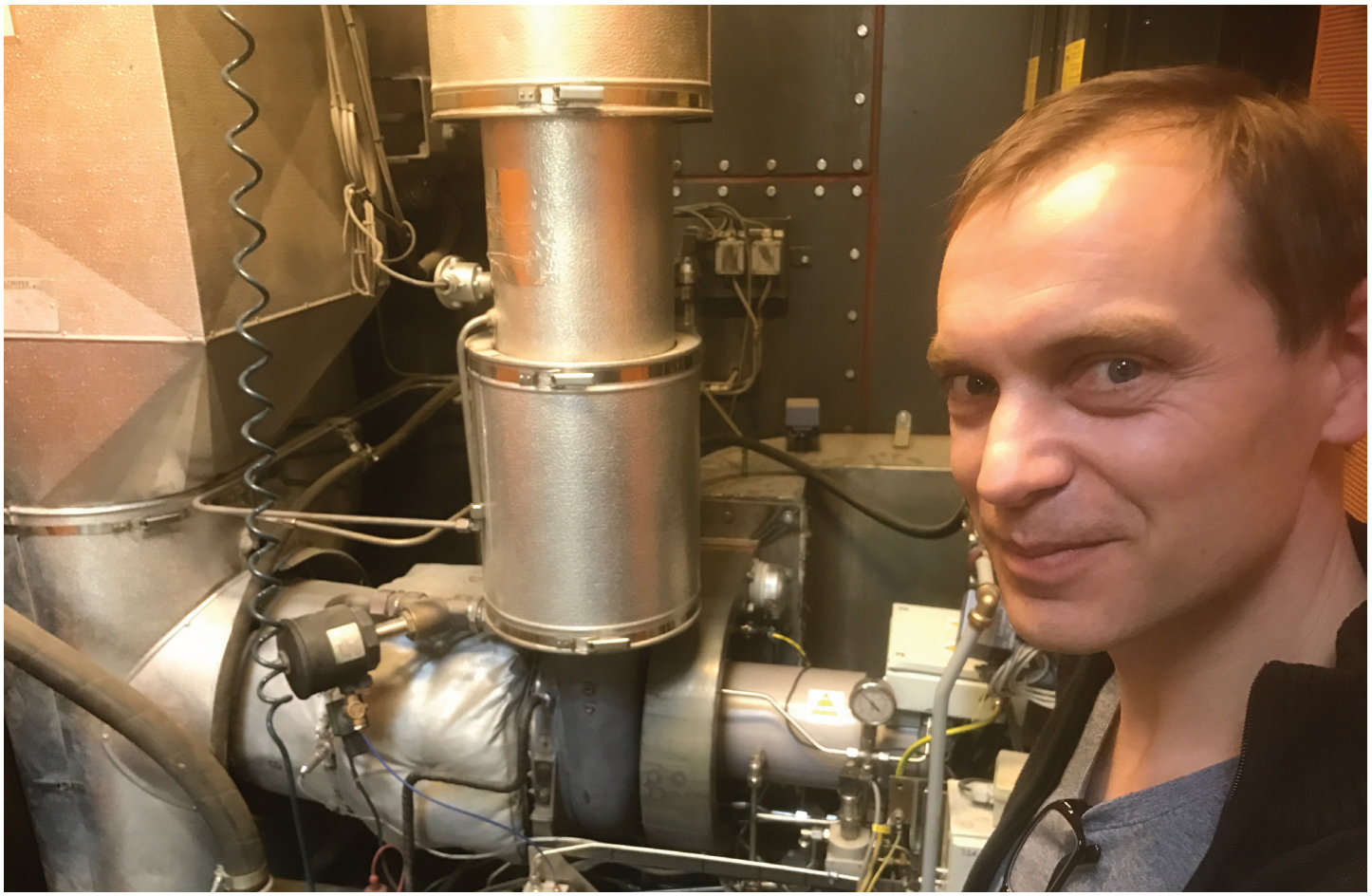
A TURBINE THAT OFFERS MORE THAN JUST HOT AIR

From fireplaces to large heating plants – wood has always been used to generate heat. In addition to heat production, wood can also be used to produce electricity. Hot air turbines use heated air from a furnace that is fed via a turbine and converted into electricity by the connected generator. The considerable residual heat is then used to produce hot water. The new technology is suitable for use in central locations of district heating networks – or in industrial and service operations that are focused on self-sufficiency of heat and electricity.



Dietrich Vogel, head of the hot-air turbine project at Schmid AG, in front of the hot-air turbine installed by Schmid AG at company headquarters in Eschlikon. Photo: B. Vogel

Technical report about the findings of a flagship project in the area of bioenergy, financed by the SFOE. The report has been published, among other places, in the magazine Erneuerbare Energien (issue June 2017).

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At first glance, the district heating network in Düdingen in the canton of Freiburg looks like any of the other hundreds of heating networks in Switzerland: In the autumn of 2015, a new district heating network started operating in the city with its 8,000 inhabitants. Since then the municipal buildings and some 180 households have been connected. In the final phase, there will be 400 households. Celsius Groupe E is the operator of the heating network. "Our company attaches great importance to innovative solutions for heat production," says Olivier David, who was responsible for the construction of the new energy center as project manager.

The energy center of the Düdingen heating network has a wood burner that produces not only heat but also electricity. Unique is the hot-air turbine technology used to generate power. In this case, the turbine and the connected generator are not driven by hot combustion gas generated in a combustion chamber, as is customary in aircraft and other gas turbines, but rather by air heated at high temperatures in the furnace and via the exhaust-air heat exchanger.

Wood Heaters Produce Electricity

To speak to the inventor of this innovation, one must travel from Düdingen through Switzerland to Eschlikon in Thurgau. There sits the headquarters of Schmid AG— a family-owned company founded in 1936, which specializes in constructing medium and large wood-fired boilers (180 to 6500 kW heat output) for heating networks, industrial and service operations. In the Schmid AG plant in Eschlikon, there are enormous steel cubes from which wood-burning furnaces of the most modern generation are produced. At the heart of these furnaces are combustion chambers with feed grate firing. This technology, which has been optimized by Schmid over decades, guarantees an optimum energy yield with efficiency levels of 92% and more.

Schmid has been producing wood-furnaces for generations. A still relatively young activity area of the Thurgauer company's industrial operations are combined heat and electricty plants—wood-fired boilers that are altered in such a way that they heat and, partly as a byproduct, produce electricity as well. Schmid has been using carburator technology and ORC turbines in these plants. The latter work like steam turbines, but use an organic liquid instead of steam. With the hot-air turbine, the plant in Düdingen is now taking a new, third step: "We have been developing the technology for years,"

The heat-to-power cogeneration system with hot-air turbine in the central energy station of the district heating network of Düdingen. Photo: Schmid AG

says Philipp Lüscher, CEO of Schmid AG. "Compared to the ORC technology, the hot-air turbine has the advantage that it operates with a lower-risk operating medium, namely air instead of organic thermal oils. The medium hot air allows a simpler system technology and thus reduces the maintenance costs. And in contrast to carburator technology, the hot-air turbine runs not only with high-quality wood fuel, but also with inexpensive wood, which reduces the operating costs."

Designed for Economical Wood Fuels

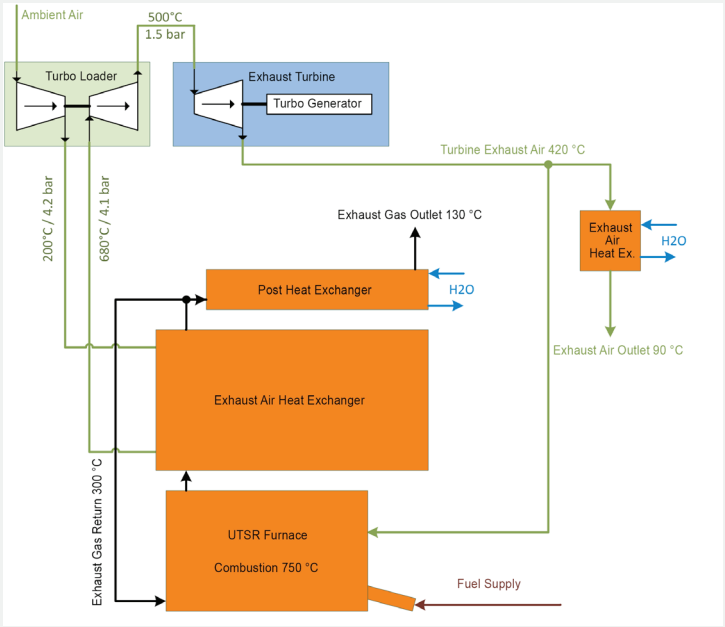
The development of the hot-air turbine goes back almost ten years. On the basis of preliminary work by an English engineer and the Ökozentrum in Langenbruck, a prototype was first built. Later in Düdingen, the first customer base was established, which was supported by the Swiss Federal Office of Energy as part of its flagship program. The hot-air turbine

has now reached the production stage. "The biggest challenge during development was communication between the main components," says Dietrich Vogel, graduate process engineer, who served at as project leader at Schmid AG and was responsible for development. "The actual innovation of the cogeneration system lies not in its components but in their interplay."

From the very beginning, the system was designed for fully automatic long-term operation with low-cost fuel. Although it can also be fed with well-dried woodchips, the plant also runs with inferior and often also damp wood types such as forest floor litterfall, bark, tree cuttings or waste from the wood industry. "Fuels with a humidity of up to 55% master our facility without problems. This reduces the fuel costs

HOW THE HOT AIR TURBINE FUNCTIONS

In a classic wood furnace, the heat energy from the combustion process is used to heat water via a heat exchanger. The hot water is then fed into the heating circuit or into a district heating system. At the plant in Düdingen, the 750 °C hot smoke gases from the wood furnace enter a heat exchanger. Here, the heat is not used for heating water, but rather to heat air that has already been compressed to a good 4 bar by a compressor and thereby preheated to 200 °C. When leaving the heat exchanger, the air is hot at 680 °C. In a three-stage process, the heat is converted into various energy forms: in the first step, the air is passed through a turbocharger that drives the compressor to compress ambient air. In the second step, the air – still hot at 500 °C – reaches the hot-air turbine, which produces electricity via the attached generator. In the third step, the hot air, which is now 420 °C, is fed into a heat exchanger, where – as in a conventional wood furnace system – it is used for heating purposes and for the production of hot water.



The heart of the plant is the smoke-gas-air heat exchanger. Transferring the heat of exhaust gases to air requires a relatively large area. Therefore, this heat exchanger is considerably larger than the smoke gas water heat exchanger of a conventional wood furnace. Hot air turbines have high working temperatures. In order to withstand the high temperatures, the heat exchanger is made of heat-resistant stainless steel - a major reason for the relative high cost of this heat and power cogeneration unit.

The plant has a thermal efficiency of 63% and an electrical efficiency of 13%, resulting in a total efficiency of around 76%. The values are for a biomass-powered cogeneration plant in the upper mid-range. With further optimization, this could increase to 80%. To ensure optimum heat transfer, the smoke gases are once again used in a post-heat exchanger (after leaving the smoke-gas heat exchanger) before being cleaned in the electrostatic precipitator and then released into the environment.

The hot-air turbine plant in Düdingen has a thermal output of 450 kW and supplies gaseous energy all year round. Heat production is supported by a wood heating system (2000 kWth) in winter and during the transition periods between hot and cold seasons. BV

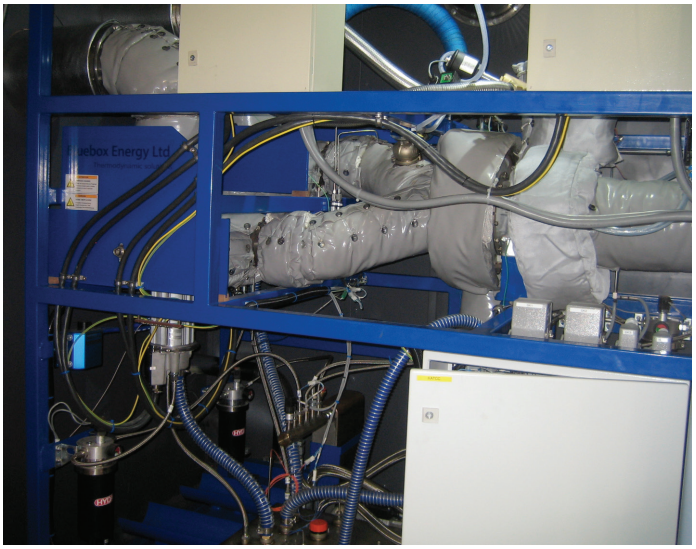
compared to a plant that runs only with high-quality wood chips, by about a good half," said Schmid project manager Dietrich Vogel. The only condition is that the wood is natural, which excludes, for example, the use of demolition wood.

Use Heat all year as Base Load

A system for the decentralized production of heat and electricity, which is operated with the indigenous, CO_2-neutral energy carrier wood – this concept corresponds very well to the requirements of current energy production. However heat and power, cogeneration systems are more expensive than conventional wood firing and are not yet competitive without subsidy measures such as compensation for energy fed into the grid. The plant is, however, interesting for example to companies that use the heat generated all year round and can also consume the electricity themselves, for example. "From a technical point of view, we have achieved the market readiness, in the future we will work to build the plant even more favorably, for example, by optimizing the exhaust gas air heat exchanger, the central component of the plant," says Philipp Lüscher.

In addition to district heating networks and industrial plants, the wood furnace with a hot-air turbine system is designed for operations with residual wood recycling, but also for large heat consumers with electricity requirements such as expanded football arenas or zoological gardens. In countries such as Austria and Italy, but also in Japan and China, the cleantech innovation of the Swiss family business is already well received.

- www.schmid-energy.ch, www.heissluftturbine.ch
- The **final report** on the project can be found at: https://www.aramis.admin.ch/Grunddaten/?ProjectID=34699
- For **further information** on the project, please contact Dr. Yasmine Calisesi (yasminie.calisesi [at] bfe.admin.ch), Cleantech Section of the SFOE
- For further **papers** on research, pilot, demonstration and flagship projects in the field of wood and other biomass, please visit www.bfe.admin.ch/CT/bioenergy.



Detailed view of the heat and power cogeneration plant in Düdingen: The turbine group with insulated supply and exhaust air pipes, bypass valves and oil cooling pipes. Photo: Schmid AG

PILOT-, DEMONSTRATION- AND FLAGSHIP PROJEKTS

The hot-air turbine of the Düdingen heat-and-power cogeneration plant is one of the flagship projects with which the Swiss Federal Office of Energy (SFOE) promotes the development of economical and rational energy technologies and supports the use of renewable energies. The prototype of the plant had previously been supported by a SFOE pilot and demonstration project. The SFOE supports pilot, demonstration and flagship projects with 40% of eligible costs. Applications can be submitted at any time.

- **Information**:
  www.bfe.admin.ch/pilotdemonstration
  www.bfe.admin.ch/leuchtturmprogramm

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