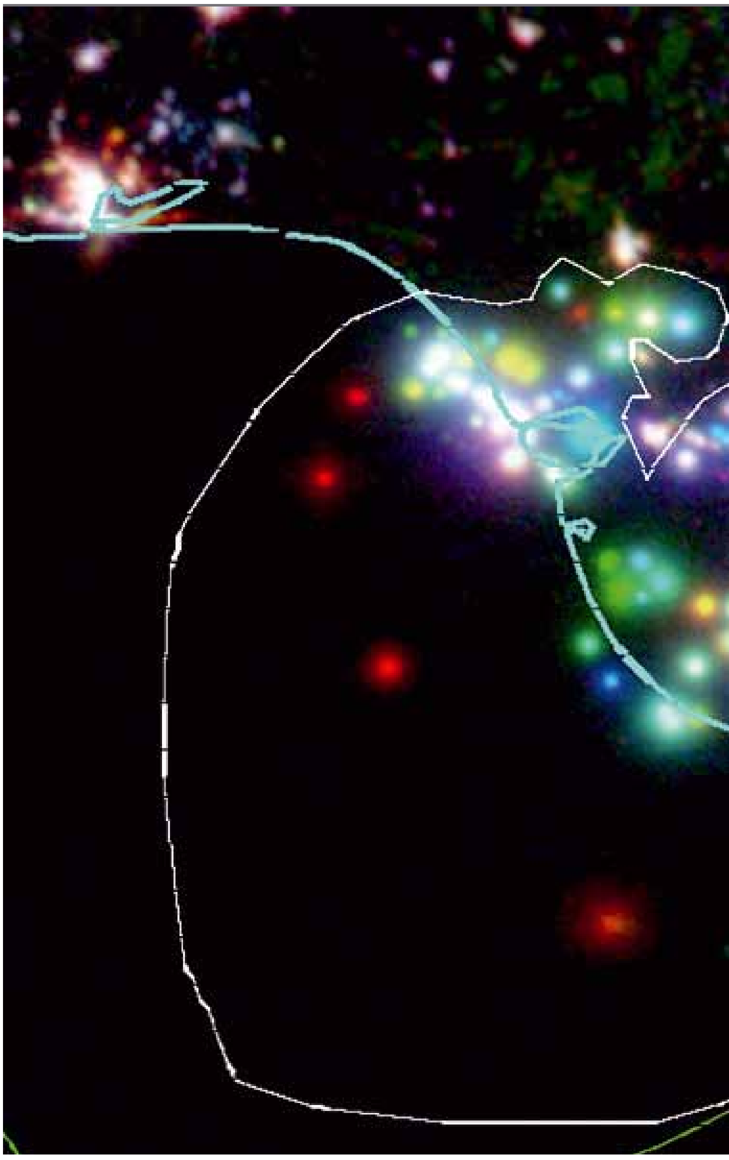
OIL PRODUCTION

Putting an End to Wasteful Gas Flaring

The amount of gas flared over oilfields per year is equivalent to the consumption of Germany and France combined. The British company CompactGTL has developed a technology that turns this gas into a valuable asset. Bayer Technology Services was an important partner.

Some 150 billion cubic meters of natural gas are uselessly flared in oil production every year – more than a quarter of this amount in offshore production.



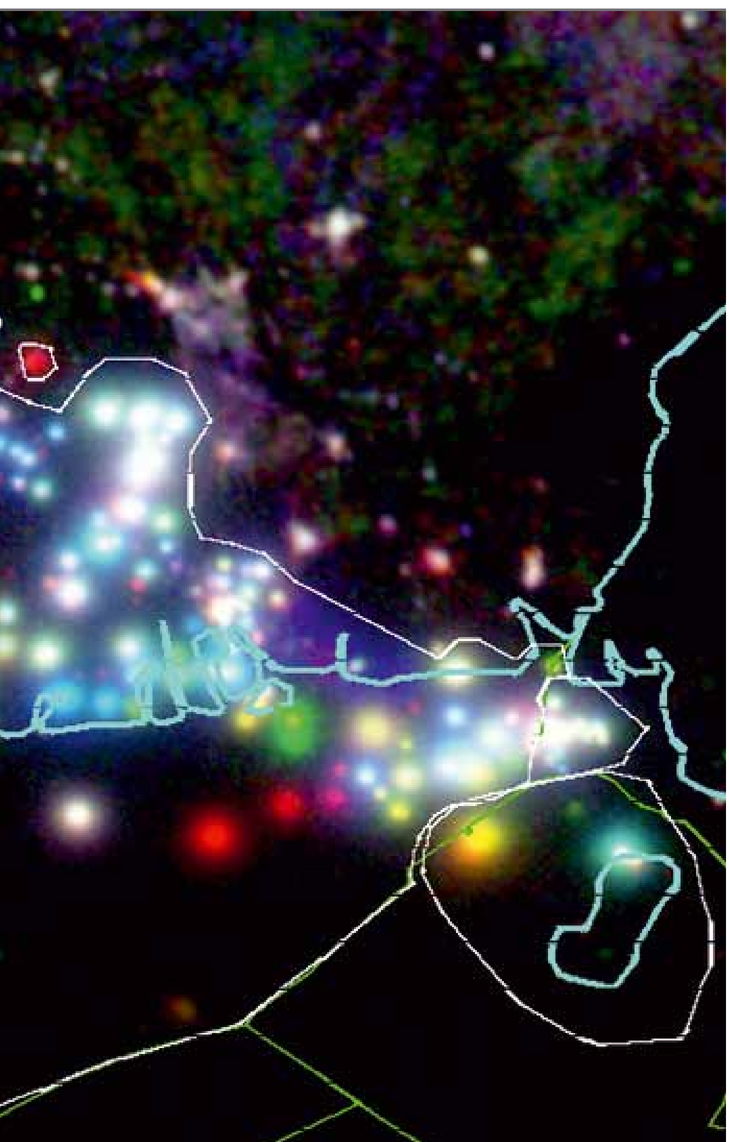
We have all seen the satellite images of the earth at night showing the brightly lit urban centers of human civilization. Other satellite images, however, reveal something quite different: mysterious light sources on the high seas. These illuminated spots are actually burning gas flares. The Gulf of Guinea in West Africa is one region where many such blazing fires can be seen.

The fires are fuelled by gas escaping from the surface during oil extraction. In terms of its chemical composition, this is, in fact, natural gas. However, since it has never been possible until now to utilize this natural resource cost effectively, the gas has simply been flared. Over the oilfields of Nigeria alone, many of which are located in the Gulf of Guinea, more than 20 billion cubic meters of this valuable raw material are lost every year. At the same time, the greenhouse gas carbon dioxide is emitted during the combustion process.

A few years ago the World Bank calculated that 512 billion cubic meters of associated gas are released from the surface of oil-well boreholes around the world. If you would collect this amount in a hollow cube, it would cover a ground surface eight times eight kilometers and would tower eight kilometers into air. This amount of gas would almost be enough to meet the entire natural gas needs of the United States.

However, instead of producing heat, electricity or chemicals from this associated gas, most of it is re-injected back into the ground. And the rest – nearly one third – is flared. Some 150 billion cubic meters are thus burned off. This is nearly 25 percent of the total U.S. consumption – and enough to cover the natural gas requirements of Germany and France combined.

The reasons for this are manifold. Firstly, many oilfields are so remote that building gas pipelines is not worthwhile. Processing to liquefied natural gas (LNG) is very rarely practicable, as it requires a certain degree of infrastructure. "Especially in the case of offshore production this is difficult to install," says Dr. Wulf Dietrich. The German chemical engineer works in Process Technology at Bayer Technology Services. Since 2009 he has headed the Bayer side of a project focused on supporting the development of a technology that turns associated gas into an economic asset – even at remote sites. The customer is CompactGTL, a British company that is targeting remote and deepwater oilfield locations with this technology. This includes the Floating, Production, Storage and Offloading units (FPSOs), which are becoming more and more popular. These floating vessels produce oil and gas by extracting it from seabed reservoirs, processing it in facilities on board and storing



The Geophysical Data Center in the United States has made offshore gas flares visible in colorful satellite images. Here are views of the southeast coast of Brazil (top left) and the coast of Nigeria (below left). The respective colors stand for the year of the photograph; the coastline is shown in cyan blue.

it in tanks in the hull. The resulting crude oil is then regularly offloaded onto tankers.

The GTL in CompactGTL stands for “gas to liquid”, the process of converting gas to a liquefied hydrocarbon product. Unlike physical liquefaction (for example to LNG) with the appropriate high pressure, however, GTL involves a chemical conversion in which liquid hydrocarbon compounds are formed from gaseous components. These compounds stay liquefied even under normal atmospheric pressure. Actually, the chemistry is not new. More than 80 years ago, German chemists developed Fischer-Tropsch synthesis. At the time, the aim was to obtain liquid hydrocarbons from coal gas, which could serve, for example, as fuel.

“The whole thing is a two-step process,” says Dietrich. “In the first step the previously purified gas is converted with steam to carbon monoxide and hydrogen. This mixture, also called syngas, reacts in a second step, the actual Fischer-Tropsch synthesis, to form liquid hydrocarbons.” For a long time, this technology was primarily used in South Africa, which had no oil deposits, but an abundance of coal.

Even though the underlying chemistry is old and established, it cannot simply be carried over to offshore application. “Conventional GTL reactors weigh some 2,500 tons,” says Dietrich. “Also, they are quite tall with high centers of gravity, thus making offshore application a particular challenge,” Dr. Ross Morgan, General Manager Technology Development at CompactGTL, adds. Additionally, there are many other aspects that must be taken into consideration for an offshore solution. “Several existing GTL technologies also require a pure oxygen supply for syngas generation,” says Morgan. “This clearly poses a significant safety challenge for the offshore environment.”

According to Morgan, conventional GTL processes do not have high turndown capabilities either. Over the lifetime of an oilfield, the production curve declines and so does the gas supply. And there is another issue that makes conventional processes difficult for offshore application. “The catalyst in the reactor has to be replaced from time to time, and so the whole facility would need to be returned to an onshore base for this procedure,” Morgan explains.

As a consequence, a lot of development work was necessary to adapt the GTL process to offshore application. The experts at CompactGTL quickly agreed on the general principle: instead of one large reactor vessel, the reactors would be based on a modular approach by which the reactions take place in an

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Dr. Wulf Dietrich, Bayer Technology Services

No Oil Without Natural Gas

What is associated gas?
Associated gas escapes during oil extraction as soon as the oil reaches the earth's surface and the pressure subsides. Its composition is similar to that of natural gas. The gas content differs depending on the oilfield location.

How much associated gas is there?
According to an estimate of the World Bank from 2008, some **512 billion cubic meters** of associated gas are released from oilfields every year. Some 28 percent of this amount stems from offshore extraction. It is estimated that 365 billion cubic meters are re-injected back into the ground, and **147 billion cubic meters** are flared. In the process, nearly 300 million tons of carbon dioxide are emitted into the atmosphere, which represents about one percent of global CO_2 emissions.

What can be done with this associated gas?
If it were possible either to transport the 147 billion cubic meters as gas or to convert it into liquefied syncrude (see main article), the potential would be enormous. For comparison, see the gas consumption of some countries in 2009 (Source: U.S. Energy Information Administration):

1. USA	646 billion m^3
2. Russian Federation	439 billion m^3
3. Iran	132 billion m^3
4. Japan	100 billion m^3
5. Germany	93 billion m^3
13. France	49 billion m^3

array of small, closely spaced mini-channels through which the gases flow. The modular system allows the reactor to react flexibly to gas flowrate fluctuations because the number of parallel modules can always be regulated. In addition, individual modules can easily be removed while the facility is in operation, for example, if they have to be equipped with a new catalyst.

A key part of the subsequent development was then to optimize the reactor module designs to provide the required stability and performance, but also taking into account the available and proven manufacturing processes. This included reactor channel dimensions, gas velocities and catalyst structure and activity. The space between each channel is also important because it influences how efficiently the heat fed into or released from the system can be exchanged.

The heat exchange, in general, is an important factor in the design of GTL technology. While the process in the first reactor only gets started at a temperature of more than 600° Celsius, the Fischer-Tropsch process in the second reactor releases a significant amount of heat. "In other words, heat has to be added to the first reactor, while the second has to be cooled," says Wulf Dietrich. "The challenge was how to best balance all of these requirements."

To clarify these questions, CompactGTL identified the need to model the reactor designs, the processes occurring and the heat transfer. For this they required additional expertise. Their search led them to the website of Bayer Technology Services, where the English team found the email address of Professor Leslaw Mleczko. So, one day the Head of Reaction Engineering & Catalysis at Bayer Technology Services discovered an email inquiry by a Iain Baxter from CompactGTL in his electronic inbox. He was also the one, together with Dr. Stephan Schubert from his team, to participate in initial discussions with CompactGTL.

Under the initial project management of Schubert, the expertise of Bayer Technology Services in reactor modeling was initially the main project focus. But subsequent projects were quick to follow. Soon CompactGTL sent the catalysts specially developed for this project to Leverkusen for testing as well. Ultimately, the German partners were also commissioned to carry out process simulations and equipment calculations. During peak periods, the Bayer team grew to 15 staff members. Wulf Dietrich took over the project management in 2009.

Partly based on the results of this work, CompactGTL commissioned a pilot plant facility at Wilton, Teesside in northern

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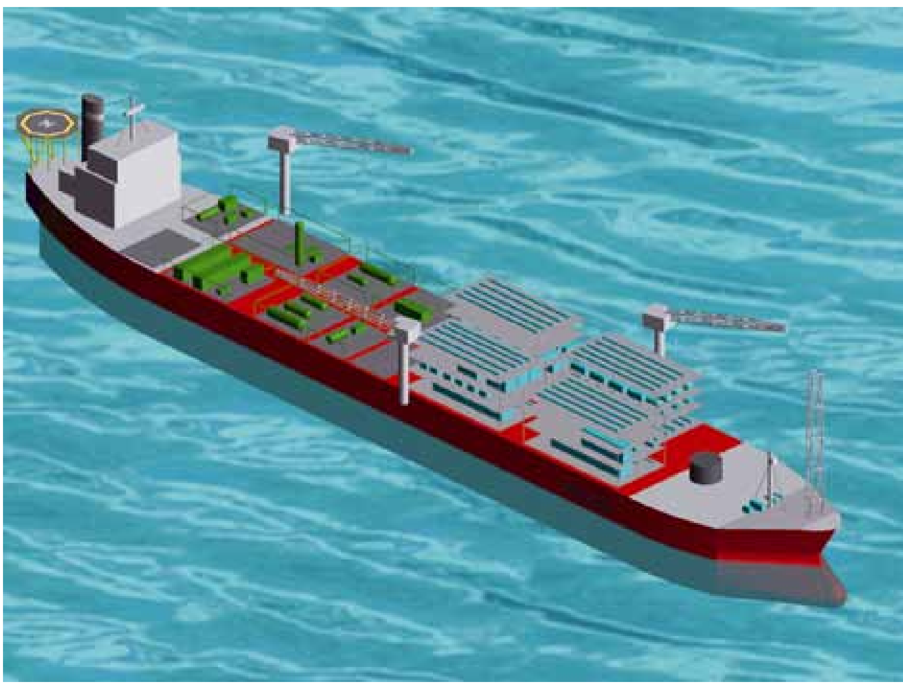

This is how a FPSO vessel with a CompactGTL facility will look one day (above left). Above right the first pilot plant in England.

England in 2008. "This test facility runs 24 hours a day and has been in operation for over two years," says Iain Baxter, now Business Development Director. From the beginning, the British company had a first prospective customer for their technology: the Brazilian oil company Petrobras. A few years ago, when the government-backed company discovered probably one of largest oilfields found in recent decades off the coast of Brazil, the question of a viable use of associated gas became particularly urgent.

A commercial demonstration plant with a capacity of almost 5,700 cubic meters per day was commissioned by Petrobras in December 2010. "The use of models developed by Bayer Technology Services in combination with results from lab tests in Leverkusen, and our pilot plant at Wilton has contributed to the successful design and operation of the plant and reactors," says Ross Morgan. Everything has been running well so far. The General Manager of Technology Development at CompactGTL also acknowledges the good cooperation with Bayer Technology Services: "The breadth and depth of knowledge, experience and expertise at Bayer Technology Services has been a great benefit in helping us to overcome several technical challenges."

The commercial demonstration plant in Brazil is now running and under test producing up to 20 barrels per day of synthetic crude oil, or "syncrude." This is the term used for the mixture of hydrocarbons produced by Fischer-Tropsch synthesis. Since the components of this syncrude are also contained in natural crude oil, syncrude can easily be mixed with the extracted oil. This is especially practical in offshore applications. The process thus eradicates the need for continuous flaring or the potentially damaging and costly injection of the gas into the reservoir. It also eliminates the need for separate product storage, transportation and marketing arrangements as required for other possible solutions.

"CompactGTL has ensured the commercial validity of the technology through collaboration with Bayer Technology Services and other independent strategic partners; establishing a supply chain to deliver commercial scale plants to meet client demand," Iain Baxter says. And one thing is certain. This unit will not be visible on any nighttime satellite images.