UniChlor® Technology

Powell
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UHDENORA
A JOINT COMPANY OF UHDE & GRUPPO DE NORA
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UniChlor® Technology

UniChlor® Technology
Advanced Processes for Chlor-Alkali Production
An Alternative to Purchasing Chlor-Alkali Commodity Chemicals

What is UniChlor® Technology?

Small chlorine plants that produce sodium hypochlorite and other commodity chemicals downstream of the chlorine/caustic generation process are an attractive alternative to making bleach from chlorine and caustic purchased on the open market. These plants, which use salt and electricity to make chlorine, caustic soda, and hydrogen on-site, can be used primarily for the production of sodium hypochlorite, ferric chloride, calcium hypochlorite, hydrochloric acid, and other chlorine derivatives, or to produce feed stocks for a variety of other chemicals.

Alternatively, the plants can be used to supply a distribution system for hydrochloric acid and caustic. Since hydrogen is a by-product of these plants, the chlorine can be burned with the hydrogen to produce hydrochloric acid and the caustic can be evaporated.

Who Can Benefit from UniChlor® Technology?

Optimal candidates for UniChlor® Technology will meet one or more of the criteria below:

- Use chlorine and caustic in quantities above 50 tons equivalent of chlorine per day.
- Use significant amounts of chlorine and caustic in sodium hypochlorite production for internal consumption.
- Produce ferric chloride, calcium hypochlorite, or other chlorine derivatives.
- Produce feed stocks for the manufacture of other chemicals.
- Produce sodium hydroxide and hydrochloric acid for distribution.

This advanced production technology for Chlor-Alkali commodity chemicals is being marketed in the US as UniChlor® Technology as a result of an agreement between Powell Fabrication & Manufacturing, Inc., and Uhdenora of Italy. Together, the two companies provide the complete chain of chlorine production facilities for plants of up to 150 to 200 tons per day of sodium hydroxide using Uhde BM-2.7 single element bipolar membranes electrolyzer technology and Powell's complete continuous process systems and components.

Contact Us for For Information

Powell
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For more information about UniChlor® Technology and Powell's complete continuous sodium hypochlorite process systems and components:

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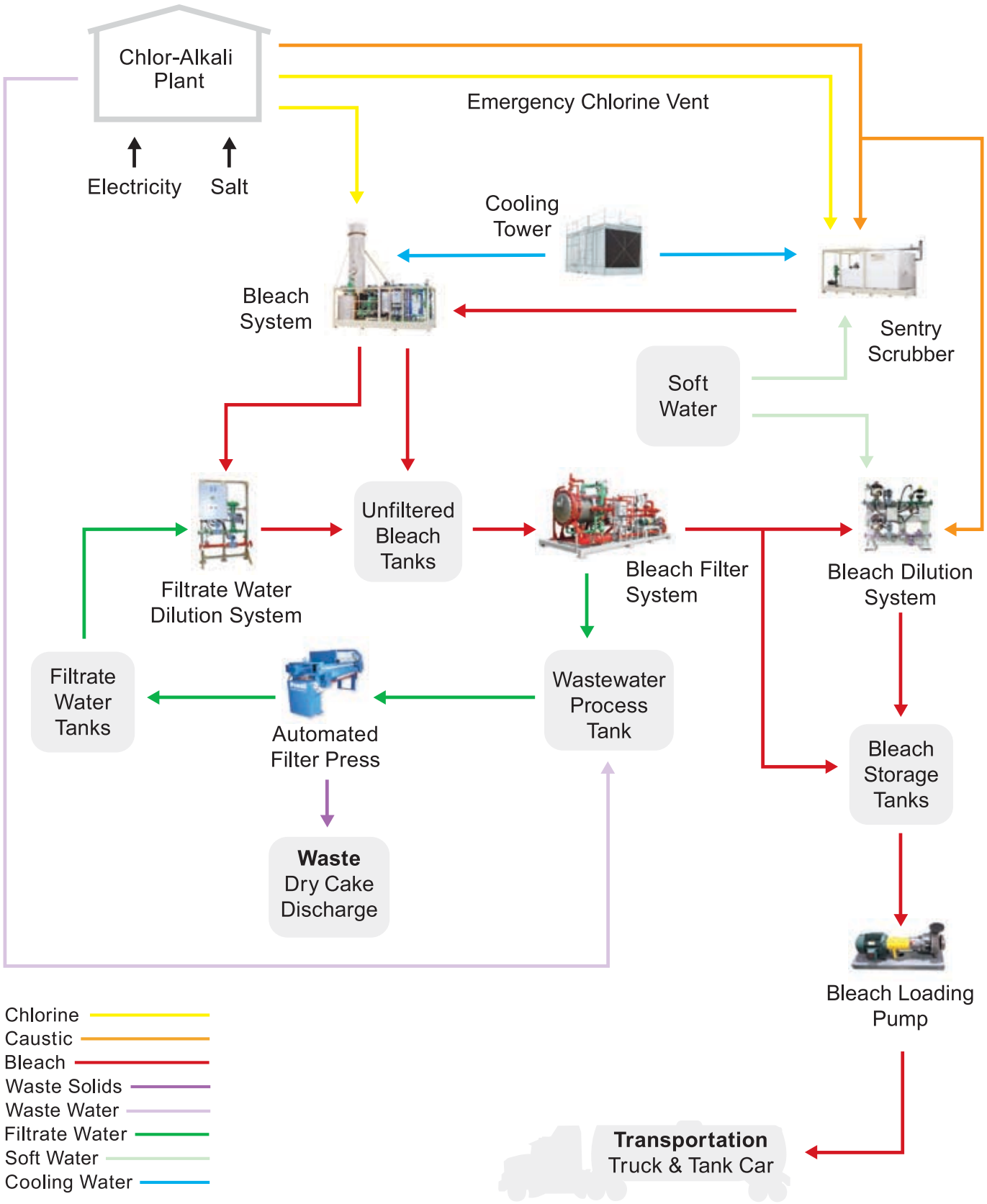
UniChlor® Technology Process Flow



Benefits of UniChlor® Technology -

A Profitable Alternative to Purchasing Chlor-Alkali Chemicals

UniChlor® Technology can provide significant economies that impact directly on the bottom line. The most obvious are discussed below:

Chlorine and Caustic are Produced for One-Third the Cost of Purchase

It costs from two to three times as much to purchase chlorine and caustic as it does to make the same amount of chlorine and caustic using UniChlor® Technology.

Chlorine and Caustic Costs are Controlled

Since all production requirements of chlorine, caustic, and hydrochloric acid can be supplied with UniChlor® Technology, the long-term costs can be controlled. As a result of controlled costs, advantageous long-term customer contracts and competitive pricing can be negotiated and controlled.

Product is Higher Quality

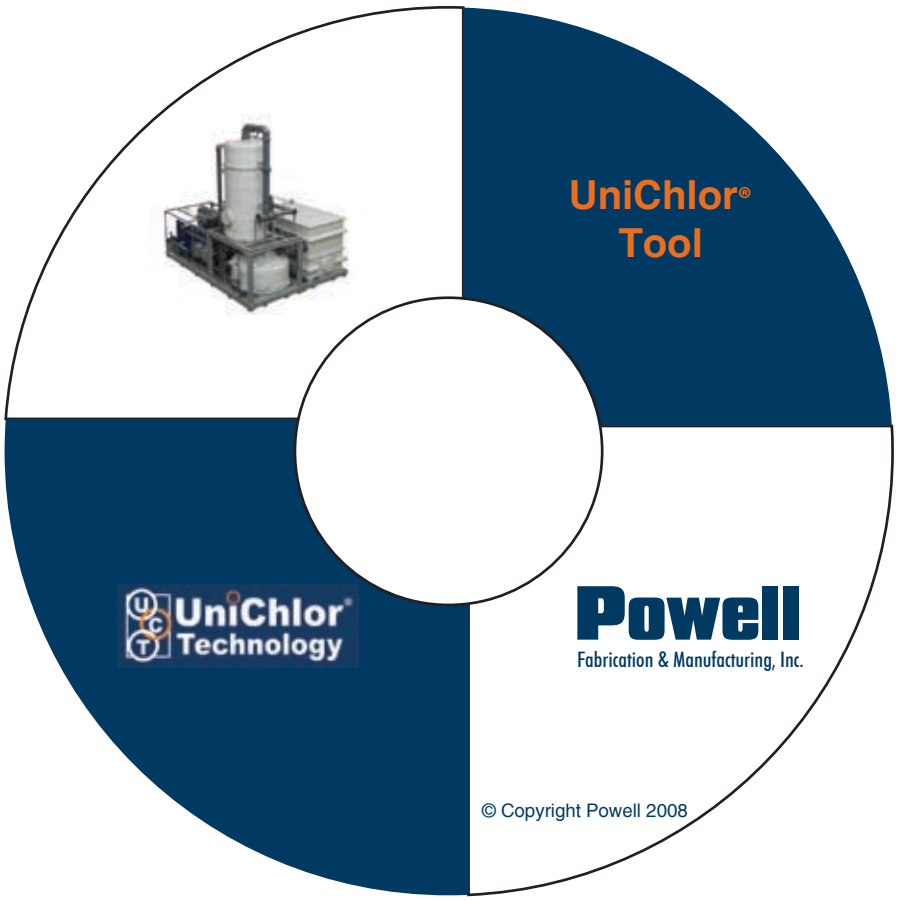
The commodities produced by the UniChlor® Technology are of very high quality, since the best membrane cell technology available today is used in their production. Similarly, since chlorine and/or caustic are produced on-site, contamination or degradation of the chemicals during transportation is eliminated.

UniChlor® Technology Enhances Site Security and Safety

The use of UniChlor® Technology does not require that liquid chlorine be stored on-site. The plants use salt and electricity to produce caustic soda and chlorine gas. Downstream, the chlorine gas - either wet or optionally dry - can be reacted in a chemical process to produce bleach, other chlorine derivatives, or chemical feed stocks. As a result, use of liquid chlorine and related storage issues are eliminated. Likewise, compliance requirements for EPA and OSHA issues can be virtually eliminated.

Is UniChlor® Technology Right For You?

In order to help establish the relationship between these factors, Powell has prepared an interactive tool available on this CD.



Economics of UniChlor® Technology

UniChlor® Technology encompasses the complete chain of chlorine production facilities for plants of up to 150 to 200 ECU's per day. The core of the technology is a small chlorine plant that uses salt and electricity to make chlorine, caustic soda and hydrogen on-site using Uhdenora technology including the Uhde BM-2.7 single element bipolar membrane electrolyzer technology. Downstream, Powell chlorine scrubber and optional sodium hypochlorite technology and equipment are used to combine the chlorine and caustic to produce bleach. Ferric chloride, calcium hypochlorite, hydrochloric acid and other chlorine derivatives, or chemical feed stocks can also be produced.

The two major components of the variable cost to produce chlorine and caustic are electricity and salt.

Power Considerations

The cost of power is one of two major variable cost components that drive the economics of UniChlor® Technology, and must be factored into the cost to produce chlorine and caustic. Following are the major considerations for power consumption:

Power Requirements

Plants using UniChlor® Technology are 24/7 operations, with only minimal downtime for repairs. Plants may run up to 97% or 98% of the time, approximately 355 to 360 days per year. For each ECU produced, approximately 2500 kilowatts of energy will be used. A typical plant producing between 75 and 90 ECU's per day will require 7 to 8.5 megawatts of power.

Power Demand Flexibility

Plants using UniChlor® Technology are designed to accommodate a wide range of power demands. As a result, off-peak power rates and mid-peak power rates can be considered, allowing the plant to operate at full capacity during the off-peak hours and ramp down to the minimum power usage during high-peak and mid-peak power cost periods within thirty minutes.

Interruptible Power

Plants using UniChlor® Technology can be taken off line instantaneously with no damage to the equipment or startup problems. More advantageous power costs can be negotiated since the power company can be allowed instantaneous trip capability in case of voltage or frequency drop during high peak demand, power generation problems, or distribution failures.

Supply Voltage

Plants using UniChlor® Technology can be designed to accept any available power supply as required. Depending on each project, the power company may provide the required substation for the power or the substation may be provided by the purchaser.

Salt Supply & Related Cost

Approximately 1.75 short tons of salt are required to produce one ECU. A 50-ECU per day plant will use approximately 85 short tons of salt per day, or 27,000 tons of salt per year. The type of salt to be used – and corresponding cost – is the second major variable that must be factored into the cost to produce chlorine and caustic using UniChlor® Technology.

Type of Salt

Three types of salt are typically used with UniChlor® Technology. Quality and cost vary according to type. These are discussed below:

- **Evaporative Salt** There are many choices of suppliers of evaporative salt. This type of salt will be used in the initial cash flow analysis.
- **Rock Salt** (Mined) Many choices exist for rock salt. However, if a rock salt is utilized, more treatment equipment and solid wastes occur.
- **Solar Salt** In some designs, solar salt may be used with additional primary brine treatment.

Method of Delivery

The combination of salt choice and delivery method will dictate how the salt is handled and treated at the plant site. There are several ways salt can be delivered to the chlorine plant. These are shown below:

- **Daily shipment** of salt crystals to the plant.
- **Periodic shipments** of salt crystals to a port, delivery to the plant, on-site storage of the salt.
- **Railcar delivery** of the salt crystals to the plant.
- **Barge delivery** of the salt crystals to the plant.
- **Barge delivery** of the salt crystals to a local storage facility.
- **Railcar delivery** of 85% salt slurry to the plant.
- **Railcar delivery** of 85% salt slurry with local rail yard storage.

Other Variable Costs of the Chlorine Plant

There are other items that add to the variable cost of the plant. These costs will vary depending on final product requirements. The variable cost factors that fluctuate based on production requirements are typically low cost factors. These include the following:

- Water
- Sewer
- Chemical treatment of the salt
- Miscellaneous other factors such as Nitrogen, natural gas, water treatment, solid waste disposal, etc.

Fixed Costs of the Plant

There are major fixed costs of the plant not related directly to the daily or yearly production of the plant, but related to the maximum output capacity and the chemicals produced. For example, adding an HCl burner and a 50% evaporator will not add operators but some additional maintenance costs will be incurred. Similarly, operating the plant at flow rates below the rated capacity of the plant will slightly increase the life of some equipment, however, no significant changes in fixed costs for maintenance will be experienced. The majority of the fixed costs will be as follows:

Cell Room Maintenance

- Every four to five years the membranes in the chlorine cell will have to be replaced. They are guaranteed for four years if operating conditions for the brine and other items are maintained.
- Every eight to ten years the anodes and cathodes will need recoating. The guaranteed life is eight years if operating conditions are maintained.

General Equipment Maintenance

As with any chemical plant, pumps, valves, heat exchangers and instrumentation will require repair or replacement.

Labor

The labor required to operate a typical small plant 24/7 is as follows:

- 1 plant production manager, responsible for the overall production, operation and engineering details of the plant.
- 4 control room operators, one per shift.
- 4 laboratory operators/testers, one per shift.
- 4 field operators, one per shift for field work.
- 1 maintenance supervisor, to supervise plant maintenance and do hands-on work on all equipment.
- 2 maintenance individuals, one shift.

Powell Sentry 2000 Chlorine Scrubber

Powell Sodium Hypochlorite Technology

An Alternative to Purchasing Chlor-Alkali Commodity Chemicals

Basic Concepts

The chlor-alkali process produces chlorine and caustic soda in set ratios of 1 unit of chlorine and 1.1 units of caustic soda. The combination of 1 ton of chlorine and 1.1 tons of caustic soda is an electrochemical unit, commonly referred to as an ECU.

UniChlor® Technology can provide significant advantage, especially when costs to produce chlorine and caustic on-site are compared with costs to purchase these chemicals. UniChlor® Technology will be most attractive to companies that use chlorine and caustic in quantities above 50 ECU's per day.

As you review the following graphs, you will note that three factors play a key role in determining if use of UniChlor® Technology is a viable option. These are the cost of electricity, the cost of salt, and the size of the plant. The cost of electricity and salt directly affect the variable cost to produce an ECU of caustic and chlorine and help to establish the economics of on-site production versus purchase of caustic and chlorine. The size of the plant - ie, the production volume that can be maintained - determines whether or not the project can be justified. Regardless of the per ECU variable cost savings available with on-site production, annual production volumes must typically be above 10,000 tons for the plant to generate anticipated annual cash flow in the range necessary to justify the project.

The graphs that follow help to explain how factors such as electricity cost, salt cost, and individual plant design and size impact on the economics of the small chlor-alkali plant.

Please Note: These calculations are intended to introduce UniChlor® Technology and the concept of the small chlorine plant. They can help to establish the relationship between plant size, power costs, salt costs, and total production costs. They should not be used as the basis of detailed analysis.

Assumptions used for the calculations that follow:

- The unit of measure is an ECU of caustic and chlorine. When comparing the cost to produce caustic and chlorine to the cost to purchase these chemicals, care must be taken to maintain the correct units of measure. If metric and US units of measure are interchanged, a 10% error can easily result.
- Calculations assume the use of evaporative salt. Other salts such as solar salt or rock salt can be utilized.
- Variable costs - Includes salt and all necessary chemicals to treat the salt in the brine treatment system, all required electricity, water, and sewer costs.
- Fixed costs - Includes labor, benefits, overhead, maintenance, and insurance.
- Total cost of production - Equals variable costs plus fixed costs. Calculations exclude interest, income tax (federal and state), depreciation and amortization.

☑ Is UniChlor® Technology Justified for Your Site?

Optimal candidates will meet one or more of the following conditions:

- ☐ Use chlorine and caustic in quantities above 50 tons equivalent of chlorine per day.
- ☐ Use significant amounts of chlorine and caustic in sodium hypochlorite production for internal consumption.
- ☐ Produce ferric chloride, calcium hypochlorite, or other chlorine derivatives.
- ☐ Produce feed stocks for the manufacture of other chemicals.
- ☐ Produce sodium hydroxide and hydrochloric acid for distribution.

Variable Costs to Produce an ECU of Caustic and Chlorine

Figure 1: The Impact the Cost of Electricity has on Variable Costs to Produce a Short Ton of NaOH

The graph in Figure 1 shows the impact that variations in the price per kilowatt hour (kWh) of electricity can have on the variable costs to produce an ECU of NaOH. In the illustration, the cost of evaporative salt is assumed to be $60 per short ton. The cost of electricity varies from $0.03 to $0.07.

Figure 1: The Impact the Cost of Electricity has on Variable Costs* to Produce an ECU of Caustic and Chlorine

*Variable costs include electricity, utilities, salt, and chemicals. For this calculation, cost of salt is assumed to be $60 per ton.

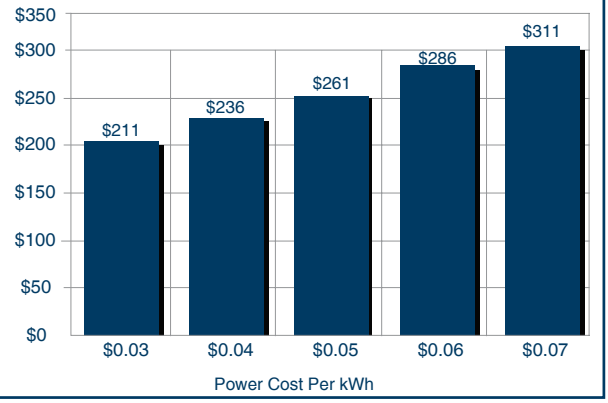


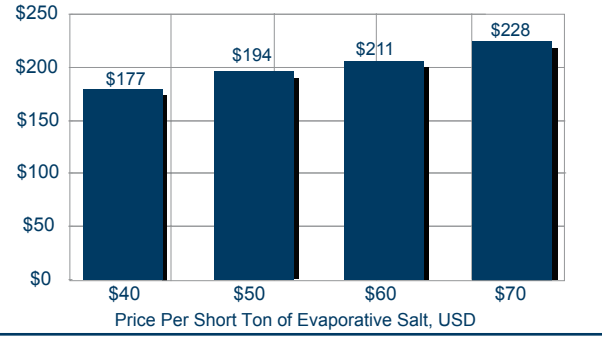
Figure 2: the Impact the Cost of Salt has on Variable Costs to Produce an ECU

The graph in Figure 2 shows the impact that variations in the cost per ton of evaporative salt can have on the variable cost to produce an ECU. In this illustration, the cost of electricity is assumed to be $0.03 kWh. The cost of the evaporative salt varies from $40 to $70 per short ton. It would be unusual for evaporative salt to be priced as low as $40 per short ton, however, in some cases, other types of salt such as rock salt, may be used.

In general, for every $10 per short ton increase or decrease in the cost of salt, a change of approximately 10% in the variable costs will result.

Figure 2: The Impact the Cost of Salt has on Variable Costs* to Produce an ECU

*Variable costs include electricity, utilities, salt, and chemicals. For this calculation, cost of electricity is assumed to be $0.03 kWh.



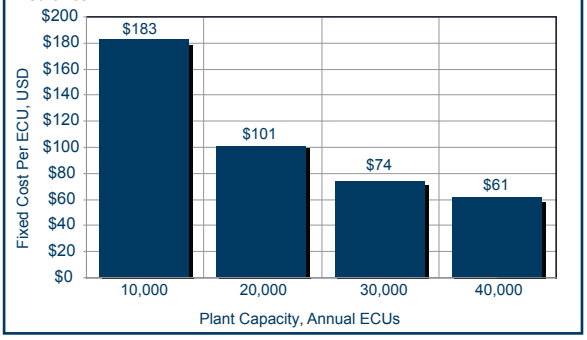
Fixed Costs to Produce an ECU of Caustic and Chlorine

Figure 3: The Impact the Size of the Plant has on Fixed Costs to Produce an ECU

The graph in Figure 3 illustrates how the size of the plant will have a significant impact on the potential feasibility of the project. Small chlorine plants are sized to accommodate a defined maximum production capacity of ECU's on a per year basis-typically 10,000, 20,000, 30,000, or 40,000. For each capacity range, there are fixed costs associated with the plant that will not change appreciably regardless of the production of the plant. For example, if the plant is designed for 10,000 ECU's per year, costs such as labor, benefits, overhead, maintenance, and insurance remain essentially the same as those of a plant designed for a larger capacity.

Figure 3: The Impact the Size of the Plant has on Fixed Costs* to Produce an ECU of Caustic and Chlorine

*Fixed cost includes labor, benefits, overhead, maintenance, and insurance.



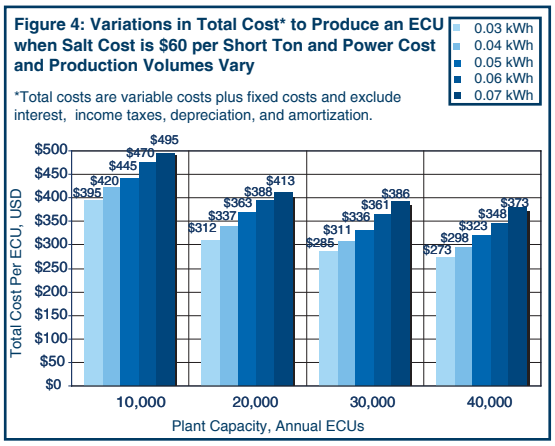
Total Costs to Produce an ECU of Caustic and Chlorine

Figure 4: Variations in the Total Costs to Produce an ECU of Caustic and Chlorine When Salt is $60 per Short Ton and Power Costs and Production Volumes Vary

When evaluating the feasibly of a plant, the total costs of the product must include both variable and fixed costs. These costs will determine if it is more economically advantageous to produce chlorine and caustic or to purchase them. The graph in Figure 4 shows variations in total costs to produce an ECU of NaOH when salt cost is $60 per short ton and power cost and production volumes vary. The total cost per ECU, including variable and fixed costs, depends on the total production volume in addition to power and salt costs.

Figure 4: Variations in Total Cost* to Produce an ECU when Salt Cost is $60 per Short Ton and Power Cost and Production Volumes Vary

*Total costs are variable costs plus fixed costs and exclude interest, income taxes, depreciation, and amortization.



Anticipated Additional Annual Cash Flow

Figure 5, 6, and 7: Anticipated Additional Annual Cash Flow Using On-Site Production When Electricity Cost is $0.03, $0.05, and $0.07 per kWh

As the price of purchased chlorine and caustic increases, the on-site chlorine plant becomes a more attractive investment.

Detailed analysis of specific business volumes, future business plans, location, and other related components are required to accurately determine anticipated additional annual cash flow advantages. However, Figures 5, 6, and 7 provide an indication of the anticipated additional annual cash flow based on plant size and power costs relative to the cost of purchased chlorine and caustic. As indicated, the larger the plant and the lower the power costs, the more feasible the project.

Please note: These numbers do not indicate total cash flow for the project. Rather, they provide an indication of the additional cash flow that might be achieved with the technology.

Figure 5: Anticipated Additional Annual Cash Flow Using On-Site Production when Electricity Cost is $0.03 per kWh

Note: Total costs are variable costs plus fixed costs and exclude interest, income taxes, depreciation, and amortization; Salt cost is assumed to be $60 Per Short Ton.

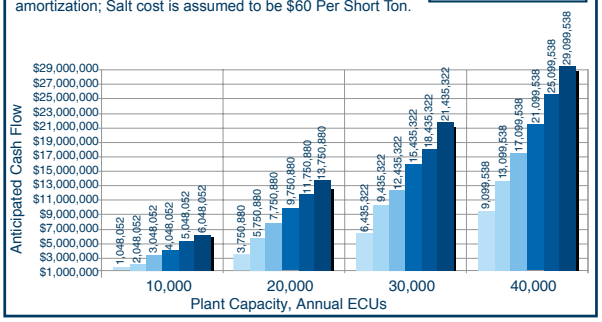


Figure 6: Anticipated Additional Annual Cash Flow Using On-Site Production when Electricity Cost is $0.05 per kWh

Note: Total costs are variable costs plus fixed costs and exclude interest, income taxes, depreciation, and amortization; Salt cost is assumed to be $60 Per Short Ton.

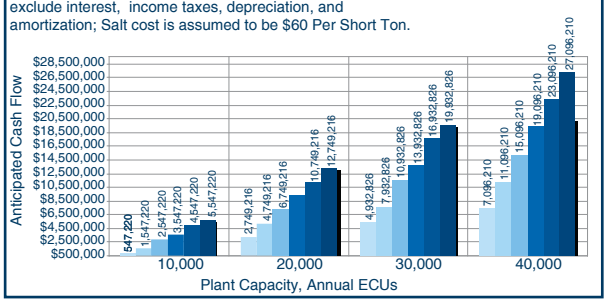
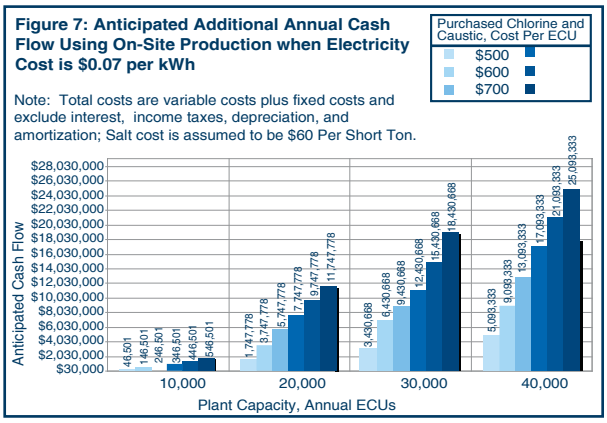


Figure 7: Anticipated Additional Annual Cash Flow Using On-Site Production when Electricity Cost is $0.07 per kWh

Note: Total costs are variable costs plus fixed costs and exclude interest, income taxes, depreciation, and amortization; Salt cost is assumed to be $60 Per Short Ton.



Other Considerations

In addition to anticipated raw material cost advantages, other considerations make UniChlor® Technology an attractive alternative. For example, transportation of chlorine can be expected to become more costly and complex as homeland security issues and other concerns drive changes in the way hazardous materials are shipped. However, if properly sized for market penetration, on-site chlorine plant will provide cost benefits and a significant market advantage. Listed below are some reasons why:

- Long term contracts for power and salt allow production costs to remain stable. The on-site producer can, in turn, offer long term contracts for HCl, sodium hypochlorite, ferric chloride, and other derivatives.
- Since storage of liquid chlorine can be eliminated with on-site production, EPA and OSHA issues can be virtually eliminated.
- As power and natural gas prices increase for existing chlorine and caustic producers, significant increases to the existing ECU costs will occur. Installation of on-site chlorine plants using the efficient, state-of-the-art UniChlor® Technology will protect the owners from these price increases.
- Use of the best available technology produces high quality caustic and chlorine with low levels of bromine, resulting in better quality products and a competitive edge.

An Alternative to Purchasing Chlor-Alkali Commodity Chemicals

Total Cost to Produce a Gallon of Bleach

UniChlor® Technology encompasses a complete chain of production facilities that utilize salt and electricity to produce chlorine, caustic soda, and hydrogen on-site. The caustic and chlorine can be combined downstream to produce sodium hypochlorite, typically at considerable savings compared to the cost to purchase caustic and chlorine on the open market.

When total costs to produce caustic and chlorine are known, the cost per gallon to produce different strengths of bleach can be calculated at various power costs. Figures 1, 2, and 3 illustrate how the variable factors of electricity cost and plant capacity impact on the cost to produce a gallon of sodium hypochlorite. For these illustrations, the cost of salt - the third variable factor - is assumed to be $60 per short ton.

As illustrated, lower electricity costs typically result in lower production costs per gallon of bleach, however, higher electricity costs can be accommodated if the plant capacity is high enough to offset the increased cost of electricity.

Of course, the feasibility of the project will require thorough evaluation of factors such as electricity and salt costs, location of the plant, and volume of bleach sold compared to the cost to purchase chlorine and caustic.

Figure 1: Cost to Produce a Gallon of NaOCl When Electricity Cost is $0.03 per kWh

Note: Excludes interest, income tax, depreciation, and amortization; Salt cost is assumed to be $60 per short ton.

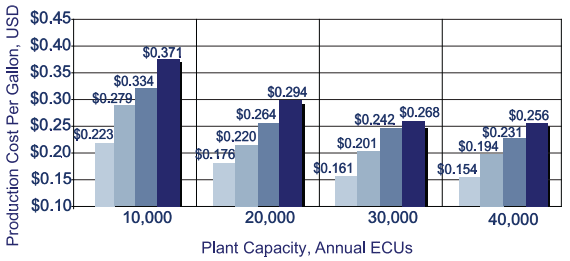


Figure 2: Cost to Produce a Gallon of NaOCl When Electricity Cost is $0.05 per kWh

Note: Excludes interest, income tax, depreciation, and amortization; Salt cost is assumed to be $60 per short ton.

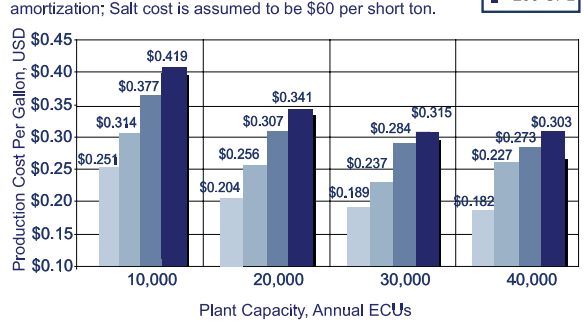
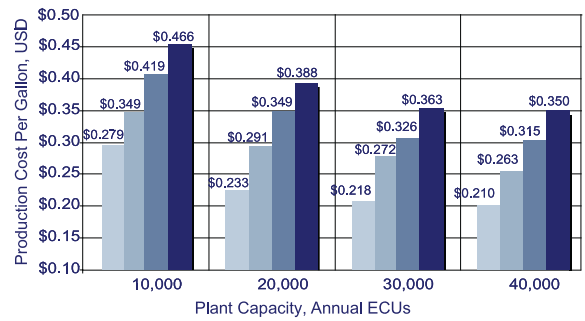


Figure 3: Cost to Produce a Gallon of NaOCl When Electricity Cost is $0.07 per kWh

Note: Excludes interest, income tax, depreciation, and amortization; Salt cost is assumed to be $60 per short ton.



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