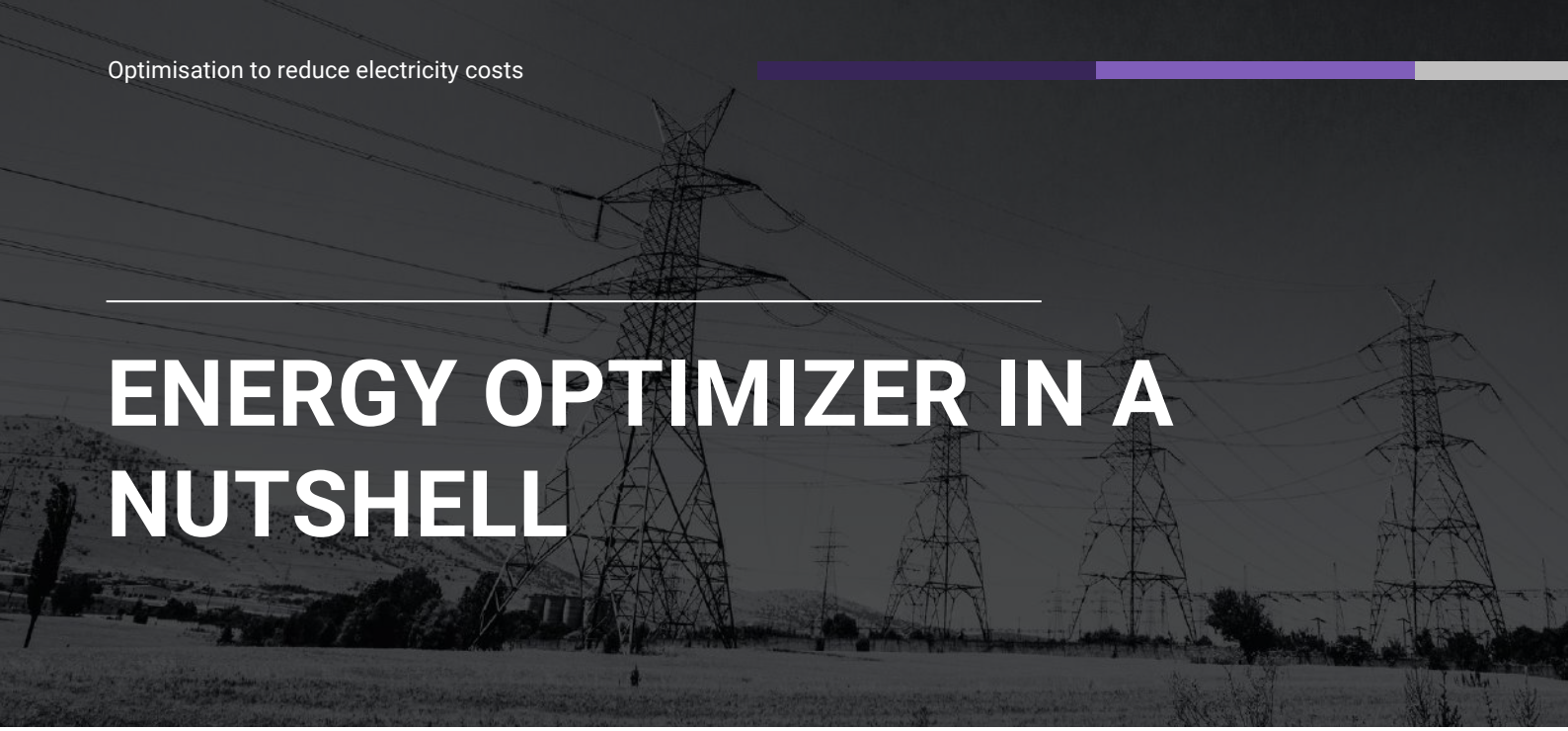
As we all have experienced in our daily lives, the energy markets in Europe are currently at record highs both in terms of prices and volatility.

This is, of course, related to the war in Ukraine and the ongoing sanctions on Russia. Still, the trend will likely continue: European countries have a desire to ensure future energy self-sufficiency, as well as increase the proportion of renewable energy sources such as wind and solar - sources which are naturally variable with weather conditions and the time of day.

Therefore, we are likely to experience a new normal, with on average (compared to the past) higher and more volatile prices both in the long and short term. This may lead to fixed price electricity contracts becoming economically unsustainable, as the long-term uncertainty is too high for sensible pricing. These factors make planning for reducing current and future energy costs a top priority for any high-energy-intensive manufacturing company operating in the European energy market.

In addition, on the societal level, consuming less power when market demand is high is an important contributor to grid stability. Secondly, it reduces CO_2 emissions, as the fossil-fuel component of the energy mix is typically larger when prices are high - coal and oil power plants have to run at high capacity to meet the demand.





ENERGY OPTIMIZER IN A NUTSHELL

With the goal of reducing energy costs, an obvious question to ask is *how can we make our equipment more efficient,* but it is also worth asking *can we take advantage of price variations*.

The answer is yes; by using mathematical optimization to adjust production to match price variability, minimizing electricity costs. This gives direct savings for electricity purchased on the spot market and also the opportunity to sell back unused power during price peaks for electricity purchased via long-term fixed-price contract.

In spot markets, large industrial companies have to nominate their demand for the next day before prices are made public.

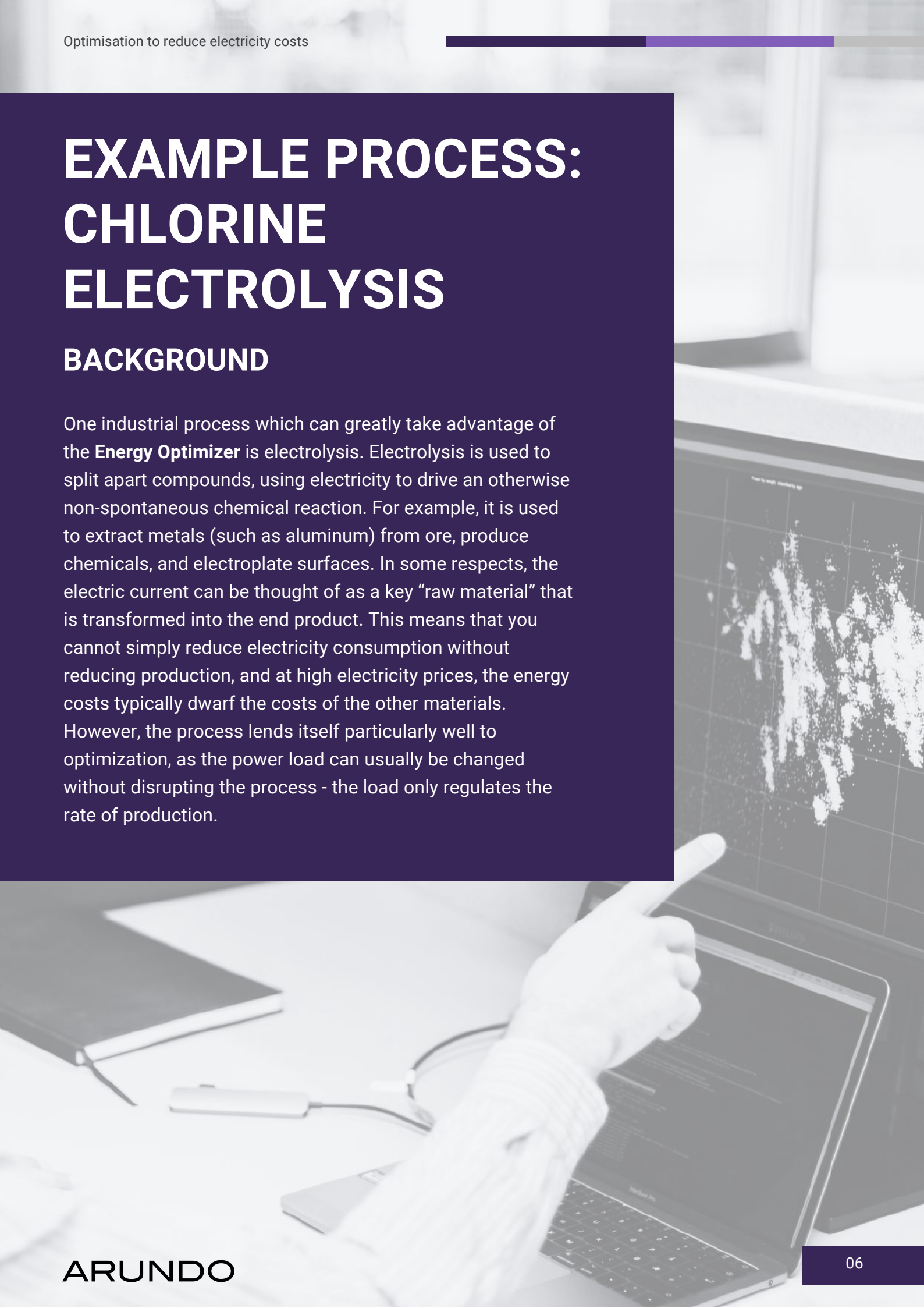
This means we have to rely on price forecasts, the accuracy of which will impact potential savings (also, if there is an imbalance between the actual consumption and placed order, imbalance charges may occur). Several companies provide sufficiently accurate electricity price forecasts using machine-learning models taking into account both fundamental data (historical consumption, renewable generation, weather data, etc.) and direct market information.

Lastly, the optimization has to take into account all the physical and operational constraints of the production process - the recommended power profile has to be realistic and actionable. The Energy Optimizer is built in a modular way so that constraints can easily be added and removed, allowing for tailoring to any energy-intensive industrial process.

EXAMPLE PROCESS: CHLORINE ELECTROLYSIS

BACKGROUND

One industrial process which can greatly take advantage of the **Energy Optimizer** is electrolysis. Electrolysis is used to split apart compounds, using electricity to drive an otherwise non-spontaneous chemical reaction. For example, it is used to extract metals (such as aluminum) from ore, produce chemicals, and electroplate surfaces. In some respects, the electric current can be thought of as a key “raw material” that is transformed into the end product. This means that you cannot simply reduce electricity consumption without reducing production, and at high electricity prices, the energy costs typically dwarf the costs of the other materials. However, the process lends itself particularly well to optimization, as the power load can usually be changed without disrupting the process - the load only regulates the rate of production.





THE CHLOR-ALKALI PROCESS

An example electrolytic process is the chlor-alkali process, which produces chlorine and caustic soda by passing an electric current through a solution of sodium chlorine and water. The total chlorine production in Europe is around 10 million tonnes annually. With a typical energy use of 2.5 MWh per tonne, this amounts to 25 TWh per year, approximately 1% of the continent's total electricity consumption, or equivalent to Ireland's annual usage.

To minimize electricity costs, we formulate an optimization problem starting from equations relating current density, power consumption, and the amount of products produced: *Based on an electricity price forecast, find the optimal current variation over time to minimize electricity costs, given a fixed amount of product to produce, subject to several operational constraints.* By allowing for a variation in the amount of chlorine in stock (leveraging available chlorine storage capacity), we can take advantage of both daily and weekly price variations. Here we assume 100% of the electricity is purchased on the spot market.

Consider a generic industrial plant comprising several chlorine-producing electrolysers. The plant is not running at full capacity, so it can vary production over time, still meeting customer demand. Being a modern semi-automated plant, changes in power can be made to all electrolysers at a maximum frequency of once every two hours.

The following operational and physical constraints are taken into account:

- Required chlorine outflow to customers
- Minimum and maximum chlorine in storage
- Maximum change in power from one hour to the next per electrolyzer
- Minimum and maximum acceptable power levels per electrolyzer

The figures below show the results for this generic plant (not reflecting any actual site), based on prices for a week with high and volatile prices, though still showing the typical pattern of higher prices during weekdays (first five days) and lower prices during the weekend (last two days), as well as characteristic morning and evening peaks. Comparing the optimized total nominated power to a flat production benchmark, producing the same total amount of product in both cases, we see that the load is about 50% lower during peak hours, corresponding to running the electrolysers at their technical minimum. The total electricity cost savings are around 15% over the seven days.

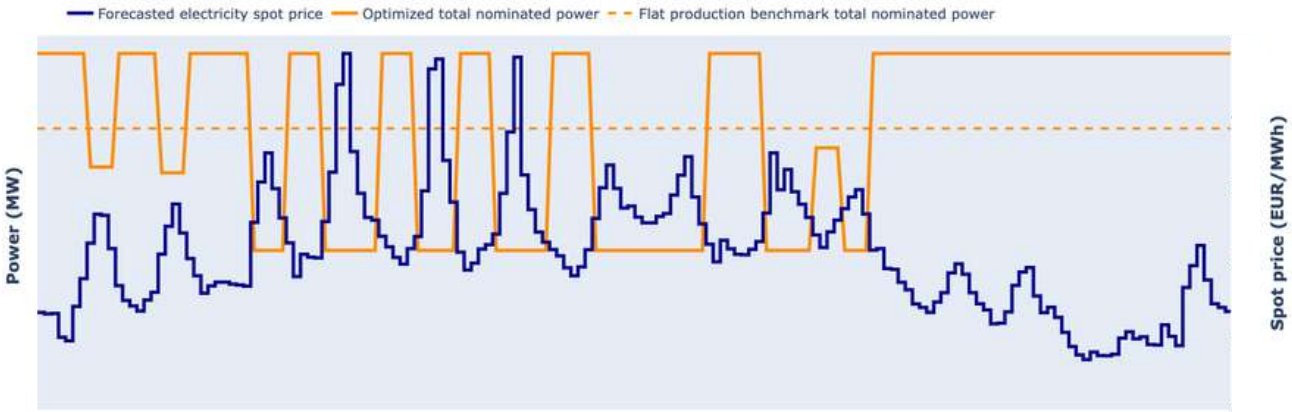


Figure 1: Optimized total power profile (orange, left axis) for several example chlorine-producing electrolyzers at a generic plant. As expected, more chlorine is recommended to be produced when prices (blue, right axis) are lower, and vice versa. For comparison, a benchmark power profile corresponding to constant production is also shown (dashed orange, left axis).

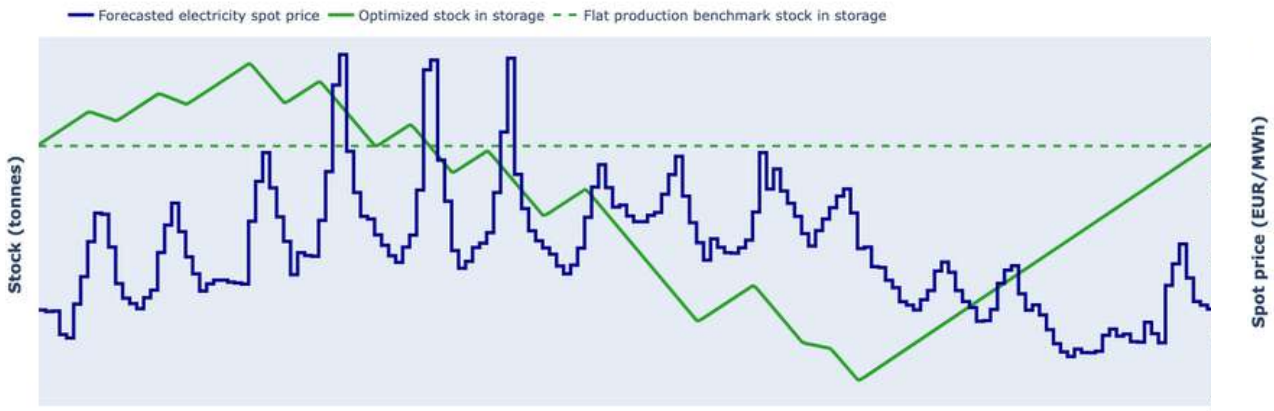


Figure 2: Amount of chlorine in stock (green, left axis) as given by the total power profile in Fig. 1 for a generic plant, limited by a maximum (capacity-driven) and minimum (safety-driven) allowable value. The amount varies with prices (blue, right axis), as available stock is taken advantage of to produce more when prices are low. For comparison, a benchmark stock profile corresponding to constant production is also shown (dashed green, left axis). Note the build-up of stock over the last two days (weekend), and depletion throughout the week.

In practice, not all chlor-alkali plants have the automation in place to achieve this relatively high degree of power variation, price forecasts are never 100% accurate, and price volatility may not be as large. Examples closer to real operating conditions, limiting the number of electrolyzers which can vary power and how often power can be changed, typically give savings closer to 5%. This is still appreciable in absolute numbers - particularly in the production of commodities, where profit margins tend to be slim. The large difference between what can be achieved in practice and the upper bound may also be a motivating factor to implement automatic and remote electrolyzer power controls instead of relying on manual processes.

INEOS INOVYN CASE STUDY



Company:

INEOS Inovyn is Europe's leading producer of vinyls and in the top three worldwide, with plants in eight countries across Europe. The company's portfolio includes vinyls, hydrogen, and sustainability-driven business units. INEOS Inovyn manufactures a wide range of chemical products used worldwide as raw materials in almost every industrial process. Electrolysis, cracking, and polymerization units are integral to most INEOS Inovyn sites, forming a comprehensive production process.

Challenge:

Committed to Net Zero emissions by 2050, but facing increasing supply chain disruptions and energy price volatility in Europe, INEOS Inovyn faced a tough challenge. The manufacturer wanted to minimize electricity costs and reduce CO_2 emissions by optimizing the daily production of their electrolyzers in the chlor-alkali process.

INEOS INOVYN CASE STUDY

Solution:

To minimize electricity costs in their chlor-alkali process, INEOS Inovyn adopted Arundo's Energy Optimizer – a cloud-based AI application combining mathematical optimization and machine-learning-based electricity price forecasts to recommend the optimal power profile to minimize costs, also taking fixed contracts into account, while meeting all physical and operational constraints. By allowing for a variation in the flow of chlorine into downstream processes and final product stocks, the energy usage can be modulated so that we can take advantage of both daily and weekly price variations.

Results:

After a short pilot phase, Arundo implemented the solution across several of INEOS Inovyn's plants enabling them to leverage load modulation and significantly cut energy costs while concurrently reducing their carbon footprint.

INEOS Inovyn is now using the application across their sites (see figure above) as part of their standard operations for electrolysis units, affording CO_2 emissions reductions in the region of 1-2% and cost savings in the region of 3-5%. The realised benefit in any period depends on spare production capacity, electricity prices, forecast accuracy, and how often and how much the electrolyzers can be adjusted during operation.

"INEOS Inovyn's use of the Arundo Analytics Energy Optimiser app is a key step in our sustainability journey to Net Zero. By implementing a big data analytics "infrastructure and software as a service" model and rapidly scaling the Energy Optimizer digital app across our electrolysis processes, we are now planning production in a more efficient way. Daily operations are dynamically responding to market volatility to use cleaner, greener energy at lower cost – a win-win!"



Joe Rumer
Digital & Analytics Program Manager
INEOS Inovyn



CONCLUSION - THERE'S MUCH MONEY HIDDEN IN THE DATA

High energy costs are profoundly affecting energy-intensive industries, and are expected to continue to do so in the following years.

Companies in these sectors are facing a pressing need for action to ensure the profitability of their businesses. Optimizing the daily production in order to minimize electricity costs is one crucial step for any manufacturer, and Arundo has developed the **Energy Optimizer** to help them do exactly that.

Especially the electrolysis industry lends itself well to optimisation, and for the chlor-alkali process the potential electricity savings can be as high as 15%. In practice, typically achievable savings are in the 3%-5% range, which is still sufficient to provide competitive advantage in commodity industries with slim margins.

ABOUT ARUNDO

Arundo Analytics supports equipment operators to make better decisions and improve efficiency, reliability, and sustainability.

Our products link data science, cloud computing, and AI with industrial IoT, providing prescriptive actions beyond simple alerts. Broad industry experience makes us a powerful partner for digitalization and process optimization, as exemplified with INEOS Inovyn.

Maximize your business' capabilities with Arundo products.

Benefit from more than 250.000 development hours for:

- Reduced costs,
- Increased revenue, and
- Reduced carbon footprint for your operations.

Would you like to learn more about the Energy Optimizer and your equipment's potential for optimization?

Get the answers you need: contact@arundo.com

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