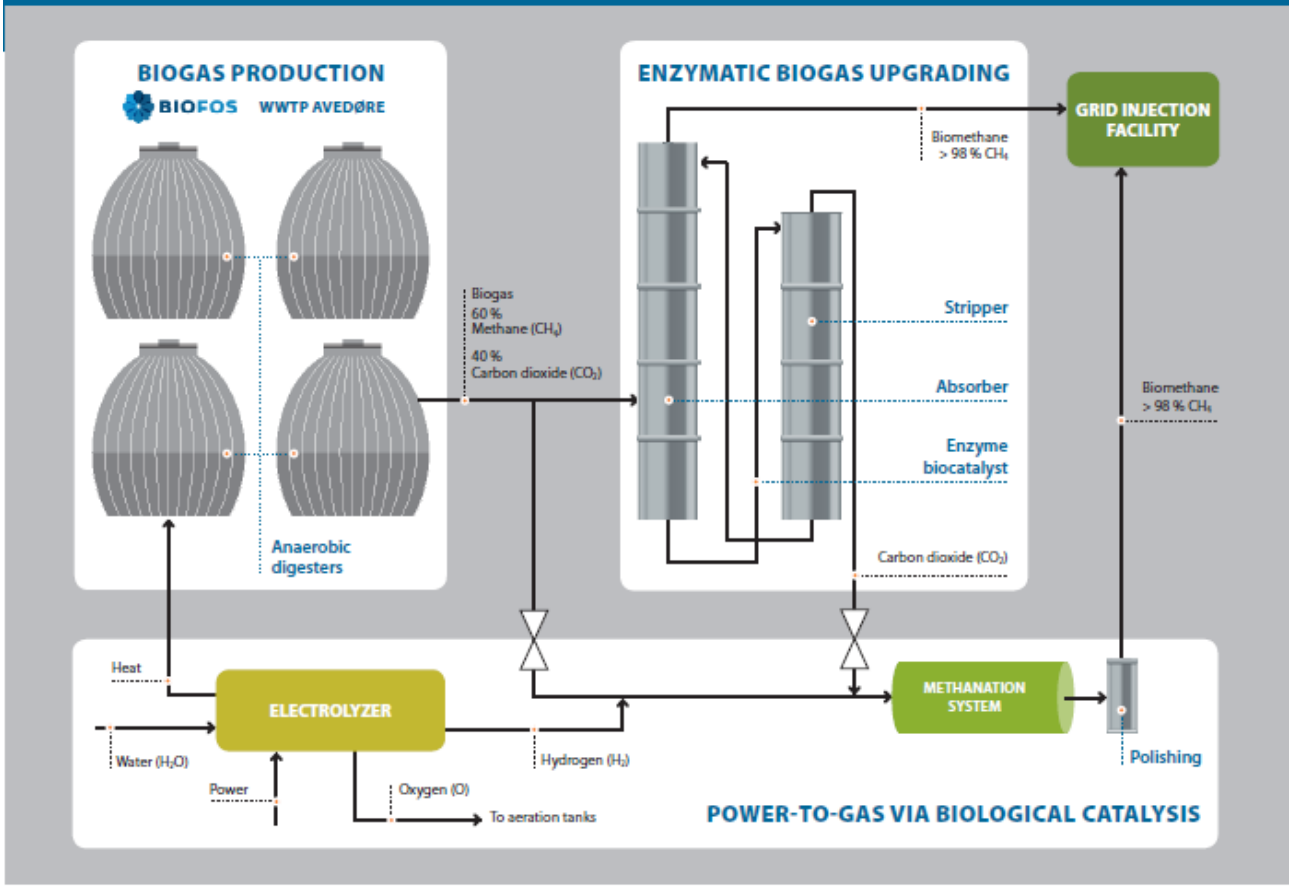
THE AVEDØRE PROJECT

HOW TO FIND RENEWABLE BIOGAS SOURCES AND INTEGRATE THEM IN THE GAS GRID BY UPGRADING AND METHANIZATION WITH NEW TECHNOLOGIES.



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BIOFOS WWTP Avedøre produces biogas from sludge and uses it in a gas engine to make power and process heat for the digesters. By installing heat exchangers and a heat buffer system they can release the biogas for external purposes.

The biogas will be upgraded to natural gas quality, in a commercial scale demonstration plant, developed by Akermin Inc. in collaboration with Novozymes. The system incorporates a novel biocatalyst technology using the enzyme carbonic anhydrase to accelerate CO_2 absorption in a non-volatile, environmental friendly solvent. Akermin's system will reduce the capital cost and reduce power and steam consumption for biogas upgrading.

The rejected CO_2 from the upgrading system will be used in the Electrochaea project 'Power-to-Gas via Biological Catalysis' to produce synthetic methane using hydrogen produced from excess renewable electricity and archaea cultures.

The upgraded biogas and the synthetic methane will be injected into the natural gas grid by HMN Naturgas I/S and delivered to end users or stored in gas caverns.

The projects are funded by the Danish EUDP Program for the upgrading and by the Danish Forsk El for the power-to-gas system.

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THE AVEDØRE PROJECT

How to find renewable biogas sources and integrate them in gas grid by upgrading and methanation with new technologies.

By Dines Thornberg, Develop-manager, Biofos and Henrik Rousing, Planner, HMN Gashandel.

Introduction

One of Denmark's largest wastewater treatments plant should in the next 2 years host 2 exciting projects for upgrading and methanation of biogas. This will make "Renseanlæg Avedøre (WWTP Avedøre)" host for demonstration-projects in international class.

The demonstrations plant will be located at WWTP Avedøre and operated by the newly merged utility company BIOFOS. BIOFOS has an ambition to reduce their carbon footprint to zero in 2020, and these projects are important contribution to achieve this target.

Today the produced biogas is used as fuel in a gas-engine, which is producing power and heat. There's an un-utilized waste-heat when the sludge-incineration is included in the heat balance. By using this, instead of operation of the gas-engine, is possible to improve WWTP Avedøre's carbon footprint.

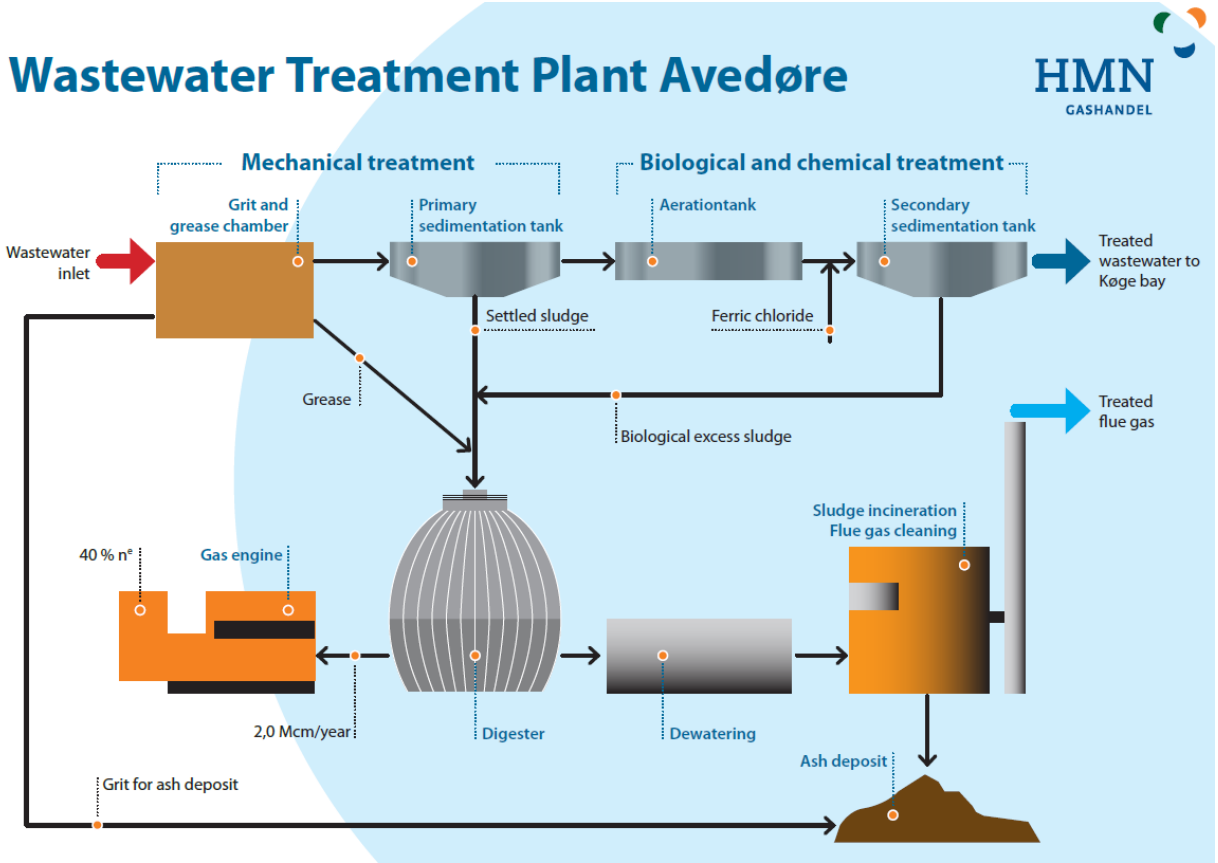

figure 1; WWTP Avedøre, overview present time.

Several alternatives

In the recent years WWTP Avedøre has considered several alternatives to use the biogas instead of as fuel for the gas-engine. The biogas could be supplied to the town gas grid in Copenhagen in line with biogas from "Lynetten," another wastewater treatment plant in the BIOFOS Group, or as fuel for city-bus services in Copenhagen. In both cases the biogas must be treated to fulfill the quality demands, for town gas with naturalgas and air according to the wobbe index, and for fuel to trucks and busses to at least 80 to 85 % methane contant, which is minimum requirement for modern automotive engines.

When the biogas must be treated, it was obvious to see on upgrading to pure methane and be injected to the natural-gas grid, to contribute to the amount of green gas in the gasgrid.

For HMN Gashandel it is an ambition to increase green gas significantly and this project is a part of HMN's strategy.

BIOFOS is also considering the possibility to expand the biogas production, thus they has more digester capacity than necessary to treat the sludge from the wastewater. In that case BIOFOS must make a choice between invest in a second gas-engine or upgrade, and "export" to the gas grid.

For few years ago BIOFOS started discussions for sale of the biogas to HMN, which had led to a contract between the parties, where HMN buys the biogas and establish an upgrading facility so the biogas can be injected to the gas grid. This contract makes it necessary for BIOFOS to restructure the heating system around the digesters and buildings at WWTP Avedøre.

Rebuilding at WWTP Avedøre

WWTP Avedøre is one of the few plants in Denmark that burns their own sludge. This process is designed as auto thermal, i.e. the combustion heat is balanced with vaporization of water in the dewatered sludge, fed into the combustion. There's actually an un-utilized heat from the incineration plants thermal circuit.

Today there is relatively large heat consumption in the digesters, because heat from digested sludge isn't recovered. A part of the rebuilding will be a Sludge in / Sludge out heat exchanger. At the same time, a heat accumulator tank will be constructed, so it's possible so different sources can contribute to the heat balance in digesters and buildings.

As a results of these changes it will be possible for WWTP Avedøre to cover own demand for heat, without using biogas, and they can release the biogas to other purposes.

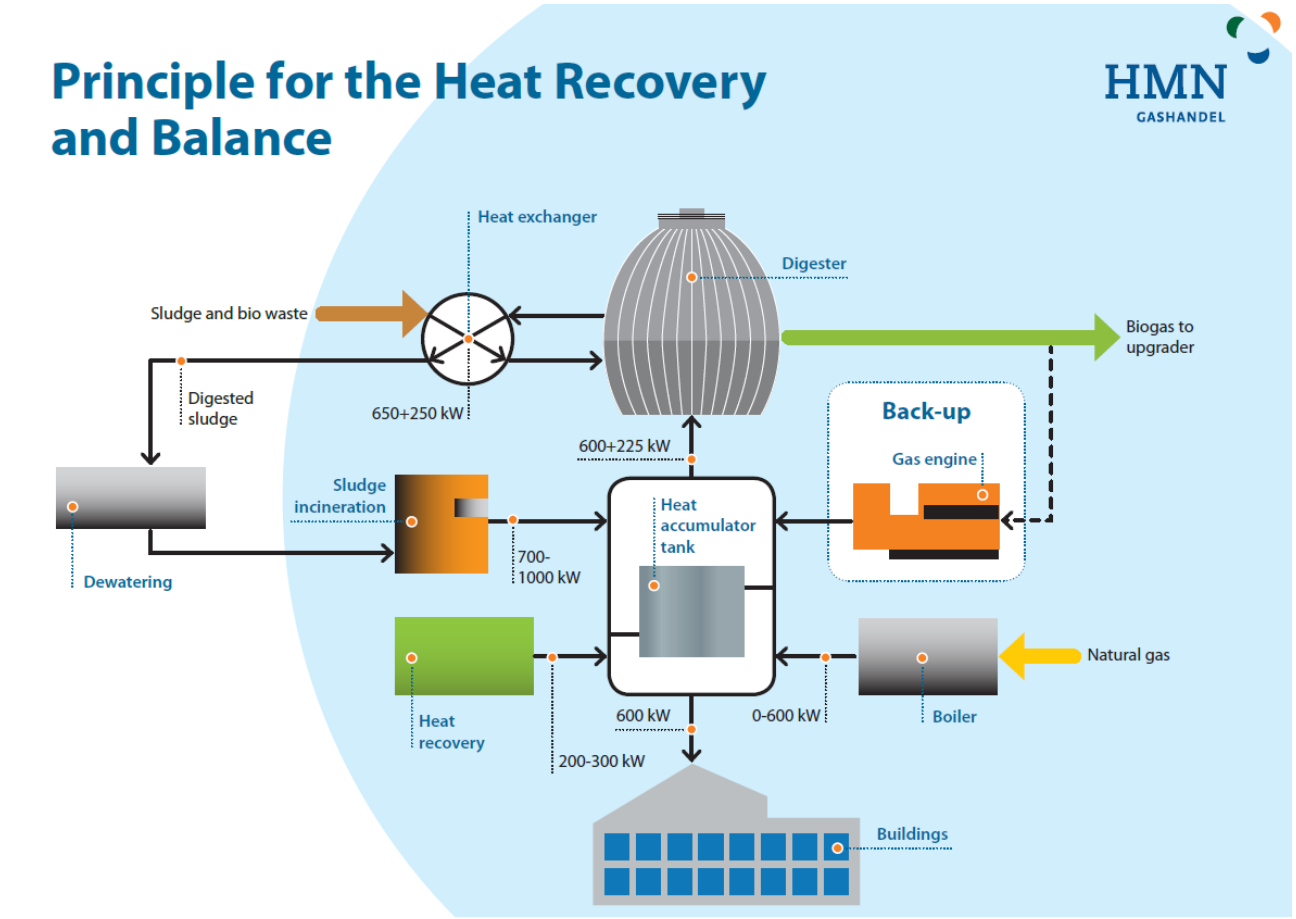

figure 2; heat balance princip

Enzymatic Biogas Upgrading

The biogas content app. 60% CH_4 and 40% CO_2, and minor amounts of siloxanes and hydrogen sulphide (H_2S), so the biogas must be cleaned and upgraded before it can meet the requirement to be delivered into the natural gas grid.

The siloxanes in the biogas derived from shampoos and deodorants, must be removed, together with the hydrogen sulphide. It's made relatively easy by sending the biogas trough an activated carbon filter, while feeding very little oxygen, either as air or pure oxygen, to control the level of nitrogen, after the filter, thus nitrogen can't be removed from the gas under the upgrading process.

To be accepted on the natural gas grid, the methane content must exceed 97,3 % (97,8 % incl. measurement unaccuracy). The techniques for removing CO_2 are well known and available on the market in a number of ways to upgrade the biogas. Scrubbing is one of them, but there are several types, all based on CO_2's ability to react with other substances. Water and amine is most widely used absorbents. Common to all types is the large capital and operation cost (CAPEX & OPEX) in upgrading systems.

Early in the cooperation discussed WWTP Avedøre and HMN the possibilty of using biogas to test a new technique for upgrading. WWTP Avedøre have, with their gas-engine, a big advantage as a host for this testplant, because the gas-engine can act as back-up system, when and if, during the test run, any challenges should occur, incl. adjustments and adaptations of the technique.

The new technique is based on amines, but added an enzyme for enchanced removal of the biogas' content of CO2. The enzyme; *Carbonic Anhydrase* is well known as an accelerator for CO_2 absorbtion and has been studied for decades. The enzyme is one of the fastest enzymes known in nature, and is present in all living organisms. Enzyme's task is to transport CO2 in and out of the body tissue as lungs and muscles. The enzyme's inability to remain active for longer periods in industrial processes, where there are high temperatures, altere pH values and impurities, has until now, prevented commercial use of the enzyme.

Akermin Inc., a bio technology company located in St. Louis, Missouri, USA, which is focused on developing economic "carbon management technologies" has solved the problem by encapsulating the enzymes in a unique protective polymer film that ensures extended lifetime for the enzymes in harsh industrial environments.

From test facilities in US, where they remove CO2 from flue gas on a power plant, there are good experiences with both the enzyme's ability to remove CO2, and enzyme life in the process.

Based on experience form this, Akermin will build a full-scale upgrading plant, there can handle the 3,3 – 4,2 million cubic meter biogas/year from WWTP Avedøre's digesters.

The enzymes used in the project comes from Novozymes A/S, the world leader in bioinnovation and they sells more than 700 different product I 130 countries. Well known examples are enzymes for detergents and production of second generation (2G) bio ethanol.

Although there are good experiences with the technology from the test facility, this is a development project, and without subsidies from The Danish Energy Agencies' EUDP program (Energy Technology Development and Demonstration Programme), the project would not have been started. Out of a total project on about 41 MDKK (5,5 million €) supports EUDP with 21 MDKK (2,8 million €).

In the project participates also Ammongas A/S, a Danish engineering company that supplies with upgrade facilities in both Denmark and Norway. Ammongas build the plant on Akermin's supervision. Danish Gas Technology Center, is responsible for measurements and reports on the operating results for the system and the quality of the upgraded biogas.

The project is well in goal when we have demonstrated that the enzyme improved upgrading reduces costs and makes it cheaper to send biogas into the natural gas grid. All things being equal, this will increase the flow of green gasses to the natural gas grid, which is in line with HMN' strategy for the future.

July 1, 2015 the biogas will be sent through the system and into the natural gas grid. The demonstration project will run until April 2017, and then will come a long period with commercial operation.

Power- to-gas via Biological Catalysis

Carbon Dioxide cleaned out of the biogas is routed into the "neighboring-project," where Electrochaea, along with a number of project participants, will demonstrate a full-scale Methanation unit. Based on experience form the test facility at the University of Aarhus (Foulom), this phase 2 study, will be supplied with Hydrogen from the electrolysis plant, delivered by Hydrogenics Europe NV. The Electrolyser have a capacity on 1 MW.

The hydrogen from the electrolyser is mixed with CO2 from biogas and sent trough the methanation unit, which contains archaea microorganism. The archaea microorganisms has its origin in the Icelandic volcanoes, where it converts hydrogen and CO2 to methane. The process can be regulated, because lack of hydrogen and carbon dioxide, will ransmit the microorganism in a sleep mode, which ceases when the supply of hydrogen and carbon dioxide are resumed.

The electrolysis is dependent on low power costs, and a part of the project is to find times with plenty of power and therefore low prices, either on normal conditions or by providing regulating power services. Methane from this system can be stored in natural gas system, and hence the desire for system integration is achieved.

Oxygen from the electrolyser will be fed into WWTP Avedøre's purifying Aeration tanks, and will hereby contribute to the purification of wastewater.

Electrochaea's process works whether supplied with untreated biogas or here carbon dioxide from the upgrader. The project will demonstrate various combinations of mixtures between biogas and carbon dioxide.

The project is supported with 27 MDKK (3,6 million €)from Energinet.dk's research funds "FORSK EL."

Grid Injection Facility

After upgrading, the purified gas is sent into natural gas grid. First step is the grid operators (HMN Naturgas I/S) Injection Station. In the Injection Station, the is the gas quality measured and weighed. Acceptance criteria are shown in fig. 3 & 4, where the key criteria is the wobbe index, according to a methane content above 97,3 % (97,8 incl. measurement uncertainty) and sulphur content, water content and temperature (due to gaspipes).

In the inlet at the Injection Station is a gas chromatograph which analyses the gas composition. Analysis results are used initially to approve the gas to send into the gas grid, or reject if it's not on spec. Results are also stored and saved, as evidence of gas quality delivered.

The upgrading system must be designed so it can receive refused gas and give it a second treatment. Normally, such an additional step gives capacity challenges, so it's normal to burn rejected gas in a flare .If gas is rejected because to high oxygen content, extra treatment is not an option, and the flare is only possibility.

At WWTP Avedøre is both a gas storage facility, with a capacity for 6 – 8 hours gas production, as well as a gas engine, which alternatively can “convert” gas to power. Here we can do more with the rejected gas, before it comes necessary to flare it.

The Injection Station at WWTP Avedøre is double line in, and single line out. With 2 lines, with its own gas chromatograph, makes it possible to measure quality separately, thus reject separately. If we got the approval from authorities, will the one line out give us a possibility to blend the gasses, if one stream is below acceptance criteria.

The Injection station is also equipped for gas pressure regulation and addition of odorant.

From the Injection Station, the gas is send to the nearest M/R-Station (Measuring- and Regulation Station). The M/R-Stations task is to down regulate gas pressure distribution network (19 bar design) to the distribution network with 4 bar design pressure. The gas from the Injection Station must have a pressure so high that it can overcome the pressure drop in the gas pipes, and have a little pressure in reserve to regulate with the M/R-Station (typically + 0,5 – 1,0 bar over design pressure).

Is the overall delivery from the upgrader, on hourly basis, over delivery from the M/R-Station, must there be arrangement so the biogas can be delivered I the same period. Installing a gas compressor, there can press the up to the higher pressure level is a possibility, but the economy must be balanced. The fewer hours, the more we must look at alternatives. Is it possible to regulate biogas production? Can we use the gas in a gas engine? Are there any other alternatives?

In this project, the offtake to distribution grid so high, that we, in combination with new costumers can deliver all gas production from WWTP Avedøre at 4 bar.

Acceptance criteria in DK (not comprehensive)	
Wobbe index	50,8 – 55,8 MJ/Nm3
Relative density	< 0,7
H2S	< 5 mg/Nm3
Total Sulphur	< 30 mg/Nm3
Oxygen	< 0,5 %
Carbon Dioxide	< 3,0 %
Siloxanes	< 1 mg/Nm3
Temperature	< 20 ° C.

figure 3; acceptance criteria at gas grid.

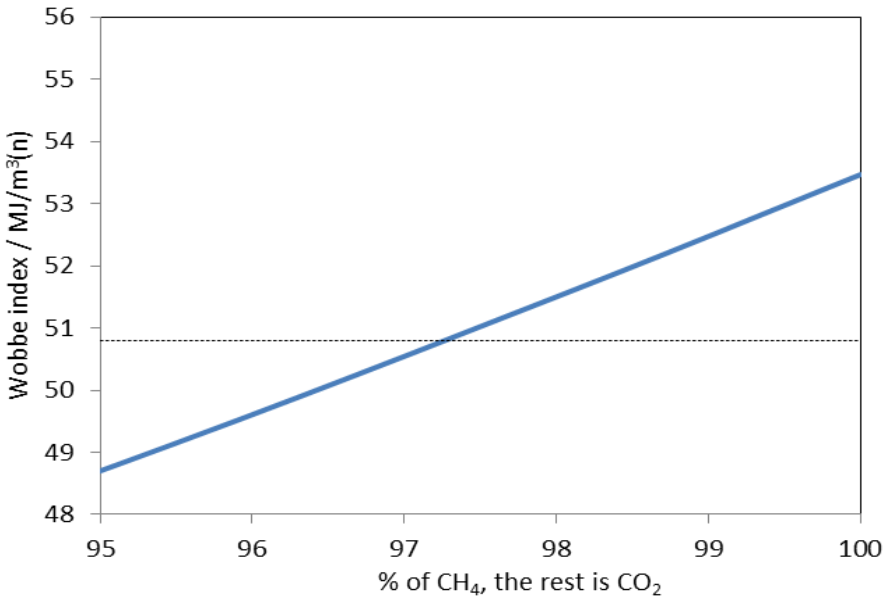

figure 4; wobbeindex converted to methane content.

Further information

At the projects homepage; www.enzup.com you will find more information, and you can follow the projects progress.

Visit also Power to gas' homepage; www.biocat-project.com

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