REPORT

Stirling Infrastructure PARTNERS LTD

A Practical Guide to Investing in **Sewage Gas Facilities**

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Evaluating the financial feasibility of investments in AD CHP

INVESTMENT BANKING CONNECTED TO INSTITUTIONAL INVESTORS

PURPOSE OF THIS REPORT:

The purpose of this report is to provide guidance to investors in the sewage gas business. It develops a framework for evaluating the financial feasibility of investments in AD CHP and newer generation THP AD CHP in the United Kingdom. The report was conceived as a starting point for a broader financial framework based on accurate feedstock analysis and local regulatory and engineering requirements. The data developed in this report are not site specific and should not be considered indicative of any specific project. The data provided serve a purely illustrative purpose.

GLOSSARY:

AD: Anaerobic Digestion

AAD: Advanced Anaerobic Digestion

THP: Thermal Hydrolysis Process

CHP: Combined Heat and Power

Conventional AD CHP: Conventional AD plants with installed CHP electricity generation capacity

THP AD CHP: AD plants with installed Thermal Hydrolysis Process Treatments and CHP electricity generation

TDS: Tonnes of Dry Solid

TDS/d: Tonnes of Dry Solid per Day

CUF: Capacity Utilisation Factor – Utilisation factor of electricity generating installations

DUKES: Digest of UK Energy Statistics

INTRODUCTION

The generation of energy from sludge treatment is a common practice in the UK. According to the 2019 DUKES (Digest of UK Energy Statistics), 194 sewage sludge digestion centres are active in the United Kingdom. The country's approximate production of sewage sludge amounts to 1.7 million dry tonnes, on a yearly basis. Its corresponding calorific value is 7.52 TWh. Only a small part of this calorific value can currently be extracted and turned into energy. The 2019 DUKES reported that sewage gas generation has recently increased to 1.0 TWh.

Therefore, a better exploitation of wastewater could help the UK to meet its renewable energy needs. An enhanced exploitation of the calorific value of sludge can be achieved through two strategies:

- Development of Greenfield projects in unexploited areas
- Efficiency Improvements through technological upgrades

However, any commercial proposition in the field of sewage sludge treatment needs to be economically viable. This report will hence investigate the numerous variables affecting the commercial viability of sewage gas projects. The multiple steps necessary to our process are set out in our methodology below.

METHODOLOGY:

The methodology employed for the purpose of this report follows a step-by step approach to the development of sewage gas facilities. It sets out the successive steps, which developers will face for the development and construction of a facility.

Firstly, the crucial factors affecting the identification of adequate locations are considered. The positive impact of economies of scale will be explained. The importance of availability of feedstock will be considered in this section.

The identification of a suitable location is followed by the selection of the technology which can best enhance electricity output while minimising costs. Estimates on the energy output of two technologies are provided.

The CapEx associated with the two installations is then estimated. The estimate is built on three models featuring three different installed capacities (kWe). However, our methodology is primarily concerned with setting the appropriate parameters for building CapEx models.

CapEx estimates are then complemented by OpEx estimates. The parameters, which need to be considered for calculating OpEx, are set out in this section.

Finally, the adequate parameters for the estimation of revenues from electricity output are set out.

ECONOMIES OF SCALE

Evidence from existing research on sewage sludge treatment centres suggests there are economies of scale in sludge treatment. Producers of gas treating large quantities of feedstock benefit from reduced processing costs. In a scenario where the throughput of feedstock increased from 5000 to 10000 TDS, the estimated decrease in unit operating costs amounted to 20%. The deriving benefit will depend on the availability of feedstock and its transportation costs.

The immediate implication of economies of scale is the centralisation of the sludge treatment process. If the adequate infrastructure is in place, quantities of sewage sludge can be transported from small-scale treatment centres to a large-scale, centrally located processing station. There, the sludge can be treated to generate electricity from sewage gas. In this scenario, the operating cost per unit decreases as the size of the plant increases. In England, the Cliff Quay and Pyewipe sewage treatment centres, operated by Anglian Water, provide examples of central hubs served by satellite centres.

However, in a financial model the benefits deriving from economies of scale will be weighed against transportation costs. Sludge can be transported on large trucks after dewatering or via pipeline. The dewatering process ensures trucks can transport larger amount feedstock without reducing its calorific value.

Any operator of sludge treatment centres will consider the economic viability of transportation. The question of the distance which can be economically covered by trucks or pipeline is a complex one and any answer will be site-specific. London Economics, a UK-based consulting firm, made estimates on the maximum distance, which can be economically covered in England. Based on the Great Billing treatment facility, 54 km was calculated as the maximum possible distance over which the sludge can be economically transported.

TECHNOLOGIES TO ENHANCE ENERGY RECOVERY

If large quantities of sludge can be concentrated in a specific site for treatment, the technology chosen for treatment will determine the CapEx, OpEx and revenue base of the facility. This information and the estimated transportation costs of the facility will allow a project sponsor to anticipate the financial feasibility of the project. Currently, the two main technologies for the generation of electricity from sewage sludge are:

- Conventional AD CHP
- THP AD CHP

While THP AD CHP achieves better productivity yields than conventional AD CHP, the corresponding CapEx and OpEx are comparatively higher.

In Conventional AD CHP, the sludge is pre-treated through a thickening process. The thickened sludge is then processed in the anaerobic digestion tank. The digestion process causes the dry solid content of the sludge to shrink. The result of the process is the production of biogas and digestate. The volatile solid destruction usually yields a biogas production of 350 cubic meters/TDS. The corresponding electricity output resulting from the digestion process amounts to 728-820 kWh/TDS.

THP AD CHP is a form of advanced anaerobic digestion. This type of digester relies on Thermal Hydrolysis technology to increase the calorific value extracted from the feedstock and minimise the disposal volume. The benefit provided by this technology is represented by the increased biogas yield. Through THP, a larger amount of biogas is produced from the same amount of dry solid. This results from a better rate of volatile solids destruction. This technology is expected to yield a biogas production of 450 cubic meters/TDS. The corresponding electricity output resulting from this process is 1020-1100 kWh/TDS.

TABLE 1
Biogas Yield and Electricity Output per Technology

Partner	Unit	Conventional AD CHP	THP AD CHP
Biogas Yield/TDS	m3	350	450
Electricity Output/TDS	kWh	728-820	1020-1100

CAPEX MODEL FOR SEWAGE GAS FACILITIES:

This section of the paper will investigate the variables affecting the capital expenditure (CapEx) incurred by developers for the construction of a sewage gas facility. The data referred to in this section have been gathered by academics by combining different sources of information. Therefore, this module of the report provides an illustration and explanation of these data for business purposes. The estimates do not represent by any means project-specific or site-specific data. The estimates presented below concern the United Kingdom. Data are meant to provide prospective developers with a general methodology for estimating total CapEx estimates in relation to the construction of a sewage gas facility. EPC contractors will provide prospective developers with extensive quotes for site-specific CapEx estimates.

Total CapEx will be a function of the CapEx for every single engineering and installation expense incurred for the construction of the plant and non-engineering expenses. The individual items making up total CapEx are divided into two categories: firstly, engineering and installation costs of individual components; secondly, non-engineering related costs. The engineering and installation costs broadly account for the following components:

- Pre-treatment and Thickening
- Anaerobic Digestion
- Thermal Hydrolysis Process
- Dewatering and Cake Storage
- Odour Treatments
- CHP and Electrical Installations
- Control and Instrumentation
- General

These engineering and installation costs are worked out from the CapEx equation explained in detail below. They are then complemented by other costs, which are only estimated as a percentage of engineering and installation costs in the present model. These costs can vary depending on the project type and on the jurisdiction. They include:

- Contractor Management
- Client Overheads

The former is estimated to be at 20% of engineering and installation costs in the present model. The latter is estimated at 10%.

For the purpose of this model, the normalised CapEx equation employed for the calculation of engineering and installation costs will be the following:

CapEx = k x S^0.6

The k-values for each engineering and installation item in the equation were calculated as an average of their cost from projects of different sizes. Each k-value is item-specific and there is no single k-value for the entire installation.

The S value refers to the size / capacity of each engineering and installation item mentioned in list. As different components process different kind of feedstocks and materials or produce different outputs, units of measurement associated with each k-value differ. The units of measurement employed are:

- TDS/d – Tonnes of Dry Solid per day
- Cubic meters
- kWe

The 0.6 exponent value was calculated by researchers as an average value from similar projects.

The three models (**Model 1**, **Model 2** and **Model 3**) presented in the following tables rely on the above-outlined methodology to estimate the Total CapEx of differently sized installations. Thus, the k-values associated with each component are used to determine the CapEx of each component and finally the CapEx of the entire plant. The difference between the models lies in the KWe installed of each plant.

Model 1 constitutes an estimate of the total CapEx for a 2500 KWe plant. This model relies on k-values to work out the CapEx of the smallest plant taken into consideration.

Model 2 constitutes an estimate of the total CapEx for a 5000 KWe plant. This model represents a transposition of the data available from previously mentioned academic research.

Model 3 constitutes a similar estimate of total CapEx for a 7500 KWe facility. This model relies on k-values and applies them to a larger scale facility to understand the associated CapEx.

The three models will be then compared to identify CapEx trends when the size of the installation varies. The comparison between CapEx at different capacities will test the extent to which economies of scale can benefit larger installations from a financial perspective.

MODEL 1:
CapEx Model for a 2500 KWe Installation

Component	CapEx (£)	Size	Unit	K
Pre-treatment & Thickening	1,751,359	50	TDS/d	167,498
AD	3,812,974.5	11000	m3	14,336
THP	3,886,014.2	50	TDS/d	371,654
Dewatering & Cake Storage	2,515,091.2	30	TDS/d	326,805
Odour Treatment	438,827.86	50	TDS/d	41,969
CHP and Electrical Installations	3,652,041	2500	TDS/d	33,402
Control & Instrumentation	520,792.44	50	kWe	49,808
General	1.340,344.1	50	TDS/d	128,189
Tot Engineering & Installation	17,917,442	/	/	/
Contractor Management (20%)	3,583,488.4	/	/	/
Client Overheads (10%)	1,791,744.2	/	/	/
TOTAL	23,292,674	/	/	/

MODEL 2
CapEx Model for a 5000 KWe Installation

Component	CapEx (£)	Size	Unit	K
Pre-treatment & Thickening	2,654,662	100	TDS/d	167,498
AD	5,779,416	22000	m3	14,336
THP	5,890,325	100	TDS/d	371,654
Dewatering & Cake Storage	3,812,236	60	TDS/d	326,805
Odour Treatment	665,165	100	TDS/d	41,969
CHP and Electrical Installations	5,535,458	5000	TDS/d	33,402
Control & Instrumentation	789,402	100	kWe	49,808

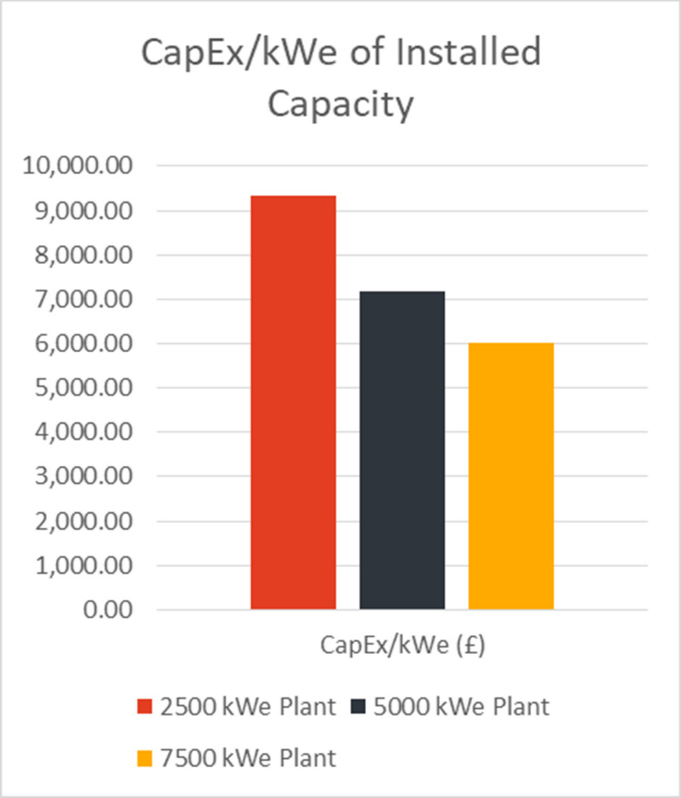
Component	CapEx (£)	Size	Unit	K
General	2,031,665	100	TDS/d	128,189
Tot Engineering & Installation	27,158,329	/	/	/
Contractor Management (20%)	5,431,666	/	/	/
Client Overheads (10%)	3,258,999	/	/	/
TOTAL	35,848,994	/	/	/

MODEL 3
CapEx Model for a 7500 KWe Installation

Component	CapEx (£)	Size	Unit	K
Pre-treatment & Thickening	3,385,804.5	150	TDS/d	167,498
AD	7,371,169.7	33000	m3	14,336
THP	7,512,613.9	150	TDS/d	371,654
Dewatering & Cake Storage	4,862,204.7	90	TDS/d	326,805
Odour Treatment	848,361.36	150	TDS/d	41,969
CHP and Electrical Installations	7,060,080.5	7500	TDS/d	33,402
Control & Instrumentation	1,006,818.9	150	kWe	49,808
General	2,591,212.4	150	TDS/d	128,189
Tot Engineering & Installation	34,638,262	/	/	/
Contractor Management (20%)	6,927,652.4	/	/	/
Client Overheads (10%)	3,463,826.2	/	/	/
TOTAL	45,029,740	/	/	/

The 3 CapEx Models developed above include Thermal Hydrolysis Process (THP) as an installation cost. Conventional AD will hence be characterised by a comparatively lower CapEx for the same installed capacity. The difference between the two technologies also entails different operational expenses, which will be analysed in greater detail in the next section of this report.

The three above-mentioned models highlight the benefit of economies of scale in the construction of sewage gas treatment facilities. As the size of the installation increases the estimated CapEx decreases. Such decrease is illustrated by the graph below.



The graph above illustrates the entity of the decrease. The price/kWe installed of large digestion sites improves as the size of the installation increases. In order to reap the benefit of economies of scale, adequate amounts of feedstock need to be available on a daily basis. As explained in the previous section, the availability of large quantities of feedstock can be enhanced by transporting the feedstock from nearby locations.

Developers of AD sites can face CapEx costs related to the transportation cost of sewage sludge. As explained earlier, the centralisation of the sludge treatment process can bring about considerable economic benefits deriving from economies of scale. Large volumes of feedstock can be transported to the treatment site:

- Via pipeline
- By facility-owned trucks

Pipelines or trucks will be accounted for as non-current assets. These assets will also have an associated operating cost. Such cost will be site specific, depending on the amount of feedstock transported and the distance covered. The total parameters for the estimation of costs include both CapEx parameters and OpEx parameters, which necessitate to be accounted for in any estimate on total transportation costs.

EPC contractors with an established track record for large industrial sites, such as the ones above, will provide prospective developers with detailed quotes on investments in sewage gas infrastructure.

OPEX FOR SEWAGE GAS FACILITIES

This section of the report will consider the operating expenditure (OpEx) faced by operators of sewage gas infrastructure. The approach for the estimation of OpEx is based on the identification of all the cost bases for the operation of a sewage gas facility. The typical cost bases for the operation of such facilities are the following:

- Electricity and Energy Use (MWh/d)
- Polymer (kg/d)
- Digestate Volume (cubic meters/d)
- Labour Cost
- Maintenance Cost (% of Capex)
- Transportation Cost

The operation of a sewage gas plant relies on a number on inputs, which lead to the final electricity output of the facility. The electricity output resulting from digestion constitutes the principal revenue base of sewage gas facilities and will be examined in the next section of the report. The three remaining operating costs concern the disposal of digestate, labour and maintenance cost, which can be estimated as a percentage of CapEx. Treatment facilities which import sludge from other sites will also incur operating transportation costs.

The Table below shows the variation in inputs and outputs for the two technologies examined. In fact, conventional AD and THP AD have different output performance and necessitate different inputs to function. This report has shown the variation in CapEx between the different technologies, determined by the presence or lack of Thermal Hydrolysis installations. Similarly, conventional AD and THP AD imply different electricity outputs per TDS processed on site. Indeed, for THP AD, the electricity output will be comparatively higher, in relation to conventional AD. Crucially, conventional AD and THP AD technologies also have different OpEx due to the different inputs required by each technology.

TABLE 2

Input/Output Performance for 1 TDS in Conventional AD CHP and THP AD CHP

Inventory Item	Unit	Conventional AD CHP	THP AD CHP
INPUT			
Electricity Output/TDS	kWh	728	1020
OUTPUT			
Electricity Consumption	kWh	135	179
Natural Gas	kWh	0	370
Diesel	kg	7.3	3.7
Polymer	kg	9.2	14.0

The Table shows a difference in the electricity and energy input associated with each facility. While conventional AD CHP requires only electricity and diesel inputs, THP AD CHP requires a natural gas input. Therefore, the increased electricity output associated with THP AD CHP is accompanied by increased energy inputs. The input data in the Table were calculated from existing data per TDS. Such information is not by any means site-specific or project specific. It is meant to offer an overview on the inputs and electricity output of Conventional AD and THP AD CHP facilities. Financial models for specific plants will require accurate, site-specific data per TDS based on the location of the facility. Based on these further elements, the potential decrease in OpEx deriving from economies of scale can be calculated.

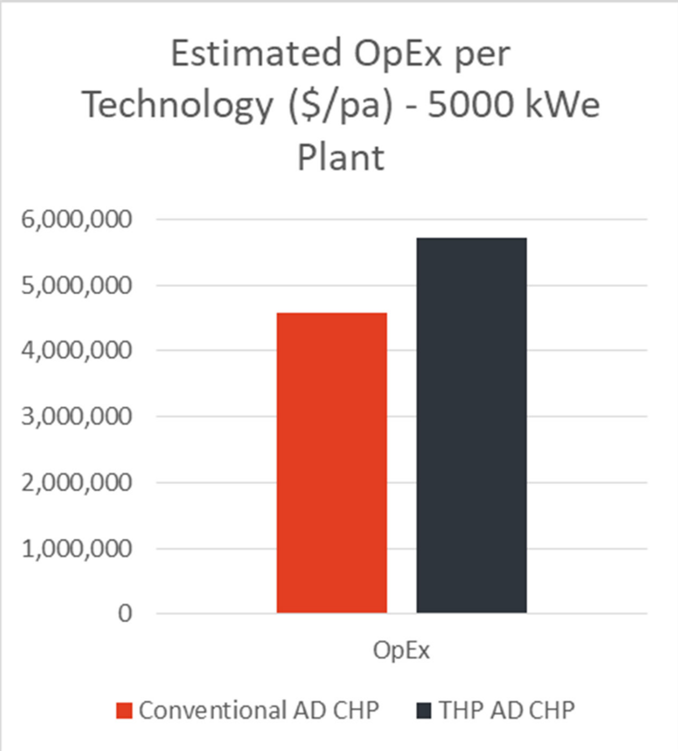
On the other hand, the resulting digestate is a by-product of this process. The disposal cost of digestate varies depending on the location of the digestion site and it is measured in £ / wet tonnes. In the United Kingdom, digestate resulting from the digestion of sludge can often be reemployed for agricultural purposes as fertiliser. However, the employment of digestate as fertiliser is reviewed on a case by case basis. In the United Kingdom the estimated range of disposal cost is £10-35 per wet tonne. In Europe the use of sewage sludge is regulated by the Directive 86/278/EEC, but its use for agricultural purposes can vary depending on the country. For instance, in the Netherlands, the recycling of sludge is not permitted by the government and the disposal cost for digestate can exceed £100/TDS.

Labour and maintenance costs can be estimated on a case by case basis. Labour costs will naturally depend on the size of the installation and the personnel necessary to operate the facility. On the other hand, estimates on the maintenance cost of such facilities can be calculated as a percentage of CapEx and are thus associated with the initial investment. Different estimates quantify maintenance cost as a percentage of CapEx but this number can vary depending on the installation.

As explained in the first section of this report, the benefit deriving from economies of scale in the sewage sludge treatment process can lead to the centralisation of the treatment process in a well-positioned site. This implies a varying degree of transportation costs, depending on the quantity of feedstock to be transported and the distance to be covered. Transportation costs can generally be regarded as an operating expense as transportation assets can be leased through an operating lease.

Alternatively, transportation can be outsourced to a third party.

Generally, OpEx for THP AD CHP installations is expected to be higher compared to Conventional AD CHP plants. A study has estimated the entity of such difference for a 5000 kWe installation. In this case, the OpEx of a THP AD CHP plant is expected to be 24.7% higher than the OpEx in a corresponding Conventional AD CHP plant. The estimated difference is shown in the graph below:



Prospective developers will estimate the combination of CapEx and Opex to make evaluations of their cost base. The data provided above are not site-specific or project specific. They are meant to provide a framework of total expenses for developers of sewage gas facilities.

REVENUE BASES

The electricity generation resulting from AD installations constitutes the revenue base of the investment. The number of kWh pa generated through AD provides an economic benefit to the producer. This benefit materialises either as savings on the energy cost of the installation or as electricity resold to the national grid.

The two factors necessary to estimate the revenue generated by an AD facility are:

- The price (£/kWh) paid for the electricity generated on site
- the kWh produced yearly based on the kWe of the installation

The value of the former factor will depend on the arrangement regulating the use of the electricity produced. If the electricity is resold to the national grid, the revenue generated by the sale of electricity will depend on the contractual agreement between the producer and the supplier of electricity. The price (pence/kWh) of the electricity produced and resold can be regulated by an off-take agreement between the producer and the supplier. If the electricity generated is used on site, its value will be calculated as yearly total savings on electricity consumption. Sewage treatments works are usually energy intensive and the electricity produced on site in not sufficient to supply the entire demand of the facility. Generally, the electricity produced through anaerobic digestion is estimated to displace a large portion (up to 50%) of the power purchased for the operation of sewage treatment works.

The second factor necessary to estimate the yearly revenue from the electricity generated is the kWh generated yearly from the capacity of the installation (kWe). Estimates of yearly electricity production can be made considering the kWe installed and the CUP (Capacity Utilisation Factor) of the facility. The CUF is the utilisation factor of the facility: it is expressed as a percentage value, resulting from the actual output of electricity of a facility over the over the maximum possible output of the facility. The EIA estimated the CUF for biomass installation to be at 49.3% in 2018. However, for sewage gas installation the CUF can be closer to landfill gas and municipal waste solid, which amounted to 73.3% in 2018 according to the EIA.

Therefore, the calculation of the total kWh generated will be estimated using the following formula:

Installed Capacity (kWe) x CUF x 365 days x 24 hours = Output (kWh)

For an illustrative purpose, in this report the CUF can be estimated to be at 50%. Therefore, the annual electricity output of a 5000 kWe facility will be the following:

5000 kWe x 0.5 x 365 x 24 = 21,900,000 kWh

The CUF of sewage gas facilities is usually higher compared to the capacity utilisation of other renewable sources. Greater supplies from sewage gas CHP could hence contribute to the stability of the national grid.

To conclude, any estimate of the revenue base of the installation will result from two further estimates:

- The electricity output resulting from the size of the installation (kWe) and the CUP
- The pence/kWh at which the electricity is resold or the yearly savings on energy generated by the facility

CONCLUSION

The overall profitability of the investment will be a function of the revenue base and the CapEx and OpEx incurred by the developer of the facility. Bankable investments will be characterised by the abundance of cheap feedstock, adequate technologies for the extraction of energy and the creation of a solid revenue base.

The development of sewage gas infrastructure will be highly beneficial for water companies and water treatment operators. The proximity and abundance of precious low-cost feedstock will provide them with an opportunity to cut electricity costs. The production of renewable electricity from sewage sludge will contribute to meeting the green energy targets of water companies by reducing their carbon footprint.

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ABOUT STIRLING INFRASTRUCTURE PARTNERS

Stirling Infrastructure Partners advises institutional investors on the due diligence and selection of infrastructure assets. The firm has expertise in the acquisition and disposal of both infrastructure, energy assets and funds. The firm is experienced in project finance and raising capital for direct investment and infrastructure funds. With a global network of over 1200 institutional investors and market participants, the firm is well placed to advise on fund manager selection, asset valuations and M&A transactions.

PURPOSE OF DOCUMENT

We have prepared this document for our clients and key relationships to present some of the key themes and data sets that this firm believes our clients should consider in order to more effectively invest into this asset class. If you would like to obtain advice from either our investment fund advisory or our M&A professionals, please contact us on the details below.

DISCLAIMER

This document has been developed by our economists and does not constitute financial analysis. It is designed for information purposes only and does not constitute a personalised investment recommendation.

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