Elessent™
MECS® TECHNOLOGIES

MECS® HRS™ TECHNOLOGY:
GENERATING CARBONLESS ENERGY FROM SULFURIC ACID PLANTS

FEATURES AND BENEFITS

- Carbonless energy generation – recovers waste heat as intermediate-pressure steam that can be used for in-plant process requirements or directed to a turbo generator for electricity production
- Enables plants to achieve net-positive energy balance
- Capable of producing steam at various conditions based on site-specific requirements
- Payback on investment can be as short as three years
- Proven technology with almost 40 years of experience and over 60 systems in use worldwide
- Key HRS™ equipment (tower, distributors, diluter, boiler, heater and preheater) are designed and constructed from MECS® ZeCor® material, a proprietary corrosion-resistant, low-maintenance alloy

UNITED NATIONS APPROVED METHODOLOGY TO REDUCE GREENHOUSE GAS EMISSIONS, WHICH IS ELIGIBLE FOR CARBON CREDITS IN COUNTRIES WITH EMISSIONS TRADING SYSTEMS

RECOVER WASTE HEAT AS PROCESS STEAM OR ELECTRICAL ENERGY

The largest single source of power generation on the planet is thermal energy. It accounts for more than half of total global energy demand[1] and is the primary contributor to carbon emissions worldwide. However, as a process that is built on the combustion of sulfur instead of hydrocarbons, the production of sulfuric acid can play a key role in the decarbonization of this vital segment of the global economy by harnessing the energy it generates in the form of process steam or electrical power.

In particular, the MECS® Heat Recovery System (HRS™) captures energy released through the formation of sulfuric acid, which in conventional acid plant designs is commonly lost to the atmosphere or cooling water systems. When combined with more traditional means of energy recovery within sulfuric acid plants, this technology enables the plant to utilize up to 95% of the process heat it generates internally as steam, which can subsequently be converted into electricity and applied in a variety of functions.

[1]Source: International Energy Agency

REDUCE YOUR PLANT'S CARBON FOOTPRINT

Through the production of both high-pressure and intermediate-pressure steam, a typical 3,000 MTPD-capacity sulfuric acid plant with HRS™ technology can prevent up to the equivalent of 300,000 tons of carbon dioxide (CO_2) emissions annually – roughly the amount of CO_2 that is generated by 64,650 passenger vehicles over the course of a year.

Due to its capacity for upgraded energy recovery, HRS™ technology has been recognized by the United Nations as an accredited method for greenhouse gas (GHG) emissions reduction and therefore can be applied to secure credits for trade on the compliance or voluntary carbon markets. For a given installation, carbon credits are awarded based on the level of CO_2 that would be expected from burning fossil fuels to obtain the same amount of power that is generated by the HRS™ unit. Specifically, each metric ton of CO_2 emissions that is avoided through operation of the HRS™ unit enables the acquisition of one carbon credit. For other key GHGs, one carbon credit corresponds to the quantity of the relevant compound that produces an equivalent heat absorption potential as one metric ton of CO_2.

Elessent Clean Technologies
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Multiple MECS® designed sulfuric acid plants featuring HRS™ technology have been granted carbon credits. As the market for carbon credits matures and the trading of credits becomes more prevalent, reliable decarbonization technologies such as HRS™ technology are poised to offer customers greater operating cost savings than ever before.

GENERATE CARBONLESS ENERGY

The MECS® HRS™ unit increases the total amount of heat that can be used to generate energy within a sulfuric acid plant compared to a conventional sulfur-burning plant design. With the addition of HRS™ technology, energy recovery from the plant rises from around 70% to nearly 95%.

Table 1 on the right provides a brief comparison of the overall steam production and energy efficiency that are expected from a typical sulfur- burning acid plant with and without the application of HRS™ technology.

Table 1: Sulfur-burning sulfuric acid plant performance by configuration

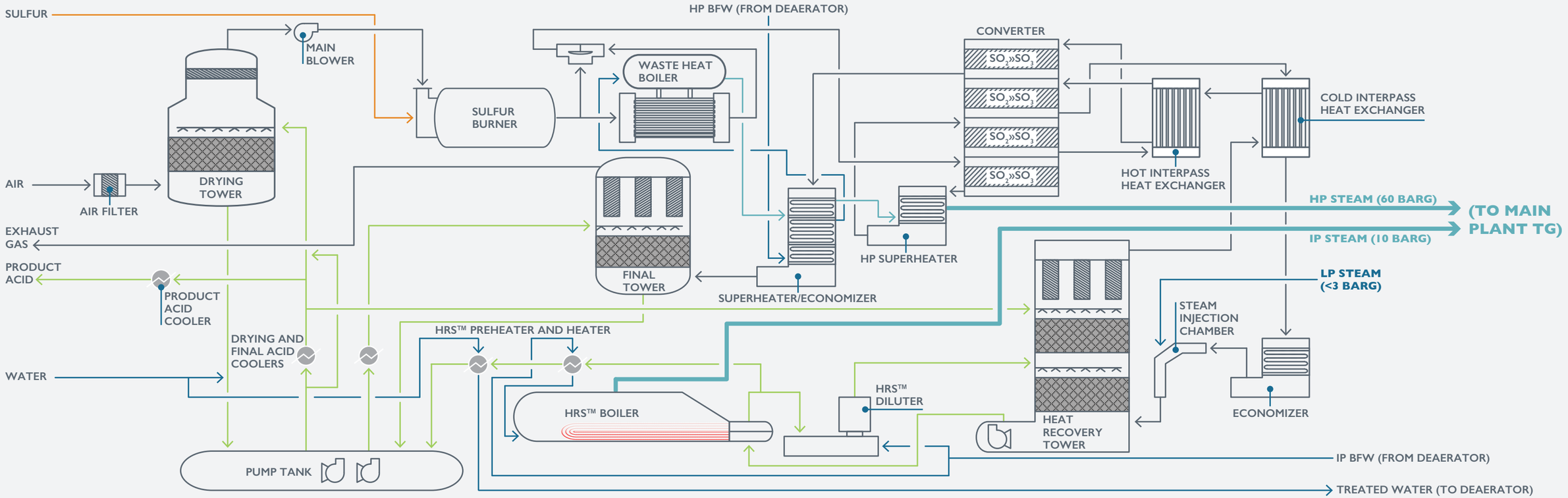
	Conventional plant	Plant with HRS™
HP steam (ton steam/ton acid)	1.27	1.25
IP steam (ton steam/ton acid)	0	0.55
Heat recovery	70%	94%
Net power (kW/ MTPD)	10.6	13.0

MECS® HRS™ TECHNOLOGY

The steam that is generated by the MECS® HRS™ unit is of sufficient quality to be processed through a turbo generator in order to convert the available energy into electricity. As a result, sulfuric acid plants featuring HRS™ technology have greater flexibility in utilizing the energy that they can capture as steam or power for various purposes, including applying it to fulfill internal plant process requirements or selling it to nearby industrial complexes or the local power grid.

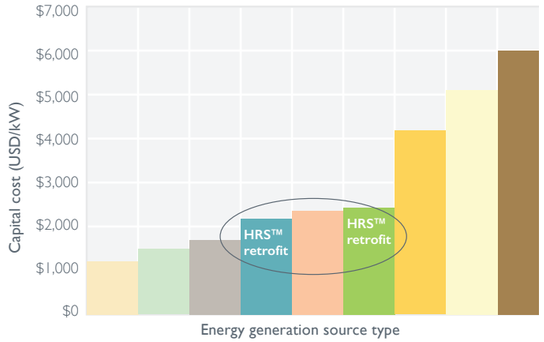
Additionally, existing plants that currently feature a conventional design can be retrofitted to include HRS™ technology. As an example, a 1,950 MTPD-capacity plant recently installed an HRS™ unit and today generates an additional 40 tons per hour of intermediate-pressure steam, which is used in turn to produce 6 MW of electric power. When compared with other sources of carbonless energy such as offshore wind, geothermal or hydroelectric power, the required capital cost per kW for HRS™ is highly competitive.

FIGURE 1: STEAM PRODUCTION IN A SULFUR-BURNING SULFURIC ACID PLANT WITH MECS® HRS™ TECHNOLOGY



MECS® HRS™ TECHNOLOGY

FIGURE 2: CAPEX EFFICIENCY OF CARBON–NEUTRAL ENERGY GENERATION SOURCES



ENERGY GENERATION SOURCE TYPE	RATED CAPACITY
Onshore wind – Large plant/Great Plains	200 MW
Onshore wind – Small plant/coastal region	50 MW
Solar PV and battery storage	150 MW
HRS™ retrofit – 3,500 MTPD production rate	**10 MW**
Geothermal (binary)	Variable
HRS™ retrofit – 2,000 MTPD production rate	**6 MW**
Offshore wind	400 MW
Hydroelectric power plant	Variable
Small modular reactor nuclear plant	

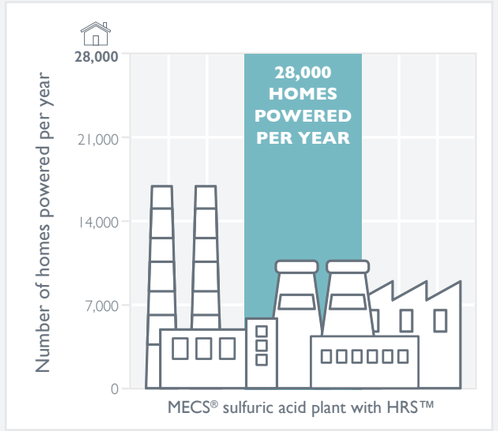
HOW MECS® HRS™ TECHNOLOGY WORKS

Within the sulfuric acid production process, highly exothermic reactions such as the combustion of elemental sulfur to form sulfur dioxide (SO_2) and catalytic conversion of sulfur dioxide to sulfur trioxide (SO_3) release large amounts of energy that can be recovered as high-pressure steam. By contrast, operations like the absorption of SO_3 and the formation and dilution of sulfuric acid have traditionally needed to be conducted at lower temperatures in order to enhance SO_3 absorption and minimize corrosion within the acid system of the plant. Consequently, the energy released by these reactions is of little value for steam production and is therefore normally discarded from the process via transfer through a series of heat exchangers to a cooling water circuit.

However, using HRS™ technology, the reactions which take place as part of the plant's acid system (including SO_3 absorption and acid formation and dilution) can be carried out at elevated temperatures while still achieving required levels of SO_3 absorption and limiting acid system corrosion, which allows plants to harness the energy that is produced to yield steam at pressures of up to 10 barg (150 psig), significantly increasing their overall thermal efficiency. The amount of this intermediate-pressure steam that is generated typically ranges from 0.4 to 0.6 tons of steam per ton of acid production, depending on the specific process conditions prevalent at the plant. If needed, this steam can then be used to generate electricity (at a rate of approximately 2-3 MW per 1,000 MTPD of acid).

The below figure is based on the following assumptions:

- Average annual electricity consumption for U.S. households: 11,560 kWh (U.S. Energy Information Administration, 2020)
- Annual power output from the sulfuric acid plant: 325,320 MWh (includes energy captured from both HP and IP steam production, equal to ~39.1 MW/h with onstream time of 95% for plant)



A SINGLE 3,000 MTPD MECS® SULFURIC ACID PLANT WITH HRS™ CAN GENERATE ENOUGH ENERGY TO POWER APPROXIMATELY 28,000 U.S. HOMES FOR AN ENTIRE YEAR.

MECS® HRS™ TECHNOLOGY

In a standard MECS® HRS™ unit, heat from the acid is removed in the HRS™ boiler, and water is added in the HRS™ diluter to control the acid concentration within the limits required by the process. Energy in the product acid is then recovered by heating water in the HRS™ heater and preheater, which results in the generation of additional steam and, by extension, a reduction in the overall quantity of steam required for consumption by the acid plant.

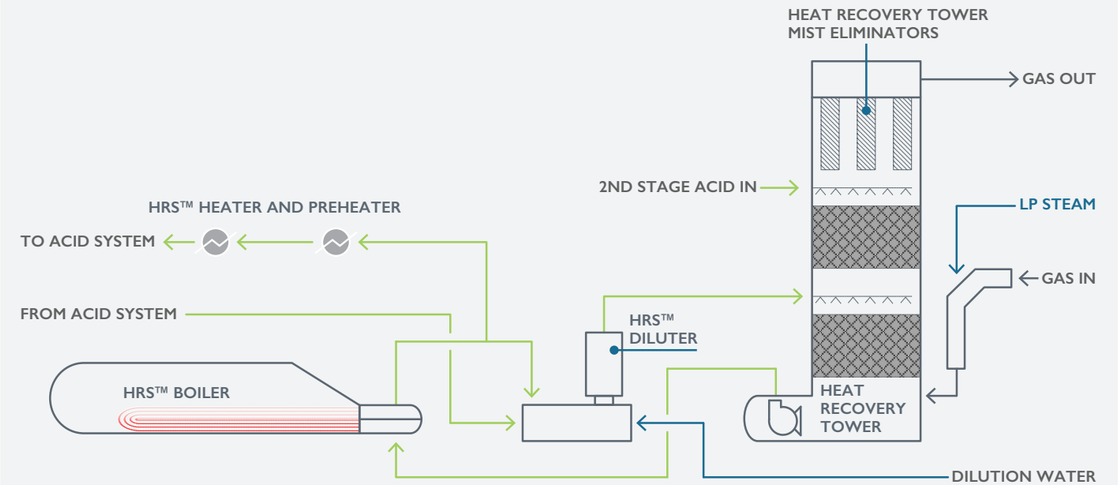
The volume of intermediate-pressure steam produced by the HRS™ unit is increased further through the implementation of steam injection. In this process, low-pressure steam is infused into the process gas stream in the steam injection chamber located directly upstream of the heat recovery tower. The steam subsequently reacts with the SO_3 present in the gas phase, raising the temperature of the process gas and forming sulfuric acid vapor as the stream enters the heat recovery tower.

Inside the tower, the sulfuric acid vapor condenses as ~100% H_2SO_4 when it contacts the cooler circulating acid stream, releasing the latent heat of the steam at the operating pressure of the HRS™ boiler while minimizing the level of the rise in concentration of the acid within the tower as it absorbs the SO_3.

Steam injection has been shown to increase the volume of intermediate-pressure steam production within the HRS™ section of the plant by up to 10% as well as provide additional benefits to the HRS™ design such as:

- Lower rise in the concentration of acid across the packing within the heat recovery tower, thereby reducing the required acid circulation rate through the tower to maintain the concentration below the upper process limit
- 30-40% decrease in the volume of water required for the HRS™ diluter, resulting in reduced vibration within the vessel due to less formation/accumulation of heat from the dilution of acid

FIGURE 3: MECS® HRS™ BASIC PROCESS FLOW DESIGN



MECS® HRS™ TECHNOLOGY

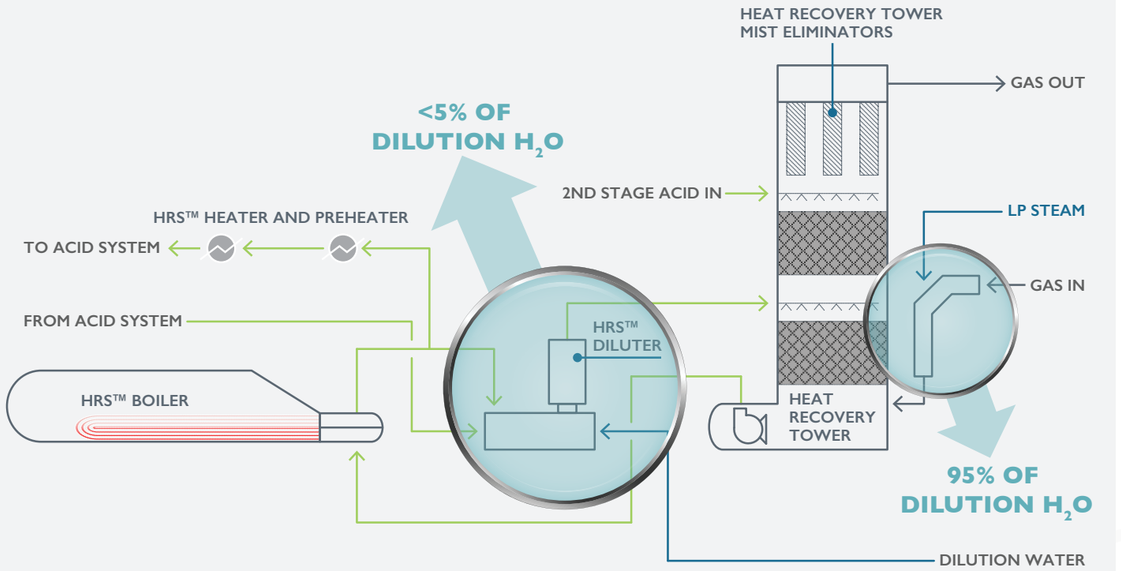
ENHANCE STEAM AND ENERGY VALUE WITH MECS® STEAMAX HRS® AND MAX3™

MECS® SteaMax HRS® technology

MECS® SteaMax HRS® is a natural extension of MECS® steam injection technology. This patented improvement to the steam injection system allows for a greater proportion of the dilution water required for the HRS™ process to be added as low-pressure steam via the steam injection chamber – with a sufficient provision of steam from the plant battery limits, 95% or more of the total water input to the HRS™ unit can be supplied as steam with a SteaMax HRS® design.

By shifting the point of delivery for dilution water from directly into the HRS™ diluter (in the form of liquid water) to the process gas stream immediately ahead of the heat recovery tower (in the form of low-pressure steam), nearly all of the heat generated from the dilution of acid within the HRS™ circuit is passed through the HRS™ boiler. This results in an increase of 30% or more in the amount of intermediate-pressure steam that is produced compared to the output from a standard HRS™ unit, giving plants added value in their overall steam output and more flexibility in meeting their site's energy needs and other local conditions.

FIGURE 4: MECS® STEAMAX HRS® PROCESS DESIGN



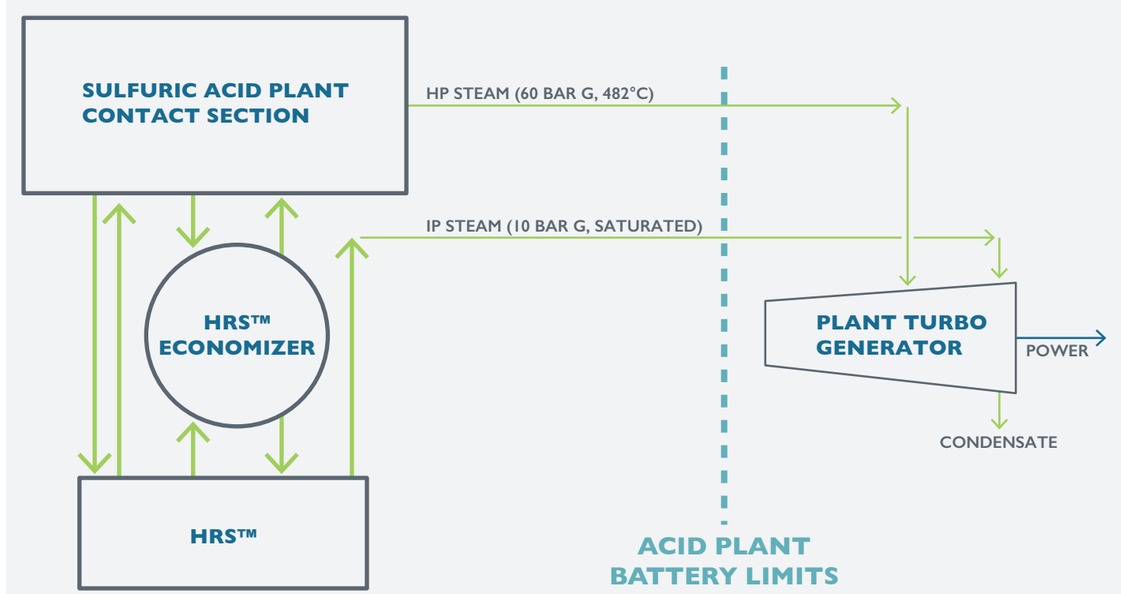
MECS® HRS™ TECHNOLOGY

MECS® MAX3™ technology

Further expanding upon recent developments with MECS® plant technologies, MECS® MAX3™ represents the next level in energy recovery for the sulfuric acid industry. In a plant featuring MAX3™ technology, the process gas exiting the heat recovery tower is sent directly to an SO_2 scrubbing system (such as MECS® DynaWave® technology) or an SO_2 recovery system (such as MECS® SolvR® technology) which effectively replaces the second stage of SO_3 absorption in a conventional acid plant design.

With the MAX3™ flow scheme, the need for the additional conversion of SO_2 after it passes through the heat recovery tower is eliminated, and the energy that would normally be used to raise the temperature of the process gas to the required range for the final pass(es) of the converter can be redirected toward the production of steam in the plant's superheaters and/or an HRS™ economizer. As a result, a significant portion of the steam that would be exported as intermediate-pressure grade from a standard HRS™ unit can be upgraded, allowing for up to 20% more high-pressure steam to be generated and enabling the plant to achieve the maximum possible return for the heat recovered.

FIGURE 5: MECS® MAX3™ STEAM SYSTEM AND UTILITY INTEGRATION



MECS® HRS™ TECHNOLOGY

AN OVERVIEW OF THE VALUE PROPOSITION FOR MECS® HEAT RECOVERY TECHNOLOGIES

For a comparison of the added value that can be obtained using HRS™ or related MECS® technologies, ***Table 2*** below presents estimated figures for the total steam production and incremental economic impact that are anticipated when each of these technologies is integrated into the process design of a typical sulfur-burning acid plant:

Table 2: High-level economic analysis for MECS® heat recovery technologies

MECS® TECHNOLOGIES	HP steam (kg/h)	IP steam (kg/h)	IRR	NPV
HRS™	156,250	68,750	20.2%	US$14.3MM
SteaMax HRS®	156,250	77,500	22.4%	US$18.0MM
MAX3™	187,500	41,250	27.0%	US$24.7MM

Assumptions:

- 3,000 MTPD plant capacity
- Typical steam export conditions (HP steam: 60 barg, 450 – 480°C/IP steam: 10 barg, 185°C)
- Low-pressure steam is available for import to plant
- Electricity cost: US$85/MWh
- Discount rate (NPV): 10%
- NPV analysis period: 20 years

MECS® HRS™ TECHNOLOGY – THE CARBONLESS ENERGY SOLUTION FOR SULFURIC ACID PLANTS

As the pioneering system for heat recovery in sulfuric acid plants, MECS® HRS™ technology has benefited from nearly 40 years of expertise that has gone into its development and optimization. MECS® HRS™ technology features more than 90 references worldwide and is customizable to the energy and process steam needs of individual plant operators. With the addition of HRS™ technology to the sulfuric acid plant process, low-pressure steam can be transformed into intermediate-pressure steam to maximize the value of the heat recovered from the plant, while intermediate-pressure steam can be further upgraded to high-pressure steam to provide plants with more flexibility in meeting downstream operational demands. Thus, for operators seeking to enhance their plant's performance while lowering its carbon emissions, MECS® HRS™ technology can offer an ideal, sustainable solution for attaining all of your site's energy goals.

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