Dynamic District Heating

A technical guide for a flexible CHP plant
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In a conventional CHP plant, the operation is based on the network heat load required, with power being sold on the electrical market. A Dynamic District Heating (DDH) plant enables operations on highly volatile electricity markets, thereby providing a path towards a dynamic power market throughout the variations in the required heat load.

By combining the efficiency and flexibility of Wärtsilä ICE technology, tailor-made and optimised CHP process, a DDH plant can efficiently operate on any European electrical market – more frequently and much more efficiently than conventional CHP plants.

In future, flexibility will be required in order to integrate the growing shares of variable renewable energy sources in a cost efficient and secure manner, while adhering to environmental requirements.

Energy markets in most parts of the world have to balance distinct needs, but fluctuating demand combined with variations in the generation of renewables makes balancing very difficult.

Wärtsilä, already today, has the perfect solution for handling variability in thermal power generation. By utilising highly efficient gas engines asset owners will achieve higher economical benefits and greater value.

Engines utilised for electricity production produce excess heat. In CHP plants the excess heat from engine cooling and exhaust gases are harnessed for district heating needs. The use of engine technology featuring flexibility and efficiency, and a CHP process that is optimised for performance, results in the plant
What is a DDH plant?

By combining the efficiency and flexibility of Wärtsilä engine technology with a tailored and optimised CHP process, a DDH plant can efficiently operate on any electrical market.

Figure 1. Load variation curve of a typical 400 MW\textsubscript{th} district heating system. The network heat load varies dynamically with the ambient temperature. The heat load is high during the cold seasons of the year and reaches maximum usually in Mid-February. The heat load is correspondingly low during the warm season.

being well suited to European energy market operations.

In a DDH plant, the prime movers are Wärtsilä 34SG gas-fired, spark-ignited, internal combustion engines. The engine is based on state-of-the-art gas technology, which is under continuous development to reach higher efficiencies and improved performance.

Wärtsilä has a proven track record in the fast and successful execution of large engineering, procurement and construction (EPC) deliveries on a global scale for industrial customers, independent power producers and utilities, with power plants installed in more than 170 countries.

Wärtsilä is one of the largest providers of gas and liquid fired power plants in the world with a total installed capacity of more than 70 GW. Currently Wärtsilä operates 34 GW of generating capacity with lifecycle solutions. Wärtsilä power plants are tailored to meet customer needs, and the company offers everything from a basic equipment delivery to comprehensive turnkey EPC solution with a lifecycle solutions that guarantee operational reliability and efficiency backed up by expert advice on optimising power plant operation and maintenance. Wärtsilä power plants deliver high simple cycle efficiency, even when running on part load and in demanding ambient conditions.

In a conventional CHP plant, the operation is based on the network heat load required, with power being sold on the electrical market. A DDH plant combined with thermal storage enables operations on volatile electrical markets, providing a path towards a dynamic power market throughout the variations in required heat load. (Figure 1)

Operation modes

A multi-unit Wärtsilä DDH plant with gas-fired engines produces more heat than, for example, a CCGT plant with the same capacity. This is because its wide load range, different operating modes, and short start-up and ramping time (a Wärtsilä 34SG power plant requires only 30 seconds to complete start-up preparations, speed acceleration, and synchronisation to the grid) enables it to operate throughout the year, whenever electricity prices allow profitable running. It also produces proportionally more electricity since it covers a bigger share of the total heat demand.

A DDH plant is capable of adapting to various operational modes, thereby ensuring the most feasible operational strategy and electricity production that is highly efficient. It also ensures that the heat demand is met (heat mode).

Because of these dynamic features and different operating modes, the DDH plant can operate in any of the various electrical markets, including day-ahead, intraday, and secondary control markets.

Electricity mode

When the price of electricity allows a positive profit margin, the DDH plant can be operated in electrical power mode. The heat produced will either be fed to the DH network or to heat storage. If the DH heat demand is being met by other plants, the Wärtsilä DDH plant can then reduce
its heat production, or even operate in electrical only mode.

**Heat mode**
In cases where the heat production from, for example, waste incineration is not sufficient to cover the heat demand, and the thermal storage has already been discharged, the residual heat demand can be met by the DDH plant operating in heat mode. In this operating mode, by reducing its electrical power output, the DDH plant can also be used to balance the DH network heat demand.

**Temperature control**
The DH water temperature is based on outside ambient temperatures. The system’s design is network specific, feeding hot or warm water to consumers and receiving colder water in return. Wärtsilä DDH plants ensure that the temperature control is optimised so as to meet local DH network temperatures, ambient conditions, and other requirements.

**Plant configuration**
A Wärtsilä DDH power plant is a multi-unit CHP plant that includes engines, boilers and pump modules. Existing Wärtsilä DDH plants are already in operation in many countries, including Denmark, Hungary and Italy. Hungarian DDH plants operate in the ancillary markets.

DDH plants are capable of high efficiency and flexible operation over a broad range of plant loads, and are thus able to respond to the demand for heat, and to fluctuations in the price of electricity. This flexibility can be further enhanced with thermal storage of the produced heat.

The size of the DDH plant should comply to the annual heat load of the network and the size of the thermal storage in order to achieve optimal utilisation of the plant. With a multi-unit configuration, the plant size can be modified for optimisation.

The DDH power plant includes engines as the prime movers and main sources for heat. The waste heat generated by the engines is recovered in the engines’ cooling water circuit and in the exhaust gas boilers. In addition to hot water for district heating purposes, waste heat can also be recovered in the exhaust gas boiler as steam for heating purposes. (Figure 2)
The engines

Different alternatives

Wärtsilä offers many different engines but the Wärtsilä 34SG model is the most suitable for DDH plants. The SG engine is a spark-ignited lean-burn otto cycle gas engine which can be configured with distinct NOx (nitrogen oxides) ratings, fuel gas methane numbers, and a range of lube oil and jacket water temperatures. Each selection has an impact on both the electrical and heat performance, as well as on the efficiency of the plant.

Impact of the methane number

A fuel’s methane number describes how well the fuel will burn in the cylinders. Hydrogen, which burns quickly relative to methane, has a low resistance to knocking, giving it a methane number of “0”. Methane, which has high knock resistance, has the number “100.” Other fuels lie elsewhere on this scale.

The fuel gas methane number impacts both electrical efficiency and the engine’s output, but the methane number sensitivity differs according to the engine tunings. Wärtsilä offers the most beneficial engine tuning to match the quality of the available fuel gas. Depending on the tuning of the engine, the de-rating point varies between the fuel gas methane numbers of 60 and 80. The indicative methane number range relative to five European countries is shown in Figure 3.

Lubricating oil temperature

It is important to use the correct temperature of lubricating oil in order to fully utilise its inherent heat. Generally, raising the lubricating oil temperature enables considerably more heat to be recovered from it. Additionally, raising the temperature of the lubricating oil will slightly boost electrical efficiency.

Jacket temperature

Engine cylinder cooling (jacket cooling) is utilised in DDH plants to boost the efficiency of the heat recovery. Higher efficiency is achieved by increasing the engine jacket temperature in order to ensure high heat recovery from the engine jacket’s cooling circuit.
HTCAC heat recovery directly with DH water
In order to increase heat recovery performance and to simplify the process, the DH water can be circulated directly through the HTCAC. In conventional systems, the DH water and water circulating in the HTCAC are separated by a heat exchanger.

Boiler and economiser
Boiler types
There are two different types of boiler available; water tube boilers and smoke tube boilers. A smoke tube boiler is one in which hot exhaust gas from the engine passes through tubes running within a sealed container of water. In water tube boilers, water circulates in tubes heated externally by hot exhaust gas from the engine.

Water tube boilers are generally more compact than smoke tube boilers with the same capacity. The boiler packages can be divided into high and low temperature sections; namely the boiler and economiser, respectively.

Boiler pinch points
The pinch point temperature between the exhaust gas and the water impacts heat recovery output and efficiency. Lower pinch temperatures require more heat transfer areas, which adds to the cost of the boiler. However, as heat recovery output is increased with lower pinch temperatures, the heat production cost (€/MWh) is often correspondingly lower. Wärtsilä selects the pinch point based on its technology and knowledge of the markets so as to achieve an optimal CAPEX and performance ratio.

Fouling rate and cleaning
All exhaust gas boilers require occasional cleaning of the heat transfer surfaces in order to compensate for fouling. By observing over a period of time the increase in the exhaust gas temperature downstream of the boiler, the need for cleaning can be determined. Fouling is more prevalent in a smoke tube boiler than in a water tube boiler, thus necessitating more frequent maintenance stops.

In general, the average downtime for cleaning is longer for smoke tube boilers than for water tube boilers. Taking into account the higher fouling rate in a smoke tube boiler, the increased number of maintenance stops will create additional losses for plants utilising smoke tube boilers. Water tube boilers are, therefore, recommended as they minimise fouling and the time needed for cleaning.

Thermal storage
Due to volatility in electricity prices, power generated during peak hours is typically more profitable than power generated during the night. In a DDH plant, the generated thermal energy can be stored in thermal storage tanks, also known as heat storage tanks, in order to decouple heat production from electricity production.

With a Wärtsilä DDH power plant and thermal storage, the variations in power prices and heat demand can be utilised to maximise the value of the heat and power generation. This is achieved by operating the engines during these peak hours and feeding the heat produced into the district heating network or to the thermal storage tank. With a thermal storage tank tightly integrated into the Wärtsilä DDH power plant, the benefits can be utilised completely. Such benefits include:

- The heat output from the engine and thermal storage will substitute other investments in heat generating capacity
- The power plant’s power output will be at maximum load during periods when the power price is high
- The engine/accumulator will decrease the operation of heat only boilers
- Eventually the value of the generated power may be boosted by selling the capacity on the balancing market

Flue gas emissions
Wärtsilä can deliver the instruments and equipment needed for measuring and monitoring the substance concentrations and properties of the flue gas, as required by German law. Wärtsilä DDH plants comply with German authority legislation and use proven technology to fulfil all such requirements.

Wärtsilä offers different NOx tuning engine alternatives. The various NOx tuning alternatives have different impacts on engine output and efficiency. A general rule is that the higher the NOx-tuning, the higher the electrical efficiency.

The Industrial Emissions Directive (IED) requires a NOx maximum of 36 ppm. With an engine NOx tuning above 36 ppm, Wärtsilä offers additional fuel gas cleaning equipment in order to meet the IED requirements. Higher NOx tuning of engines means that both CAPEX and OPEX costs are higher, as an emission control system is required in order to comply with the flue gas emission limits.

Depending on the market price of electricity, a higher NOx tuning can still be beneficial since a higher NOx tuning will give greater electrical efficiency from the engine.

Noise
Noise legislation and guarantees
A power plant must meet country-specific legislative noise limitations and requirements. The emission limit for all noise sources at a German industrial site is 70 dB(A). Wärtsilä complies with these limits. If the plant is close to a residential area, Wärtsilä can guarantee even lower noise values at the closest receptor.

With full scope power plant projects Wärtsilä can again ensure that all the noise limitations for the plant are fulfilled. For EEQ projects, Wärtsilä guarantees the values (sound power level or surface averaged sound pressure level) for the delivered equipment.
Wärtsilä technology provides accurate measured and predicted noise levels at distances between 100 and 500 m, to within +3 dB(A) of uncertainty, as specified by ISO 9613. In other words, the results are very reliable.

**Power plant design from the point of view of noise**

Wärtsilä’s modularised solutions and advanced engineering skills ensure compliance with the stringent German noise requirements. Among these solutions are:

- Concrete sandwich panels, concrete walls, or double sandwich panel walls for attenuation of engine body noise emissions.
- Individual engine cells
- Extra silencers for the attenuation of noise from the ventilation equipment, intake air inlets and exhaust gas outlets
- Once through cooling (sea or river water) engine cooling is preferred as a means of noise control.
- Ultra low noise radiators with fan specific silencers and sound baffles around the radiators attenuate noise inflicted by radiator fans
- Reactive and dissipative silencers for the attenuation of exhaust gas noise inside the engine hall and in the exhaust gas stack.

**Process**

Wärtsilä has a number of global CHP reference projects. By optimising the process and equipment configuration for each project, Wärtsilä always ensures optimal heat recovery, regardless of the DH temperatures. To reach full flexibility, engine backup cooling of the HT water is needed to enable the plant to be capable of running in electrical only mode. (Figures 4 and 5)

**Process systems**

**Ventilation**

The temperature of the intake air to the engine should be above -20°C. To ensure the function of the engines, the intake air can be heated. Higher

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**Figure 4. Typical total plant efficiency as a function of the DH supply and return temperature.**

**Figure 5. Indicative plant efficiency as a function of investment cost.**

High efficiencies are achievable, but have an impact on CAPEX.
intake air temperatures are also beneficial from a performance point of view, giving a significant increase in plant efficiency.

The temperature of the low temperature (LT) water is insufficient to allow the water to be utilised for heat recovery. However, the LT water can be used for heating the intake air. As a positive effect of this, the engine turbo acts as a heat pump and transfers heat from the LT water to the HT water through the engine charge air cooler, which can then be utilised for district heating. The COP value for this process reaches about 1.3, which means that the HR circuit gains 1.3 times the LT heat dissipated to the pre-heating of the charge air. A further benefit of utilising excess engine LT water heat is that the heat dissipation required in the radiators is reduced, thus minimising heat losses.

Thermostatic valves
There are several types of thermostatic valve. One major difference between the valve types is the amount of water leakage, i.e. how tight and exact the valves are in their control. By selecting the correct valves, the thermal performance is improved significantly.

Layout
Wärtsilä’s extensive experience from thousands of power plant projects provides the basis for the company’s modularised and optimised plant layouts. The power house and plant layouts are designed to ensure all noise, fire protection, and maintenance requirements are fulfilled. In DDH plants, the power house has two floors, with the generating set and auxiliaries on the first floor, and the ventilation, exhaust gas heat recovery, and emission reduction equipment on the second floor. (Figure 6)

Services
Wärtsilä’s lifecycle solutions for the energy industry provide guaranteed operational reliability and efficiency, backed up by expert advice on optimising power plant operation and maintenance. Guidance on equipment performance and operations surveillance ensure the continued performance and maximised uptime of the power plant. By partnering with Wärtsilä, power plant owners can feel secure, knowing where to get help and support when needed.

Solutions can be customised to suit the power plant’s operating profile and answer the power plant owner’s and operator’s needs in the most efficient way.

Operations and maintenance
Enter into a partnership where we agree on and work towards shared
productivity goals. The solution covers every aspect of the day-to-day operation of your power plant(s) as well as all related maintenance and administration tasks. An Operation and maintenance agreement helps to maximise the productive lifetime of your power plant and your return on investment, and the solution is tailored to your specific needs – including performance and lifecycle cost guarantees.

Guaranteed asset performance
Ensure the reliability and availability of your power plant. With our solution, you can manage operations and outsource the maintenance and its management to us. An onsite support engineer, online data and remote operational support enable advanced support and immediate response from our experts to ensure reliable operation of your power plant.

Optimised maintenance
Make sure that your investment is secure and predictable. An Optimised maintenance agreement transfers the responsibility for maintenance of your power plant to Wärtsilä. The solution covers maintenance planning and services whenever needed, with fixed prices for inspection, remote operational support, spare parts, training and maintenance.

Project execution
Wärtsilä has a proven track of around 1000 EPC and EEQ projects in more than 100 countries globally. Wärtsilä meets customer needs and requirements by customising every project. Wärtsilä is capable of handling everything from fast track EEQ projects to full scope EPC projects.

With experienced and certified project execution personnel, Wärtsilä understands the requirements for power plant execution projects and is fully able to handle and manage the complete range of contracting arrangements.

A DDH in facts and figures
- Multi-unit power plant sizes from 4.5 to 500+ MW → investment according to need, with the possibility to increase in stages.
- 90% total efficiency at any plant load
- High yet flexible power to heat ratio, thanks to being able to decouple electricity and heat production
- Non-spinning (no fuel consumption and no emissions) secondary frequency control → Synchronisation within 30 s → Full load in less than 5 min
- No maintenance impact (EOH) for frequent starts and stops
- More than 20% primary frequency control
- Reactive power control

Figure 7. The Győrhö cogeneration plant in Hungary with 3 x Wärtsilä 18V34SG engines.

Abbreviations
- CAPEX Capital Expenditure
- COP Coefficient of Performance
- DH District Heating
- DDH Dynamic District Heating
- EEQ Engineering, Equipment Delivery
- EPC Engineering, Procurement, Construction
- GW Gigawatt
- HR Heat Recovery
- HT High Temperature
- HTCAC High Temperature Charge Air Cooler
- IED Industrial Emissions Directive
- IPP Independent Power Producer
- LO Lubricating Oil
- LT Low Temperature
- OPEX Operational Expenditure
### References

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<th>Electrical Power</th>
<th>Heating Power</th>
<th>Delivery</th>
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<td>Mainz, Germany</td>
<td>KRAFTWERKE MAINZ-WIESBADEN</td>
<td>Gas</td>
<td>10 x Wärtsilä 20V34SG</td>
<td>100 MW&lt;sub&gt;e&lt;/sub&gt;</td>
<td>Up to 96 MW&lt;sub&gt;th&lt;/sub&gt;</td>
<td>2019</td>
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<tr>
<td>Cheong Soo, Korea</td>
<td>CHEONG SOO</td>
<td>Gas</td>
<td>3 x Wärtsilä 20V34SG</td>
<td>25.4 MW&lt;sub&gt;e&lt;/sub&gt;</td>
<td>21.3 MW&lt;sub&gt;th&lt;/sub&gt;</td>
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<tr>
<td>Bolgiano, Italy</td>
<td>BOLGIANO</td>
<td>Gas</td>
<td>2 x Wärtsilä 20V34SG</td>
<td>19.4 MW&lt;sub&gt;e&lt;/sub&gt;</td>
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Sasolburg, South Africa

**SASOLBURG**
- Fuel: Gas
- Prime movers: 18 x Wärtsilä 20V34SG
- Electrical power: 175 MW\textsubscript{e}
- Steam delivery: 41.6 MW\textsubscript{th}
- Delivery: 2012

Ujpalota, Hungary

**UJPALOTA**
- Fuel: Gas
- Prime movers: 3 x Wärtsilä 20V34SG
- Electrical power: 29 MW\textsubscript{e}
- Heating power: 19 MW\textsubscript{th}
- Delivery: 2004

Ringkøbing, Denmark

**RINGKØBING**
- Fuel: Gas
- Prime movers: 1 x Wärtsilä 20V34SG
- Electrical power: 8 MW\textsubscript{e}
- Heating power: 9.6 MW\textsubscript{th}
- Delivery: 2002
Wärtsilä Energy Business is leading the transition towards a 100% renewable energy future. As an energy system integrator, we understand, design, build and serve optimal power systems for future generations. Wärtsilä’s solutions provide the needed flexibility to integrate renewables and secure power system reliability. Our offering comprises engine-based flexible power plants – including liquid gas systems – hybrid solar power plants, energy management systems and storage and integration solutions. We support our customers over the lifecycle of their installations with services that enable increased efficiency and guaranteed performance. Wärtsilä has 70 GW of installed power plant capacity in 177 countries around the world.

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