ABB's Energy Transition Equation

Being resourceful with wastewater treatment

Contents

Introduction

This paper explores how greater implementation of state-of-the-art technologies in areas of automation, digitalization and electrification can help operators of wastewater treatment plants reduce carbon emissions and achieve improvements in cost efficiencies, productivity and energy usage.

Its intention is to demonstrate the role of technology in optimizing wastewater facilities as they navigate the energy transition and seek to achieve sustainability objectives and preserve water resources.

The approach taken is to develop a series of hypothetical scenarios, based upon real life projects (ABB & non ABB) concerning the development of brand new wastewater facilities, and in the modernization of existing plants. Applicability to hybrid facilities is also included.

Specifically for the purpose of this study we have selected a 95 million liter greenfield facility and a 50 million liter brownfield facility to demonstrate the scale of opportunity available to utility providers. These facilities represent a municipality serving a population of approximately 300,000 (95 ML) inhabitants and 150,000 (50ML) inhabitants respectively. Each wastewater plant is different – characterized by its own features, location, size and investment capabilities. By designing and developing cautious and aspirational scenarios rooted in real world experience for both greenfield and brownfield sites, the range of benefits that are possible for customers across different geographic and operational situations can

Sample Facilities:

95 ML Greenfield Facility
(serving ~300k people)

50 ML Brownfield Facility
(serving ~150k people)

The financial, economic, environmental, and other benefits from the use of ABB technology and expertise are applicable to both greenfield and brownfield situations.

Net benefits have been estimated based upon the impact of technology adoption on one facility. However, the implications on supply chains, labor and economic Gross Value Added[1] have also been considered.

ABB technologies and digital solutions included in the assessment can be reviewed later in the report and in the appendix. Whilst the findings have been created by applying ABB solutions and expertise, the results, to some extent can be applied to alternate products of a similar nature and technology level.

The economic modelling and findings in this report have been developed by Steve Lucas, Developmental Economics following nine months of research in conjunction with ABB Energy Industries.

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[1] GVA is defined as output (at basic prices) minus intermediate consumption (at purchaser prices); it is the balancing item of the national accounts' production account. GVA can be broken down by industry and institutional sector.

Executive summary

Achieving net zero emissions as per the Paris Agreement by 2050 requires a complete transformation of the energy landscape.

The energy transition is not just about reducing carbon emissions and moving away from fossil fuels to produce power, although this is key part of it. It is also about delivering sustainability across all facets of life. Water is a precious and declining resource that we need to protect urgently to survive.

Safe, clean water is one of our most basic human needs, not only in the developed world but across the planet. It is also critical for socio- economic development and a prerequisite for peace.

Water demand is increasing but supplies are not. By 2050, consumption is projected to increase by up to 30%[2], driven by the rising demand in industrial and domestic sectors. With the world's population forecast to reach nearly 10 billion by 2050[3], ensuring everyone has access to safe and reliable water supply is a critical challenge.

By 2050:

Water demand

30%

World population

10 billion

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[2] Water, Food and Energy | UN-Water (unwater.org)

[3] World's population will continue to grow and will reach nearly 10 billion by 2050 (worldbank.org)

Wastewater treatment is an important resource in the battle against water scarcity.

The wastewater treatment industry is key in addressing this challenge. Converting wastewater through treatment, from its unusable state so that it can be returned to the water cycle with minimal environmental issues or reused for another purpose, is vital in helping bridge the gap between the growing demand for and scarcity of this precious resource.

Currently enormous volumes of wastewater are pumped into rivers, oceans and streams. The effect on the environment, fisheries, animals and public health if it is not properly treated can be extremely negative. Not to mention it is a ‘waste’ of water too.

> The more reclaimed water we can direct towards agricultural and landscape irrigation, industrial processes and non-potable urban applications (such as toilet flushing, street washing, and fire protection) means the less freshwater we are using for these purposes.

Wastewater plants contribute **up to 3% of global energy output.**

However, treating and processing wastewater to make it safe to return to the watercourse takes a lot of energy. Research has shown that wastewater plants consume up to 3% of global energy output. State-of-the-art facilities consume 20-45 kWh per population equivalent (PE) connected[4].

Working with utilities and municipalities to improve their processes with the aim of increasing productivity, reducing energy usage, minimizing losses and optimizing the use of chemicals is therefore an integral part of helping them to achieve their sustainability goals.

In this context, this report seeks to quantify the return on investment in automation, electrification, and digital technologies for operators of existing and new wastewater facilities.

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[4] Circular Economy: Tapping the Power of Wastewater - International Water Association (iwa-network.org)

Specifically, it assesses how much digital, control and electrical technologies can optimize wastewater facilities to reduce their carbon footprint, deliver fiscal savings & support increased reuse and re-entry of wastewater into the water cycle.

Our water is drying up

How can we build an accessible, sustainable water future?

↓

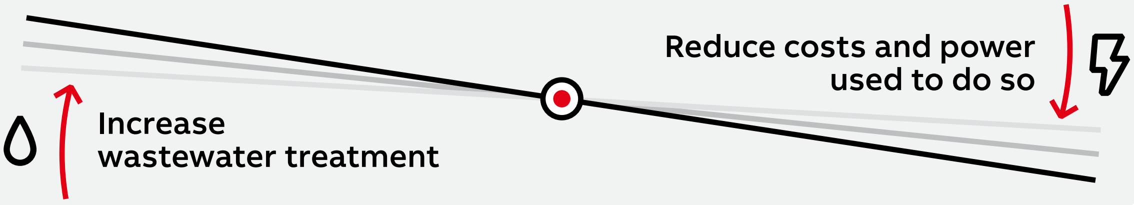
One solution is wastewater.

Effectively treated wastewater can be reused for industry or agriculture.

But wastewater treatment costs are high

and the process consumes huge amounts of power.

Finding the balance



By investing in automation and digital solutions, water utilities can achieve significant carbon and cost savings.

With over 50,000 **wastewater plants around the world, when scaled, the potential impact is savings upwards of 100 million tons of CO_2**

ABB is making every drop of water count

The results of the modelling indicate that operators could achieve:

- Average carbon savings across brownfield and greenfield sites of 10% per annum, equivalent to:
  - taking up to 1,000 passenger cars off the road[6]
  - powering up to 1,300 homes a year[6]
  - preservation of 32 million kg of glacier mass lost each year[7]
- Average annual operating cost savings across brownfield and greenfield of 9.5%
- With With over 50,000 wastewater plants around the world, when scaled, the potential impact is upwards of 100 million tons of CO$_2$[8]

This can be broken down as follows:

In the case of a 95 ML greenfield facility (based on a 4-year development phase and 32-year operational life cycle)[5]:

Carbon savings[9] per plant

Average annual saving
2,780 tons

Life cycle saving (32 years)
89,000 tons

Approx. 10% reduction in emissions per annum, the equivalent of

taking
1,390 cars
passenger cars off the road[6]

or powering
1,800 homes
with electricity for a year[6]

volume of CO$_2$ responsible for up to
44 million kg
of glacier mass lost each year[7]

OPEX saving per plant

Average annual saving
$843,750 USD

Life cycle saving (32 years)
$27 million USD

Approx.
8% savings
per annum

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5 The average figures reported here uses the low/high results from the two scenarios detailed further in the document and relates to an entire project life cycle period, based on a 4-year development phase followed by a 32-year operational phase.

6 Calculations based on data from the Netherlands, found here: What exactly is 1 ton of CO$_2$? We make it tangible. - Climate Neutral Group

7 Global warming to date could 'obliterate' a third of glacier ice - Carbon Brief, Nature Climate Change, by the researchers B. Marzeion, G. Kaser and F. Maussion.

8 waternewseurope.com/global-database-of-wwtps-and-their-effluents/#:~:text=More%20than%2058%2C000%20wastewater%20treatment,the%20wastewater%20treatment%20plants%20drain

9 It should be noted that grid emissions are likely to decrease over the life cycle period which could affect these carbon calculations.

In the case of a 50ML brownfield facility (based on an additional 32-year operational life cycle of an existing 30-year-old brownfield plant):

Carbon savings per plant

Average annual saving

1,300 tons

Life cycle saving (32 years)

41,600 tons

Approx. 10% reduction in emissions per annum, the equivalent of

taking **650 cars** passenger cars off the road

or powering **845 homes** with electricity for a year

volume of CO_2 responsible for up to **22 million kg** of glacier mass lost each year

OPEX savings per plant

Average annual saving

$1.5 million USD

Life cycle saving (32 years)

$48 million USD

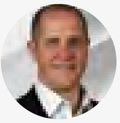
Approx.

11% reduction in costs per annum

Other benefits for wastewater plant operators, and society as a whole, can also be expected including:

- Enhanced control of water quality re-entering the water cycle, with consequential benefits for ecology and biodiversity in river systems & seas
- Improved management of overflows and discharges during disturbances (such as during storm events) with subsequent benefits for public health
- Opportunities for tracking of energy and chemical reagent usage and further enhancement of performance
- Enhanced opportunities for materials recovery from wastewater
- Better opportunities for the re-use of water for a range of purposes, including agriculture, industry and/or as potable water. This is likely to become an increasingly important issue given increasing demand for water linked to both population growth and increased standards of living in most markets, coupled with long term challenges to water supply in some areas linked to climate change

> “We are facing one of the most serious water crises ever, with the UN predicting a global water deficit of 40% by 2030. Making every drop of this precious resource count is crucial. Wastewater offers us a solution, yet still today much of it remains untapped. When treated and managed efficiently wastewater can help address water shortages by reusing water that would otherwise be lost. But wastewater treatment costs can be high and it consumes a lot of energy. With a growing population and industry demanding more water it is critical now more than ever that we enable more wastewater treatment using less power. This is where investment into automation, digital and electrical technologies can make a world of difference.”



Brandon Spencer, President, ABB Energy Industries

The Opportunity

Global freshwater use has increased six fold over the past 100 years.[10] This has been driven by industrial and agricultural demand. While agricultural water use is the biggest water use category globally, industrial water use is also significant although it varies greatly by country.

An answer is wastewater. The treatment of wastewater, for its re-utilization for various activities, such as manufacturing and agriculture, really is the need of the hour.

With over 50,000 wastewater plants currently worldwide, the global wastewater treatment market size was valued at USD 281.75 billion in 2021. The market is projected to grow from USD 301.77 billion in 2022 to USD 489.07 billion by 2029, exhibiting a CAGR of 7.1% during the forecast period.[11] The major factor credited for this growth is the limited availability of freshwater across the globe, population increase and stringent environmental regulations implemented by governments.

Global freshwater use has increased

six fold

over the past 100 years.[10]
This has been driven by industrial and agricultural demand.

The market is projected to grow from

USD **$301.77 billion** in 2022

to

USD **$489.07 billion** **by 2029**

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[10] 375751eng.pdf (unhabitat.org)

[11] fortunebusinessinsights.com/water-and-wastewater-treatment-market-102632

Water is a global issue, but the management of wastewater is determined locally, characterized by topography, population, and industry requirements. The one constant in cities throughout the world is that we must achieve more with fewer resources. This requires innovation to develop new methodologies that reduce the risk of water shortages by increasing resilience, optimizing water production while reducing energy consumption, as well as minimizing the threats posed by flooding, contamination, and poisoning.

Wastewater has potential to be an even more important resource and one that municipalities could utilize much more efficiently. Currently there is the opportunity to get much more out of facilities by investing in smart water management that drives a circular water economy.

An economy that reuses and recycles wastewater to reduce water consumption and energy usage to support the industry's contribution to net zero.

As technology advances and we look to the future we should be thinking not just about treatment and reuse but also about recovery. There is a huge opportunity for utilities to recover much more from wastewater than just water, such as nutrients and heat. In doing so operators can open many other value streams, becoming independent users or producers of energy and by recovering carbon for use. In this sense we are moving into an era when wastewater plants will become valuable resource factories.

Introduction to Economic Scenarios

For both greenfield and brownfield situations, scenarios were developed to assess the potential financial and environmental benefits for utilities by developing more cost-efficient and sustainable wastewater treatment facilities.

The scenarios have been developed from examples of real world projects with individual features and circumstances. Lessons can be drawn from these case studies, however, and applied to other projects with broadly similar characteristics. For example, the 95 ML daily capacity greenfield facility serves an urban area with a population of 250,000-300,000 people[12], whereas the 50 ML capacity facility would serve an area around half that size.

A 2021 cost base was used in the assessment. Where necessary, estimates of capital costs dating from earlier than 2021 were adjusted using up-to-date construction and civil engineering cost inflation indices.

Certain costs were excluded from the assessment, including land costs, site groundworks, planning and legal costs. These costs were excluded because they vary greatly from site-to-site, and because it is difficult to isolate ‘typical’ costs for these categories. Furthermore, these types of costs are not influenced significantly by the use or otherwise of automation, electrical or digital technologies and are therefore common to all scenarios considered.

1. Baseline scenario

The purpose of this scenario is to provide a baseline against which the performance of two alternative scenarios, with technology, can be assessed against a range of selected performance metrics. It explores the implications for operational efficiency and environmental performance of developing and operating a new wastewater treatment facility without integrating advanced, digitized and fully automated control and electrical systems.

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[12] Examples of urban areas with populations in or around this range include Tampa and Buffalo in the United States, Brighton in the UK, Catania in Italy, and Karlsruhe in Germany

2. ‘Moderate’ scenario

The second scenario is one where the more intensive use of automation, digital control, and electrical systems creates potential to deliver additional operational efficiencies and sustainability gains over and above the levels expected under the baseline scenario. However, the range of potential benefits associated with these systems is subject to uncertainties. This scenario utilizes a range of relatively cautious assumptions concerning the potential for cost savings and environmental gains.

3. ‘Aspirational’ scenario

To explore more fully the potential for a more ambitious set of outcomes, we have also developed a variant of the second scenario that utilizes slightly more aggressive, but still plausible, assumptions with respect to the delivery of gains.

Findings

With respect to both greenfield and brownfield situations, the specification of the facility and the principal metrics of performance for the respective scenarios are as follows:

- Annual operating costs
- Annual value of costs over 32 years of operation discounted at 3.5% p.a
- Annual production of CO_2e associated with the energy usage of the facilities

i. Greenfield baseline scenario

The development of a new wastewater treatment with a 95 ML daily capacity facility is assumed to require a four-year period for design and development (including construction and pre-production testing). The appraisal period includes this four-year pre-production phase, followed by a minimum of 32 years of operations. (Note: these assumptions are common to all scenarios).

Principal assumptions used in the assessment of the counterfactual scenario are summarized in the table below (note: values are based on 2021 prices):

Maximum annual capacity of the facility:

95 ML

of wastewater per day

Development costs: USD

715 MILLION

(undiscounted)

Cost of treating wastewater: USD

0.60

per m^3

The development costs have been sourced from a real-world development located in Western Europe (UK). Although these costs are reflective of the scale of costs likely to occur elsewhere in similar locations in Western Europe and North America, inevitably costs will vary site-by-site due to local factors, such as topography and the regulatory environment.

Aspects of operational costs that are potentially capable of being influenced by use of ABB technology and know-how include expenditure on:

Maintenance
(assumed to typically account for
12%
of annual operating costs)

Energy usage
(typically around
25%
of annual running costs)

Usage of chemical reagents
in wastewater treatment processes (typically around
3%
of annual costs)

There is also some potential for savings on labor supply costs, but this is likely limited to use of sub-contractors for aspects of plant maintenance and is a relatively modest component of annual savings potential.

Under the counterfactual scenario, the development of the facility would be expected to require investment with a value of $668 million (2021 prices, discounted).

Annual running costs would be expected to average $21 million p.a. (2021 prices, undiscounted) during the operational period. Over a 32-year operating period, this annual sum would have a present value of $353 million.

Annual CO_2e emissions associated with energy usage at the facility are expected to average 13,900 tons per annum during the operating period.

Table 1: Greenfield Scenario 1 (Baseline) results

Topic	Result
PV of development and construction costs	$668 million
PV of annual operating costs over 32 years	$353 million
Average annual CO_2e emissions	13,900 tons

ii. Greenfield Scenario 2: With ABB ’Moderate’ scenario

The next scenario to consider is the one where greater use of digitized control, and electrical systems is applied to enhance the potential for operating cost and energy efficiencies for a greenfield treatment facility. The assumptions used in the assessment of the second (moderate) scenario are summarized in the table below, focusing on those that differ from those used in the baseline scenario.

Table 2: Greenfield Scenario 2 - ‘Moderate’ scenario assumptions

Assumption	Change with respect to baseline scenario
Development costs	Increase by 1.5%.
Annual plant maintenance costs	Reduced by 5% p.a. compared to baseline
Annual energy costs	Reduced by 10% p.a. compared to baseline
Labor costs (contractors, etc.)	Reduced by 0.5% p.a. compared to baseline
Chemical reagents costs	Reduced by 5% p.a. compared to baseline

Assumptions regarding the potential for energy efficiencies and reduced usage of chemicals are sourced from a paper authored by ABB entitled ***ABB Ability™ Smart Solution for Wastewater: Achieve optimal operating conditions,*** dated March 2022. Other assumptions have been developed following a workshop with the ABB ‘Water’ Team but are the responsibility of Development Economics Limited.

The implications of adjustments to project performance include reduced operating costs and expenditure on energy supplies. The table below summarizes the expected performance results that flow from the deployment of the assumptions in the table above.

Table 3: Greenfield Scenario 2 - ‘Moderate’ scenario results

Topic	Result
PV of development and construction costs	$681 million
PV of annual operating costs over 32 years	$340 million
Average annual CO_2e emissions associated with energy usage	12,500 tons

In the case of annual operating costs, the PV of these over a 32-year operating period under the second scenario are expected to amount to $340 million (2021 prices). This represents a reduction of around $13 million compared to the equivalent figure for the baseline scenario.

The reduction in annual operating costs under the moderate scenario is around 3.6% compared to the baseline scenario.

The analysis presented here is based on cost curves and supply chain relationships that pre-date the current (2022) spike in global energy prices. Higher energy prices increase the scope for savings for managers of wastewater facilities that use digital, automation and electrical solutions to maximize energy efficiencies, but the additional savings that might be available currently has not be quantified as part of this analysis.

In terms of carbon dioxide equivalent emissions associated with energy use, these are expected to average 12,500 tons per annum under the second scenario, which is around 1,400 tons per annum lower than the baseline. Over a 32-year operating period, this would amount to an overall reduction of around 44,000 tons of CO_2e compared to the baseline. In addition to these savings, there are likely to be other indirect carbon savings associated with reduced usage of chemical reagents in wastewater treatment, but indirect carbon savings of this type are not included in the assessment[13].

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[13] 'Indirect' refers to the CO_2e associated with the manufacture and distribution of chemical reagents

iii. Greenfield Scenario 3: 'Aspirational' scenario

The assumptions used in the second scenario are relatively conservative. The view of ABB experts is that annual energy savings of between 10% and 20% are achievable following the implementation of advanced levels of digitization and automation, so the approach taken in the development of the second scenario is to deploy an assumption based on the lower boundary of this range.

There is a possibility, therefore, that the systematic use of cautious and conservative assumptions across a range of parameters results in a set of outcomes that significantly underestimate the level of efficiencies that the use of this technology has the potential to deliver to its customers. It is therefore useful to consider the scope for uplift in outcomes that could be achieved if less cautious assumptions were used instead. The third scenario to consider, therefore, is a variant of the second, whereby relatively conservative assumptions are replaced with more ambitious (but still plausible) alternatives. This third scenario is termed the 'aspirational' scenario.

The table below summarizes the alternative assumptions used in this third scenario. For convenience, the equivalent assumptions used in the second scenario are set out in the table as well.

Table 4: Greenfield Scenario 3 - Aspirational assumptions (Scenario 3 vs Scenario 2)

Assumption	Greenfield Scenario 2 (Moderate)	Greenfield Scenario 3 (Aspirational)
Development costs	Increase by 1.5% compared to baseline	Increase by 1.5% compared to baseline
Annual maintenance costs	Reduced by 5% p.a. compared to baseline	Reduced by 10% compared to baseline
Annual energy costs	Reduced by 10% p.a. compared to baseline	Reduced by 20% p.a. compared to baseline
Labor costs (contractors, etc.)	Reduced by 0.5% p.a. compared to baseline	Reduced by 1.5% p.a. compared to baseline
Cost of chemical reagents	Reduced by 5% p.a. compared to baseline	Reduced by 10% p.a. compared to baseline
Other variable costs	Reduced by 1% compared to baseline	Reduced by 3% compared to baseline

The implications of further modifications to project performance parameters for the variant greenfield scenario include additional reductions for annual operating costs and energy savings compared to both the moderate scenario and the baseline. The table below summarizes the expected performance results that flow from the deployment of the assumptions relevant to the third scenario.

Table 5: Greenfield Scenario 3 - 'Aspirational' scenario results

Topic	Result
PV of development and construction costs	$681 million
PV of annual operating costs over 32 years	$327 million
Average annual CO_2e emissions	11,100 tons

The PV of annual operating costs over a 32-year operating period for Scenario 3 are expected to amount to $327 million (2021 prices), which is a reduction of around $14 million compared to Scenario 2 (and a reduction of around $27 million compared to the baseline scenario).

The reduction in annual operating costs under the aspirational scenario is around 7.5% compared to the baseline scenario.

In terms of carbon emissions associated with energy usage, these are expected to average 11,100 tons per annum under the aspirational scenario. This represents an annual reduction of around 1,400 tons compared to the second scenario, and 2,800 tons p.a. compared to the baseline.

The expected aggregate carbon reduction associated with energy usage over 32 years under the aspirational scenario is around:

- 44,000 tons of CO_2e p.a. compared to levels anticipated under the cautious Scenario 2
- 89,000 tons of CO_2e p.a. compared to levels anticipated under the baseline scenario

Additional (indirect) carbon savings associated with the production of chemical reagents – usage of which is likely to be lower with the aspirational scenario compared to both the baseline and moderate scenarios – are likely to occur but have not been quantified as part of this assessment.

iv. Brownfield scenarios

Many of the operational advantages that can be obtained through the use of automation and digitalization on new sites can also be obtained through the introduction, modernization and greater integration of advanced technology in existing wastewater treatment facilities. Ageing wastewater infrastructure can be associated with higher-than-normal costs for repair or reactive maintenance: the potential for operational efficiencies associated with improved control of treatment processes, use of reagents, and energy usage all have the potential to make a significant contribution to the enhancement of a business case for replacement of old or obsolete plant with advanced technology.

For example, in the case of the San Jose-Santa Clara regional wastewater facility in California, ABB is currently advising on a range of projects to replace or upgrade infrastructure, including digester gas storage facilities, emergency diesel generators, reagent feed-in equipment, and aeration control systems.

Operator objectives in seeking technology advice and support includes:

- Improved plant operational efficiency by increasing the resilience and reliability of control systems
- Reduced energy usage by replacing obsolete systems
- Reduced dependence on grid-supplied electricity, by exploiting opportunities for production of energy from cogeneration and digester gas sources

A challenge with assessing the potential scale and range of improvements that is achievable with existing treatment facilities is the wide range of average costs associated with wastewater collection and treatment. A study produced by KPMG revealed that average costs across a sample of European and North American cities ranged from $0.37 to $2.92 per m^3, with an overall mean cost of around $1.20 per m^3.[14] Factors that can influence where any individual urban area will lie on this continuum of costs include age of infrastructure, local topographical factors, energy costs, and the regulatory standards that apply in that jurisdiction.

The baseline scenario for the brownfield situation is based on a hypothetical 50 ML wastewater treatment facility assumed to be around 30 years old. Under this scenario for the brownfield situation, annual operating costs for the facility are assumed to amount to around $13.1 million per annum, with fixed costs accounting for around 74% of overall annual costs and variable costs 26%. The breakdown of annual operating costs is assumed to be as follows:

Table 6: Brownfield baseline scenario – breakdown of annual running costs

Personnel	49.8%
Energy costs - fixed	4.4%
Energy costs - variable	20.2%
Maintenance - fixed costs	12.8%
Other fixed costs	4.7%
Reagents	2.3%
Waste/sludge removal	5.6%
Other variable costs	0.2%
Total	**100%**

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[14] MG *Benchmarking City Services (2017)*, page 53

As with the greenfield scenarios considered earlier, the aspects of operational expenditure that are most capable of being influenced by introduction of technology in older wastewater plants concern spending on maintenance, energy usage, and usage of reagents. In addition, there is also some (i.e., more limited) scope for savings on other costs, including staffing.

The approach once again is to contrast the performance of a baseline scenario with two alternative scenarios that assume the introduction of modern systems into an older plant: both the moderate and aspirational scenarios assume introduction of the same type and scale of equipment and technology, with one scenario adopting relatively cautious assumptions regarding the scale of impact on operating costs, with the other scenario adopting less cautious (but still plausible) assumptions.

The table below sets out assumptions that are deployed for the respective scenarios concerning annual operating costs. In both cases, the scale of potential annual savings for the cost category is presented in comparison to levels assumed to occur under the baseline.

Table 7: Brownfield Scenarios - assumptions

Assumption	Brownfield Scenario 2 (Moderate)	Brownfield Scenario 3 (Aspirational)
Annual maintenance costs	Reduced by 5% p.a. compared to baseline	Reduced by 10% compared to baseline
Annual energy costs	Reduced by 10% p.a. compared to baseline	Reduced by 15% p.a. compared to baseline
Labor costs (contractors, etc.)	Reduced by 1% p.a. compared to baseline	Reduced by 2% p.a. compared to baseline
Cost of chemical reagents	Reduced by 10% p.a. compared to baseline	Reduced by 15% p.a. compared to baseline
Other variable costs	Reduced by 1% compared to baseline	Reduced by 3% compared to baseline

The next table summarizes the results from the brownfield scenarios, based on the assumptions outlined above.

Table 8: Brownfield scenario's results

Indicator	Brownfield counterfactual	Brownfield Scenario 2 (Moderate)	Brownfield Scenario 3 (Aspirational)
Annual operating costs (USD million)	13.09	11.88	11.58
Annual operating costs per cubic meter	0.72	0.65	0.63
Average annual CO_2e emissions (‘000 tons)	8.40	7.56	7.14

Under the moderate brownfield scenario, annual operating costs are estimated to amount to $11.88 million, which is a saving of around $1.20 million p.a. compared to the baseline reference case, which represents a reduction of around 9%. Under the moderate scenario annual operating costs would fall to $0.65 per cubic meter, compared to $0.72 under the baseline.

Average annual CO_2e emissions from energy use under this scenario would be expected to amount to just over 7,500 tons compared to 8,400 tons under the baseline.

Savings and efficiencies under the more aspirational scenario are of course greater, with overall annual operating costs expected to fall to $11.58 million, with the average cost per m^3 falling to $0.63. The annual operating costs under this scenario are around 11% lower compared to the counterfactual scenario. Energy-related carbon emissions under the aspirational scenario are also lower, at just over 7,100 tons of CO_2e per annum.

As with the greenfield scenario, it is recommended that the focus be on the potential range of relative (percentage) savings for the brownfield scenario rather than the absolute level of estimated savings. This is because the precise level of savings will vary site-by-site and will be influenced by local factors, such as topography, the cost of energy, and the regulatory regime that is applicable in that jurisdiction.

It should be noted that both the moderate and aspirational brownfield scenarios are both cautious, in that they assume that electricity supply is still drawn from the grid. A further possibility is that ABB technology and expertise could be used to enable a brownfield wastewater treatment facility to become much less reliant on grid supply by delivering solutions that help generate some or all the facility’s electricity needs. This variant option has not been quantified here, but it is a potential source of additional benefits that may be suitable in some situations.

v. Expansion of existing sites

Although the focus in the report has been on the benefits associated with the development of new (greenfield) wastewater treatment facilities or the retrofitting of advanced technology to existing (brownfield) plants, there is a potentially important ‘blended’ scenario that could also be considered: this is the situation where an existing facility is expanded substantially. This blended scenario could occur either in a number of circumstances, such as:

- Where an urban area is growing, and an existing facility needs to expand to accommodate recent and/or expected future growth of the area
- Where the intention is to replace several smaller facilities with a single larger facility

The precise level of efficiency savings that are possible in these types of situations would need to be considered on a project-by-project basis but are likely to lie within the range of outcomes predicted for the greenfield and brownfield scenarios discussed earlier in this paper.

Impact of ABB Technology

Over the past fifty plus years, ABB has deployed technology for hundreds of projects around the world, and not simply as an automation partner but increasingly as a holistic partner helping utilities, municipalities, and other stakeholders with the whole life cycle of water. Applying our technical knowledge, we seek to find solutions that are feasible, economically viable and crucially, adaptable to different local needs.

Our technologies have been developed specifically to drive efficiency of operations and optimize the value of wastewater. Among these include:

ABB Ability™ Smart Solution for Wastewater is a scalable and modular digital solution blending expert knowledge in advanced process control, digital twin, process simulation, and performance optimization. The solution builds on two pillars of ABB's digital portfolio, ABB Ability™ Optimax and ABB Advanced Process Control. ABB Ability™ Smart Solution for Wastewater increases operational control and efficiency whilst lowering plant energy use and running costs of operations. In fact, it can help utilities achieve up to 25% savings in process related energy expenditure (specifically related to bioreactors aeration) and up to 10% reduction of usage of chemicals.

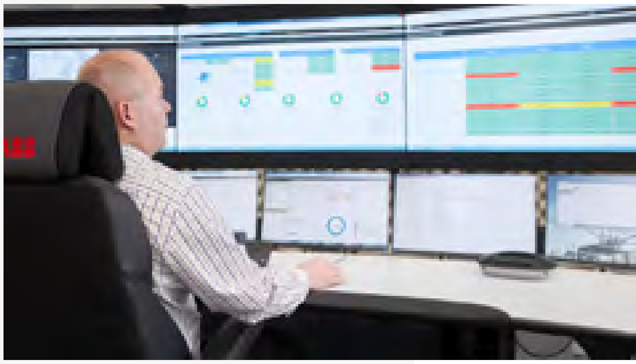
ABB Ability™ automation systems have helped utilities automate their water and wastewater plants optimize process and subsequently their performances. The two flagship platforms, ABB Ability™ Symphony® Plus (available both as Distributed Control System and as SCADA) and ABB Ability™ System 800xA have been applied to water and wastewater facilities across multiple geographies and with the most diverse sizes. Most recently, they have been confirmed as the solution of choice by the City of Baltimore, US to optimize the efficiency and output and reduce costs and by the City of Nashville, US to increase water capacity, drive operational efficiency and ensure clean, safe and dependable delivery of water to all residents.

Pump management. Energy accounts for 55–60% of the life cycle cost of a pump. Optimizing the way each pump is used and defining the best number to run at the same time can result in a significant reduction of energy employed and in an optimization of the maintenance costs. ABB's solution automates variable speed pump groups to operate the pumps. It enables the energy optimized control of pump groups. Exploiting given pump characteristics, the overall efficiency is calculated on-line for different possible scenarios. The best scenario is automatically selected and applied to the actual control.

Water Quality Instrumentation

Aeration systems typically use more than half the electricity consumed in a wastewater treatment facility. So, when operational decisions are based on incorrect dissolved oxygen readings, they can create significant unnecessary electrical energy costs, as well as impacting treatment effectiveness. The new ADS420 smart optical Dissolved Oxygen (DO) sensor delivers the essential measurements that help utilities avoid those costs.

ABB Ability™ Collaborative Operations. At the heart of ABB's digital portfolio is ABB Ability™ Collaborative Operations, a service delivery model which connects people in production facilities, headquarters and ABB to deliver objective data insights that ultimately increase profitability by improving plant efficiency, increasing safety, reducing risk and lowering costs. The model bundles industry knowledge, cloud-based solutions and services into a 24/7 service delivery concept.



Conclusion

The growth of the global wastewater market, currently valued at an estimated $281.75 billion in 2021 is largely driven by the limited availability of freshwater across the globe. Hence the critical need to treat wastewater, and its reuse, as a vital resource. If not properly treated, the effect on the environment can be disastrous, not to mention it is a “waste” of water.

However, treating and processing wastewater to make it safe to return to the water cycle takes a lot of energy, with research showing that wastewater plants consume between 1% and 3% of global energy output and contributes over 1.5% in greenhouse gas emissions.[15] That’s why we need to take the waste out of wastewater and ensure that treatment at this scale is efficient and sustainable. This requires technology, which requires investment, but in turn delivers ROI.

This report outlines how the smart use of advanced automation, electrification and digital technologies can help minimize energy use and carbon emissions across the sector and make cost savings that will increase production at the same time.

With over 50,000 wastewater plants around the world, when scaled, the potential impact is upwards of 100 million tons of CO_2.

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[15] Wastewater treatment for carbon capture and utilization | Nature Sustainability

ABB is working with its customers to reduce their annual CO_2 emissions by more than 100 megatons by 2030, as per our sustainability strategy.

Our water needs managing to ensure a balance between the demand for it, and its availability. We need to treat more wastewater but keep the power consumption needed to do so low. Operators must find a balance between eliminating carbon emissions yet managing capital and operational costs.

This is critical if we are to successfully navigate the water scarcity challenge, and achieve wider energy transition goals. In this respect investing in technology can make a world of difference to wastewater operators helping them in making every drop of water count in the most sustainable and cost-effective way.

Appendix

Data sources

This economic modelling has been based on a wide range of sources including:

1. Internal—ABB Intel & Case Studies

The starting point for the assessment was to obtain advice from ABB as to the categories of capital and operational expenditure relevant to wastewater treatment facilities that are relevant to ABB's areas of expertise. In the case of wastewater management, these were determined to include digitization, automation, instrumentation, electrification, and control systems.

ABB also advised on the scale, intensity, and duration of benefits associated with a scenario where a greenfield wastewater treatment facility was fully enabled with automation, instrumentation, electrical, and other control systems.

In the case of brownfield sites, advice was received from ABB about the types of system upgrades or replacements that are typically in-scope, which was suggested to include upgrades or replacements of compressors, generators, reagent feed-in equipment, digestor gas storage facilities, and so on.

ABB summary paper: **ABB Ability™ Smart Solution for Wastewater: Achieve optimal operating conditions,** March 2022 was utilized in the report.

ABB Case studies referred to include:

The Patapsco Wastewater Treatment Plant, City of Baltimore, Maryland

Central Wastewater Treatment facilities, Metro Water Services, City of Nashville, Tennessee

San Jose-Santa Clara Regional Wastewater Facility, San José's Environmental Services Department, City of San Jose, California

2. External—Desk-based research

For the assessment of greenfield sites, desk-based research was undertaken to determine "typical" costs for the construction of a new wastewater treatment facility. Available data suggested that a relevant example to use concerned a new facility with a 95 ML daily capacity, which is equivalent to a municipal area with a population of 250,000–300,000 people.

However, certain types of costs were excluded from the assessment, including land costs, site groundworks, planning and legal costs, etc. These costs were excluded because they may vary very greatly from site-to-site, and because it is difficult to isolate 'typical' costs for these categories. Furthermore, these types of costs are not influenced significantly by the use or otherwise of ABB technologies and are therefore common to all scenarios considered.

For both greenfield and brownfield sites, desk-based research was also undertaken to establish benchmark information on operational aspects of operating typical wastewater treatment facilities. This research covered aspects, including:

- Annual operating costs, disaggregated by categories such as expenditure on workforce, energy consumption, maintenance, chemical reagents, sludge disposal, and other operating costs.
- Associated carbon emissions.

A 2021 cost base was used in the assessment. Where necessary, estimates of capital costs dating from earlier than 2021 were adjusted using up-to-date construction and civil engineering cost inflation indices.

- Academic and non-academic literature

Data sources used to determine CapEx and OpEx costs associated with different asset types included a desk-based review of academic sources listed below.

Other data sources—including the UK's Office for National Statistics—were used to develop assumptions to convert potential operating costs savings into estimates for additional economic output at the level of a national economy.

Acampa et al, Water Treatment Cost Evaluation Tools, MDPI Water Journal, May 2019

Campos et al, Greenhouse Gas Emissions from Wastewater Treatment Plants, Hindawi Journal of Chemistry, 2016. Available at **Greenhouse Gases Emissions from Wastewater Treatment Plants: Minimization, Treatment, and Prevention (hindawi.com)**

PDF Coffee, Integrated Cost Design and Operation for Wastewater Treatment. **Available at Cost Data for wastewater treatment plant - PDFCOFFEE.COM**

E-Source operating cost models for Wastewater Treatment Plants (Various)

KPMG Benchmarking City Services (2017)

Pajares et al, Cost of Urban Wastewater Treatment and Ecotaxes: Evidence from Municipalities in Southern Europe, MDPI Water Journal, December 2018

Peacehaven Wastewater Treatment Plant (near Brighton, UK). Various sources were used to estimate capital and operating costs for this facility which became operational in 2014.

SSI Aeration: Cost Models for Wastewater Treatment Plants (2021) Available at: **How Much Does a Wastewater Treatment System Cost? | SSI Aeration**

(UK) Office for National Statistics, UK Input/Output tables, 2022. Available at **UK input-output analytical tables - industry by industry - Office for National Statistics (ons.gov.uk)**

(UK) Office for National Statistics, Non-Financial Business Economy tables (2010-2020). Available at **Non-financial business economy, UK: Sections A to S - Office for National Statistics**

(UK) Office for National Statistics, UK Construction Industry Inflation Statistics, 2010-2021

J van Staveren, Cost Estimating Relationships for Wastewater Treatment Plant Projects, University of Twente, July 2019

Carbon equivalent calculations

Equivalent car emissions

Results from report	**Greenfield**	**Brownfield**	**Average across greenfeld and brownfield**
Avg. annual carbon savings in tons	2,780.00	1,300.00	2,040.00
Avg. annual carbon savings in kg	2,780,000	1,300,000	2,040,000
Avg. life cycle carbon savings in tons	89,000.00	41,600.00	
Annual equivalent no. cars	1,390	650	1,020
Life cycle equivalent no. cars	44,480	20,800	32,640
Methodology	**Annual –** 1 car produces 2 tons CO_2 each year, so we have divided the total CO_2 savings in tons by 2	**Life cycle –** annual figure x 32	
Link to source	What exactly is 1 ton of CO_2? We make it tangible. - Climate Neutral Group		
Narrative of source	1 car on gasoline driving half a year in NL (average km's per year with passenger car, gasoline: 9,994 km, source CBS, Dutch National Statistics)[1]		
Sub-sources	[2] Calculated with the CO_2 calculator that we use for CO_2 Footprint calculations. This is based on the Green House Gas Protocol and our up-to-date emission factors, Dutch National emission factors, excl. flying (UK BEIS, formerly DEFRA)		

Equivalent powering homes

Results from report	**Greenfield**	**Brownfield**	**Average across greenfeld and brownfield**
Avg. annual carbon savings in tons	2,780.00	1,300.00	2,040.00
Avg. annual carbon savings in kg	2,780,000	1,300,000	2,040,000
Avg. life cycle carbon savings in tons	89,000.00	41,600.00	
Annual equivalent no. homes	1,807.54	845.25	1,326.40
Life cycle equivalent no. homes	57,841.35	27,048.11	42,444.73
Methodology	Based on source data, we have calculated that 1 household generates 1.538 CO_2 from electricity consumption	1 ton / 0.65 households = amt. CO_2 generated per household/ year - calculation below	
Link to source	What exactly is 1 ton of CO_2? We make it tangible. - Climate Neutral Group		
Narrative of source	Electricity consumption (grey) by 0.65 households in one year in NL (average consumption HH: 2765 kWh, source Milieucentral)[2]		
Sub-sources	[2] Calculated with the CO_2 calculator that we use for CO_2 Footprint calculations. This is based on the Green House Gas Protocol and our up-to-date emission factors, Dutch National emission factors, excl. flying (UK BEIS, formerly DEFRA)		

Equivalent glacier mass

Results from report	**Greenfield**	**Brownfield**	**Average across greenfeld and brownfield**
Avg. annual carbon savings in tons	2,780.00	1,300.00	2,040.00
Avg. annual carbon savings in kg	2,780,000	1,300,000	2,040,000
Avg. life cycle carbon savings in tons	89,000.00	1,600.00	21.70
Equivalent kilogram glacier mass	44,480,000	20,800,000	
Rounded out figure	44 million	20 million	32 million
Link to source	ABB Emission Reference Guide, taken from carbonbrief.org	Global warming to date could ‘obliterate’ a third of glacier ice - Carbon Brief	
Narrative of source	16kg of glacier mass is lost every year per kg CO_2	The article refers to a study published in Nature Climate Change, by the researchers B. Marzeion, G. Kaser and F. Maussion.	

Other comparisons we can draw, based on other benchmarks

Results from report		**Greenfield**	**Brownfield**
Avg. annual carbon savings in tons		2,780.00	1,300.00
Avg. annual carbon savings in kg		2,780,000	1,300,000
Avg. life cycle carbon savings in tons		89,000.00	41,600.00
Equivalent of up to…	**fire extinguishers**	1,390,000.00	650,000
	number of 500m³ hot air balloons	2,780.00	1,300.00
	cubic meters of Cola	347,500.00	162,500
	liters of Cola (125 m3 = 125,000)	347,500,000.00	162,500,000
Narrative of source		What exactly is 1 ton of CO_2? We make it tangible. - Climate Neutral Group	"1 ton of CO_2 looks like…500 CO_2 fire extinguishers; a 500 m³ hot air balloon; 125m³ of cola."

Average annual cost savings

Results from report	**Greenfield**	**Brownfield**	**Average across greenfeld and brownfield**
	$843,750	$1.5 million USD	$1.17 million USD
	0.08	0.11	0.10
	843,750.00	1,500,000.00	1,171,875.00

ABB solutions included in this assessment

Solutions evaluated in this report include:

- **ABB Ability Smart Solution for Wastewater**
- **ABB System 800xA - process, electrical, safety, telecoms in one system**
- **ABB Ability™ Symphony® Plus SCADA - Symphony Plus**
- **ADS420 | Dissolved Oxygen Sensor| Optical | Manufacturer | Supplier - Continuous Water Analysis | Solutions (Analytical Measurement | Products | Instruments | Equipment) | ABB**
- **ABB Collaborative Operations**
- **ABB Ability OPTIMAX for Sites - Optimax solution suite (Energy Management)**

About Stephen Lucas

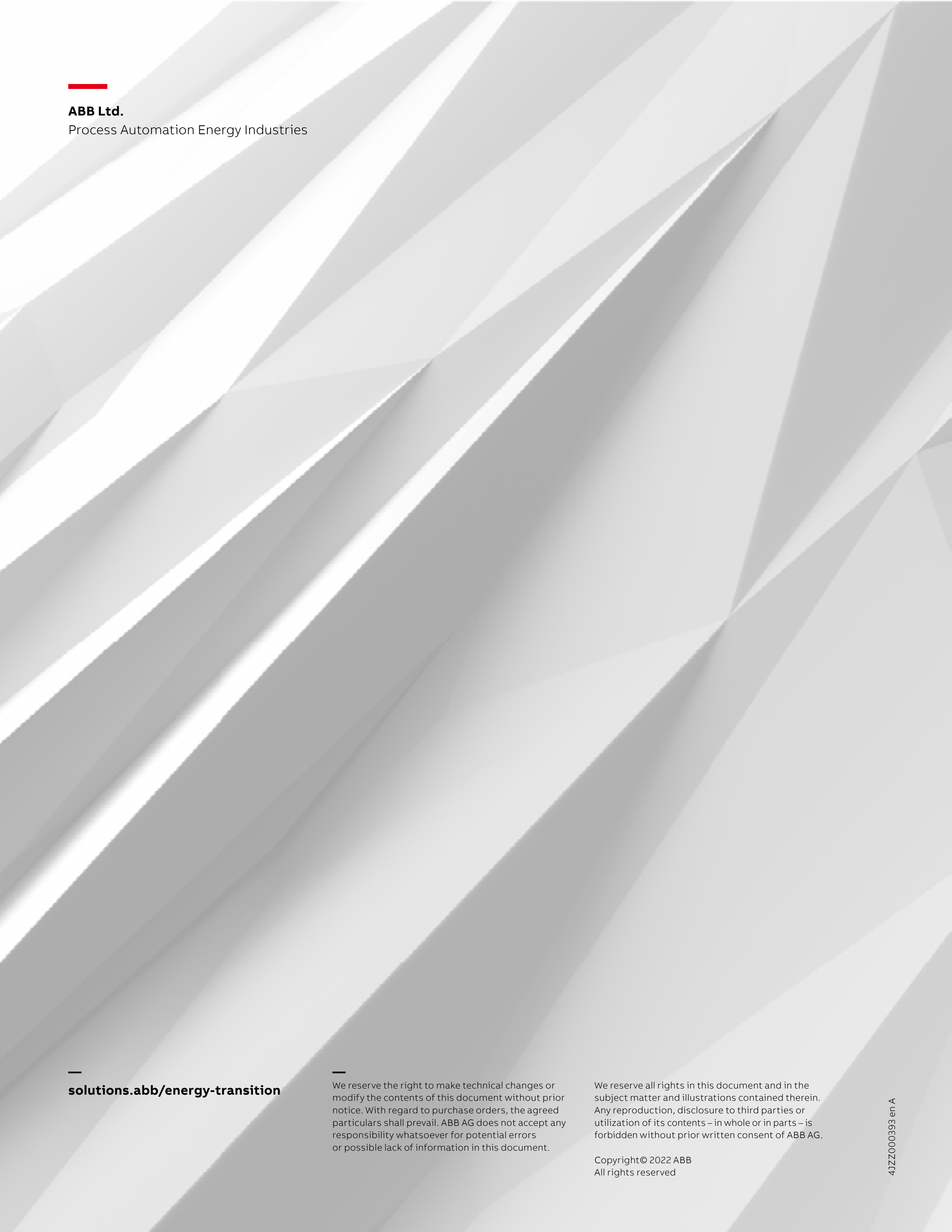
Stephen Lucas, Managing Director of **Developmental Economics** has over 30 years' experience in delivering research and cost benefit analysis, economic impact assessment, project appraisals and feasibility studies for major infrastructure. He has also conducted over 50 Green Book compliant appraisals representing a total investment of over USD50 billion. Specializing in energy and transport infrastructure, he has been heavily involved in advising on onshore and offshore renewable energy projects, energy-from-waste facilities, and major electricity grid infrastructure investments. Most recent projects have included a socio-economic assessment of proposed new energy generation or transmission infrastructure. Increasingly his assessments have included an assessment of carbon production and other emissions considerations.

About ABB Energy Industries

ABB (ABBN: SIX Swiss Ex) is a leading global technology company that energizes the transformation of society and industry to achieve a more productive, sustainable future. By connecting software to its electrification, robotics, automation and motion portfolio, ABB pushes the boundaries of technology to drive performance to new levels. With a history of excellence stretching back more than 130 years, ABB's success is driven by about 105,000 talented employees in over 100 countries. **abb.com**

ABB Energy Industries is a division of ABB operating under its Process Automation arm. Its focus is enabling safe, smart, and sustainable projects and operations for businesses across the oil, gas, chemicals, power generation, life sciences and water sectors. Driving integrated solutions that automate, digitalize, and electrify industry we connect our people and technology to help our customers adapt and succeed. With over 50 years domain expertise, we continue to innovate and reshape traditional approaches across the energy sector. Our technologies and solutions are designed to create value, improving operational efficiency and productivity, enhancing safety, and minimizing risk.
solutions.abb/energy-transition

More about ABB's Sustainability Strategy 2030 **global.abb/group/en/sustainability**



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