TECHNICAL GUIDELINES

District heating systems

September, 2018

EU4Energy

Covenant of Mayors for Climate & Energy

Demonstration Projects Eastern Partnership

Technical guidelines for refurbishment of District Heating Systems with special focus on the integration of biomass boilers

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Definitions and Abbreviations:

District Heating Company: a district heating company is a public or private utility that is responsible for the operation of the district heating system.

System Owner: System owner is the institution that is the legal owner of the system and takes financial decisions about refurbishment projects.

Construction Company: the company which is selected to implement a renovation project

Site Supervisor: The Site Supervisor inspects and monitors the implementation of the refurbishment project on behalf of the System owner/District heating company.

Supply water: “hot” water from the boiler supplied into the district heating system

Return water: “cold” water from the district heating system to the boiler house

VSD Pump: Variable speed pump

1 Introduction

1.1 Background information

In the Eastern Partnership countries (EaP) the fuel consumption of district heating systems is significantly higher than in Western European countries. The majority of the installed equipment of municipal boiler houses was constructed in 60 -70^{s} of the 20th century and currently is in a poor technical condition. As a result, the local district heating systems show a low level of energy efficiency for energy production and distribution and provide unsatisfactory services to consumers.

District heating systems play a key role in the energy system of the majority of European cities. If well managed, district heating systems provide heat energy to consumers to competitive prices and in a very resource efficient way. District heating systems are a valuable asset of cities that creates jobs and income for the public sector.

These guidelines should therefore encourage and enable municipalities and district heating companies to convert their facilities into modern and energy efficient district heating systems that provide high level services to their consumers.

2 Overview of the refurbishment of DH systems

When planning the refurbishment or extension of a district heating system (boilers, control system, heating equipment, pumps, district heating pipelines, heat substations, etc.) the following steps should be applied:

2.1 Step 1: Preparation for Energy Audit (EA) / Feasibility study (FS)

Before an Energy Audit or Feasibility study can be conducted the exact scope of the EA / FS should be elaborated. Based on the defined scope of work, a skilled and experienced Energy Auditor shall be selected.

<u>Result of Step 1:</u>

- Scope of work (f.e. boiler house No 2 including district heating network), ToR for Energy Auditor
- Selected Energy Auditor

2.2 Step 2: Elaboration of an Energy Audit / Feasibility Study

Based on the scope of work the EA / FS will provide a list of potential refurbishment measures. Details of Energy Audits / Feasibility Studies see chapter 3.

<u>Result of Step 2:</u>

- Energy Audit / Feasibility Study Report

2.3 Step 3: Selection of the refurbishment measures

Once the Energy Audit or Feasibility Study has been finalised and presented by the Expert, the System Owner and the District Heating Operator decide which refurbishment measures will be further developed. Usually the available budget limits the number of measures that will be selected for the preparation of the project design during the next step. Please note that an accurate estimation of the investment cost/operational costs will be available only after all project details have been developed (project design). For this reason, the final selection of measures shall be undertaken only during/after the project design phase.

Result of Step 3:

- Minute of meeting with selected refurbishment measures (f.e. replacement of a gas boiler by a biomass boiler system in boiler house No 2)

2.4 Step 4: Project design of selected refurbishment measures

After the selection of a skilled and experienced project design company, the project design of the chosen refurbishment measures will be elaborated. Beside the elaboration of the technical details, also the following information should be developed:

- Detailed investment costs for each refurbishment measure (accuracy +/-10%)
- Detailed operational costs for each refurbishment measure (accuracy +/-10%)
- Energy savings in MWh per year for each refurbishment measure
- Savings of operational costs per year for each refurbishment measure

That information will be used in the economic analysis to calculate/update key financial parameters (Payback period, Project IRR, etc.). For details of a simplified financial analysis see chapter 4.

Result of Step 4:

- Project design for each of the refurbishment measure
- Summary report (description of the measures, investment costs, operational costs, energy savings, financial analysis (see also chapter 4), other relevant information).

2.5 Step 5: Selection of the refurbishment measures for the approval and procurement procedure

Once the project designs of the selected refurbishment measures have been finalised and the final investment/operational costs are available, the System Owner and the District Heating Operator decides which of the refurbishment measures will be submitted to the authorities for approval and for procurement. The basis for the selection of the final measures is the summary report of Step 4. Usually the available budget determines the selection of the measures.

Result of Step 5:

- Minute of meeting with selected refurbishment measures (f.e. replacement of a gas boiler by a biomass boiler system in boiler house No 2)

2.6 Step 6: Authority approvals and procurement

Submission of all required documents for achieving the approvals from the state inspectorate and elaboration of the procurement documents. It is crucial that all technical requirements and components are properly described and the provided information and technical data is coherent in all documents (technical description, technical drawings, Bill of Quantity, etc.).

Once the procurement documents are developed the refurbishment project can be tendered and a construction company can be selected based on predefined selection criteria.

Result of Step 6:

- Authority approvals
- Procurement documents
- Selected construction company

2.7 Step 7: Implementation and site supervision

Before the Construction Company can start the implementation of the project, the System Owner/District Heating Operator has to select a suitable site supervision expert who ensures that the project will be implemented according to the project design and the technical specifications in the procurement documents. The site supervision expert should have access to all project documents and must be fully familiar with the project design and the procurement documents. It is recommended that all parties participate in a starting meeting where the details of the project (i.e. time schedule, critical components, installation practices, etc.) will be explained by the project design company and site supervisor to the construction company. The site supervision should organise weekly meetings throughout the construction period with all parties. Minutes of the weekly meetings (decisions, problems, agreements, etc.). will be sent to all parties. After the finalisation of the construction works, the site supervisor shall organise and conduct the final acceptance of the works and services with all parties.

Further details on site supervision see Annex A.

Result of Step 7:

- Implemented refurbishment projects according to the project design
- Final acceptance including a list of deficiencies/defects (which must be corrected by the construction company)

2.8 Step 8: Monitoring of results

After the implementation of the project, the District Heating Operator has to monitor and analyse the actual results in order to see whether the goals were achieved or not. In case the expected results (outlined in the summery report in Step 4) will not be met, the monitoring results should be used to optimise the system. Further details and example see Annex B.

Result of Step 8:

- Actual energy savings in MWh
- Energy performance benchmarks

3 Energy Audit (EA) of a district heating refurbishment project

The main purpose of the Energy Audit is to assess the current situation of the district heating system with regard to its energy consumption/production respectively energy needs, elaboration of energy efficiency measures (EE) and renewable energy measures (RE), and provide a cost effectiveness analysis of the proposed EE/RE improvement interventions.

The EE/RE measures shall aim at reduction of the operating costs (e.g. reduction of fuel costs), improvement of the services provided to consumers (e.g. sufficient temperature for heating the buildings, providing of hot water for sanitary purposes) and the environmental impact (CO_2 emissions).

The Energy Audit / Feasibility Study should include at least the following activities:

1. Data request, data collection
2. On-site visits and measurements
3. Identification and development of suitable energy saving measures and/or renewable energy measures
4. Economic analysis
5. Development of the Measurement & Verification plan
6. Drafting of the energy audit report and improvement of the report in line with comments provided by the System Owner/District Heating Operator

3.1.1 Data request and data collection

The Energy Auditor should get in contact with the System Owner and the System Operator of the district heating system to discuss the scope of work and the required data. The Energy Auditor shall hand over a list of data and information to be prepared by the System Owner and System Operator. An example list of required data is prepared in Annex C.

3.1.2 On site visits, measurements and calculation of benchmarks

Once the Energy Auditor has received all relevant information from the System Owner/System Operator on site visits will be conducted. During the on site visits the Energy Auditor shall analyse all installed equipment, conduct measurements (e.g. power consumption of pumps, flue gas losses of boilers) and complement missing information.

Once all data of the district heating system are available, benchmarks should be calculated to identify problematic components and inefficiencies in the operation. The following benchmarks should be calculated:

- Annual efficiency of each boiler in % (annual heat produced in kWh / annual fuel consumption in kWh)

Recommended efficiency of gas boilers[1]: > 85%
Recommended efficiency of biomass boilers[1]: > 80%

- Annual efficiency of the entire boiler house in % (total thermal energy produced in kWh / total fuel consumption in kWh)
  Recommended efficiency: > 80%
- Annual efficiency (heat losses) in the network in % (total thermal energy delivered or sold to consumers in kWh / total thermal energy produced in the boiler house in kWh)
  Recommended annual efficiency of the network (without summer operation): > 85%
  Recommended annual efficiency of the network (with summer operation): > 80%
- Annual electricity consumption per produced thermal energy in kWh_{el} per MWh_{th} (total electricity consumption of the boiler house in kWh / total thermal energy produced in the boiler house in MWh)
  Electricity consumption per produced MWh_{th}: < 15kWh_{el} per MWhth
- Annual fresh water consumption per MWh produced thermal energy in m^3/MWh_{th}

For an Example see Annex B.

3.1.3 Identification and development of suitable energy saving measures and/or renewable energy measures

Based on the findings of the site visits and the results of the calculation of benchmarks the Energy Auditor shall identify and develop suitable energy saving measures or renewable energy measures.

- Identification of suitable measures
- Development of the EE/RE measures (description of the measure, define and list all the required technical components and works, consultation of manufacturers, elaboration of basic drawings, etc.)
- Assessment of the local legislation and/or standards which are relevant for the implementation of the proposed EE/RE measures (e.g. fire safety regulation, emission limits)
- Estimation of the annual energy savings/energy production, cost savings and CO_2 emission reductions for each EE/RE measure. The savings shall be determined by:

  Baseline Savings = energy consumption of the baseline scenario[2] - energy consumption of the proposed EE/RE measure

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[1] Please note the difference between boiler efficiency and annual efficiency of a boiler:
Boiler efficiency: efficiency at nominal capacity and predefined conditions for a very short period. This a theoretical value that is usually not achievable as the boiler under on site conditions.
Annual boiler efficiency: actual efficiency of a boiler system on site throughout a longer monitoring period (usually 1 year)

[2] The savings should be calculated by comparing the energy consumption before and after the project implementation. BUT the situation before is often not comparable with the situation after the project (heating comfort, operation time, weather conditions, etc.). Therefore, the establishment of a “baseline” is needed to have comparable conditions before and after the project implementation. The baseline usually represents the calculated (theoretical) energy consumption before the project implementation considering the same service level as after the project implementation (i.e. same heating degree days, operation hours, same indoor temperatures, same heated floor area, etc.).

Actual Savings = actual energy consumption[3] - energy consumption of the proposed EE/RE measure

Assumptions for calculation of the energy savings and savings of CO_2 emissions shall be transparent, traceable and shall be well described.

- Elaboration of a rough implementation plan for each measure

3.1.4 Financial analysis

Once the measures have been identified and developed a financial analysis shall be conducted for each individual measure. The following activities shall be considered:

- Determine the assumptions for the financial analysis (calculation period, energy tariffs, other tariffs, annual price increase of tariffs, discount rate, etc.);
- Estimation of the investment costs and operational costs. The investment and operational costs shall have an accuracy of +/-20%. The basis and sources of the estimations shall be stated by the Energy Auditor.
- Calculation of basic financial parameters for each of the selected EE/RE measures (Internal Rate of Return (IRR), Payback Period, Net Present Value (NPV))
- Finally, the EE/RE measures will be ranked according to suitable criteria's (e.g. Payback Period)

3.1.5 Development of a Measurement and Verification plan

The Energy Audit should include a Measurement and Verification Plan which outlines the parameters to be monitored/measured to improve the databases (f.e. detailed load profile during winter, summer) for the technical design and to evaluate the results after project implementation.

An example Measurement and Verification Plan is attached in Annex D.

4 Economics of district heating refurbishment projects

Before any decision and implementation of a larger refurbishment project can take place, it is recommended to assess the profitability of the measure. The main objective is to assess the profitability of a project or to compare 2 or more potential options to find the most profitable project option.

The first and most important assessment will be done during the Energy Audit phase. Usually the following approach will be applied:

4.1 Elaboration of a project concept

During the Energy Audit / Feasibility Study phase the concept of the project need to be elaborated which includes:

- Description of the measures to be implemented
- Preparation of the required equipment and materials
- Assessment of the legal requirements

[3] Actual energy consumption: average of the energy consumption of the last 3 year

4.2 Estimation of investment costs, operational costs, savings

The key element of the analysis is the elaboration of the investment costs and the operational costs.

The following approach shall be applied:

- Estimation of the investment costs
  Investment costs for main components such as biomass boiler system, heating equipment, construction works, etc. should be based on offers from potential suppliers. Other costs such as installation costs, project preparation costs (project design, project management, etc.), costs for site supervision can be estimated based on experiences gained from similar projects;
  The accuracy of the investment costs shall be +/- 20%. A sufficient reserve for unforeseen activities/components should be included.
- Estimation of the annual operational costs (fuel costs, electricity, fresh water, sewage, staff, other operational costs). The accuracy of the operational costs shall be +/- 10%.
- Calculation of the annual energy savings
  Baseline Savings = energy consumption of the baseline scenario[4] - energy consumption of the proposed EE/RE measure
  Actual Savings = actual energy consumption[5] - energy consumption of the proposed EE/RE measure

See Annex E for an example of how savings are calculated.

4.3 Calculation of key financial parameters

The following key financial parameters shall be calculated:

- Project Internal Rate of Return in %;
- Project payback period in years;
- Net present value (NPV)

It is recommended to rank the EE/RE measures according to a suitable criteria (e.g. Payback Period). Based on the outcome of the financial analysis the Project Owner decides to move forward with the measures or to adapt the project (e.g. to drop one (or more) measures as its not profitable or too expensive).

A template for a financial analysis (dynamic calculation model[6]) is attached in Annex F.

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[4] The baseline usually represents the calculated (theoretical) energy consumption before the project implementation considering the same service level as after the project implementation (i.e. same heating degree days, operation hours, same indoor temperatures, same heated floor area, etc.).
[5] Actual energy consumption: average of the energy consumption of the last 3 year
[6] The dynamic calculation model considers the timing of payments over the project lifetime and the expected increase of energy prices.

4.4 Update the financial assessment during the project design phase

It is recommended to recalculate/update the financial analysis during the project design phase as more information (e.g. updated and more accurate investment cost, operating cost) is available which could have an impact on the profitability of the project.

5 Typical problems in district heating systems

5.1 Boiler house

5.1.1 Low backflow temperatures → corrosion in the boiler

Very often the temperatures in the district heating system do not comply with legal or technical requirements. Usually the temperature from the network to the boiler (return water) is very low (< 50°C) which results in condensation in the flue gas pipes of the boiler. The condensate is leading to corrosion and leaking boiler bodies.

Picture 1: Corrosion in a gas boiler, leaking boiler body	Picture 2: Too low temperature to the boiler (33°C only)
	

Recommended improvements

The temperature of the return water to the boiler has to comply with the requirements of the boiler manufacturer (for gas boiler usually >50°C, for biomass boilers >75°C - depending on the water content of the fuel, the higher the water content the higher the temperature of the return water to the boiler). This can be achieved by a proper temperature increase (pump system or 3-way valve) of the district heating water before it enters the boiler.

Picture 1: Pipe system incl. pumps and sensors to increase the temperature of the water to the boiler


5.1.2 *Poor and hydraulic inefficient pipe system in the boiler house, no heat insulation of pipes in the boiler house, poor insulation of exterior pipes → high electricity cost for pumping, heat losses*

Due to adaptions of the pipe system over the years, often inefficient pipe connections have been installed. Such incorrect pipe installations can result in uncontrolled streams that lead to high pressure losses and high pump costs. Heat insulation is very rarely applied on pipes in the boiler house which causes substantial heat losses throughout the year (heat losses ranges typically between 80-120 W per meter of not insulated pipe).

Picture 3: Missing heat insulation of pipes in the boiler house	Picture 4: Inefficient pipe connections (inefficient hydraulic situation), no heat insulation
	

Picture 5: Poor heat insulation of exterior district heating pipes	Picture 6: Poor heat insulation of exterior district heating pipes
	

Recommended improvements of interior pipes:

All pipes in the heating system shall be heat insulated and protected against mechanical damages by applying a coating (e.g. aluminum coating). It is recommended to apply the following insulation thicknesses:

Insulation thickness of pipes[7] in the boiler house:

Pipe diameter in mm (outside)	Insulation thickness in mm
< 20	20
21 - 34	30
35 - 50	40
> 50	50

Recommended improvements for exterior district heating pipes:

It is strongly recommended to install pre-insulated district heating pipes according to the European standard EN 253.

<u>Insulation material:</u> Thermal conductivity Lambda ≤ 0.03 W/mK, polyurethane hard foam > 60 kg/m³,

Nominal pipe diameter medium pipe	Pipe diameter jacket pipe in mm (outside)
DN 20 (3/4”)	110
DN 25 (1”)	110
DN 32 ($1^{1/4}$”)	125
DN 40 ($1^{1/2}$”)	125

[7] Insulation thickness according to German Energy Saving Ordinance “Energieeinsparverordnung 2009”

DN 50 (2”)	140
DN 65 ($2^{1/2}$”)	160
DN 80 (3”)	180
DN 100 (4”)	225
DN 125 (5”)	250
DN 150 (6”)	280
DN 200 (8”)	355

Recommended improvements for pipe design (interior pipes):

The pipe system in the boiler houses or at heat consumers shall be designed to minimize the pressure losses and to reduce the pump costs (correct 90° bows, correct pipe connections, etc.).

Picture 7: Sufficient heat insulation of interior pipes, correct pipe design, correct indication of flow direction

5.1.3 *Outdated and oversized district heating pumps → high electricity costs*

Very often district heating pumps from the initial operation of the district heating system are still in operation. During the last 20 years the heat load dropped by 50% or even more and the pump systems are highly over dimensioned for the current consumption which leads to in inefficient operation and high electricity costs.

Picture 8: District heating pump 90 kW

Picture 9: District heating pump 90 kW over dimensioned, outdated, leaking

Recommended improvements:

District heating pumps should be consequently replaced and correctly dimensioned according to the actual parameters of the district heating system (including demand). For recommended design parameters of district heating systems see Chapter 6.

5.1.4 Poor water quality in the district heating system → corrosion, deposits in pipes, pumps, valves

District heating system usually do not use treated water due to a lack of water treatment equipment in the boiler house. Furthermore, the water quality typically is not tested on a regular basis. This practice can lead (depending on the indigenous water composition) to corrosion and deposits in the system.

Recommended improvements:

It is recommended to perform an annual test of the water quality. Depending on the result, the need of a further treatment of the water should be decided (f.e. softening unit or chemical adding for oxygen elimination, etc.).

European norms for district heating system require the following parameters[8]:

- Electrical conductivity in µS/cm: 100 - 1500
- PH value: 9 – 10,5
- Oxygen in Mg/l: <0,02
- Alkaline in mmol/L: <0,02

5.1.5 Lack of meters installed in the boiler house

Very often heat meters, but also electricity and fresh water meters are missing in boiler houses or do not work properly. Even if electronic meters are installed, the data from the meter is not always collected and analyzed. As a result, the energy production cannot be analyzed and optimized.

Recommended improvements:

The following meters are recommended to be installed:

- Gas meter for the gas boiler system
- Heat meter for the gas boiler system (optional)
- Heat meter for the biomass boiler system (if installed)
- Heat meter for heat production of the entire boiler house
- Fresh water meter (boiler house)
- Electricity meter (boiler house)

Data from the meters should be regularly (in case of electronic meters monthly) extracted and analyzed. For an example of recommended meters, and the monitoring and calculation of performance indicators see Annex B.

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[8] Source: German "AGFW Arbeitsblatt FW510" Requirement for circulation water in industrial and district heating systems

5.1.6 Outdated, worn out boilers

Sometimes the boilers are simply outdated and worn out and cannot not provide a secure and efficient heat supply.

In such cases it is recommended to replace the entire boiler system or to provide the required heat energy from another boiler house in the system (if technically feasible).

5.2 Control systems in the boiler house

5.2.1 Lack of modern automatic boiler control systems

The existing boiler control systems are usually outdated and do not control the boiler system (fuel supply, combustions air fan, exhaust gas fan, etc.) automatically according to the actual needs of the district heating system. The outdated control systems result in an inefficient operation of the boiler system. Typically, the efficiency of such “manually” controlled system is 5% to 15% lower compared with a boiler equipped with a fully automatic boiler control system.

Picture 10: Outdated gas burner and control of a gas boiler

Recommended improvements:

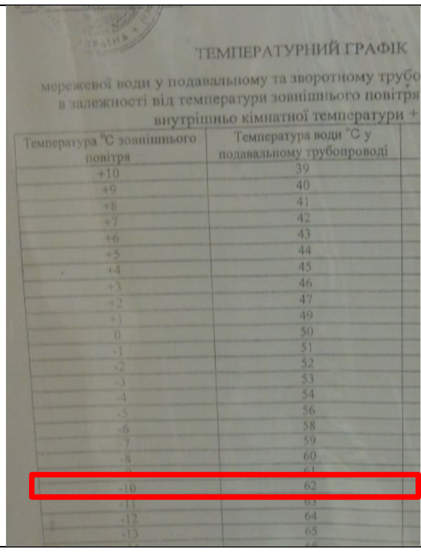
The improvement or upgrade of the control system of outdated boiler systems is difficult and in many cases technically/economically not feasible. It is recommended instead to replace the entire boiler system by a modern boiler including a fully automatic control system.

5.2.2 Lack of automatic control system of the temperature of the supply water

The temperature of the supply water into the district heating system is usually manually controlled by the operation staff. Such a manual control of the supply temperature is inefficient and results in unnecessary heat losses. The temperature regime for the district heating system is usually too low for an optimized operation of the district heating system (see picture 12)

Picture 11: Manual control of the supply temperature (manual mixing valve)

Picture 12: Temperature regime of a district heating system (example: outside temperature -10°C → supply temperature +62°C



ТЕМПЕРАТУРНИЙ ГРАФІК

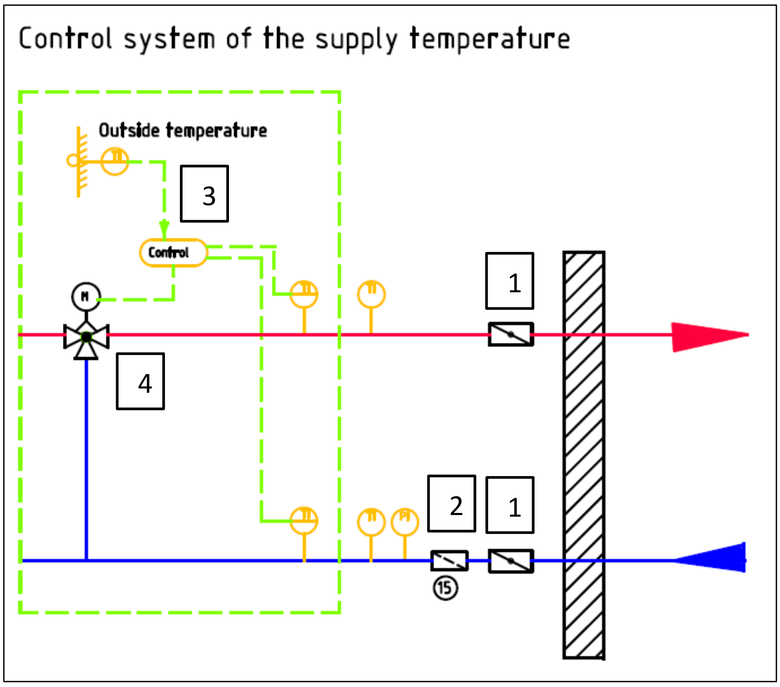
мережевої води у подавальному та зворотному трубо
в залежності від температури зовнішнього повітря
внутрішньо кімнатної температури +

Температура °С зовнішнього повітря	Температура води °С у подавальному трубопроводі
+10	39
+9	40
+8	41
+7	42
+6	43
+5	44
+4	45
+3	46
+2	47
+1	49
0	50
-1	51
-2	52
-3	53
-4	54
-5	56
-6	58
-7	59
-8	60
[illegible]	61
-10	62
-11	63
-12	64
-13	65

Recommended improvements:

It is recommended to install an automatic control system of the supply temperature which acts dependent on the actual outside temperature. The temperature of the district heating network should be increased to provide sufficient heat energy to the consumers.

A principle scheme of the automatic control system for the supply water dependent on the outside temperature and a 3-way valve is shown below:



1: Shut off valves
2: dirt filter
3: Outside measurement and control system
4: 3-way valve to control the temperature of the supply temperature

5.2.3 Lack of an overall control system

Most district heating systems operate several boilers in a boiler house. Usually each boiler is controlled individually and without any integration into an overall load control system (also called load management system). Boilers will be controlled "manually" by the boiler staff according to a predefined regime dependent on the outside temperature. In case of a multiple boiler system, the boilers will be turned on/off manually by the boiler staff. Typically, the efficiency of such "manually" controlled multiple boiler systems is 5% to 15% lower compared to a boiler house with an automatic overall control system.

Recommended improvements:

Boiler systems comprising of more than 1 boiler should be controlled by an overall load management system. Such a load management system starts/stops each boiler according to predefined parameters and according to the actual needs of the district heating system (usually supply water temperature). Such a control system will also manage automatically the boilers in case of a failure of one boiler.

In particular for boiler systems comprising of biomass boilers a load management is crucial for an efficient operation of the district heating system. Further details on biomass system see Chapter 7.

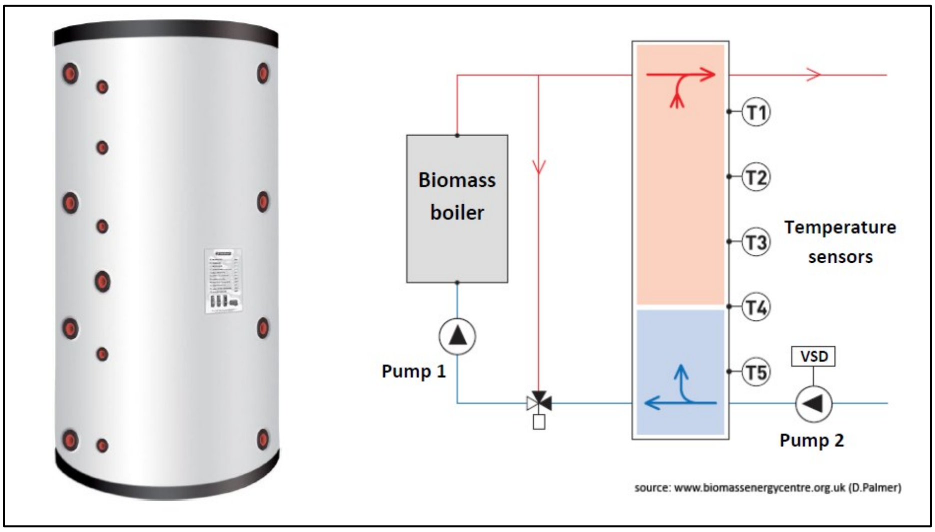
5.2.4 Lack of an accumulator tank (in biomass boiler systems)

Most heating systems do not have installed an accumulator tank system. In particular when biomass boilers are included in a boiler system an accumulator tank is recommended in order to maximize the heat production of the biomass boilers and to cover short term peaks of the network.

Recommended improvements:

The main advantage of an accumulator tank is to maximize the utilization of the biomass boiler system (>2,000 full load operation hours). This will decrease the total heat generation costs. Simple systems use just two sensors (T1 and T5), one near the top (T1) and one at the bottom (T5). 2 sensors offer only crude control while more refined systems will have 3 or more sensors so that progressive control is possible. The size of the tanks must be properly designed for each boiler system but, as a rule of thumb 20 – 40 l per kW boiler capacity can be used for a preliminary estimation. The ratio between height and diameter of the tank shall be around 2,5 : 1.

The figure below shows a principle scheme of such a system:



T1…..T5: temperature sensors to control the boiler system

P1: pump biomass boiler (conventional pump, no VSD required)

P2: pump of district heating system (VSD highly recommended)

5.3 District heating network (incl. ancillary equipment)

5.3.1 Boiler capacity too large for actual consumer load

During the last 20 years many consumers were disconnected from district heating systems due to unsatisfactory services while the boiler houses remained with very large boilers. Such over dimensioned boiler system cannot be operated at it's nominal capacity and the overall efficiency drops.

In case of massive over dimensioned boiler houses 2 strategies can be followed:

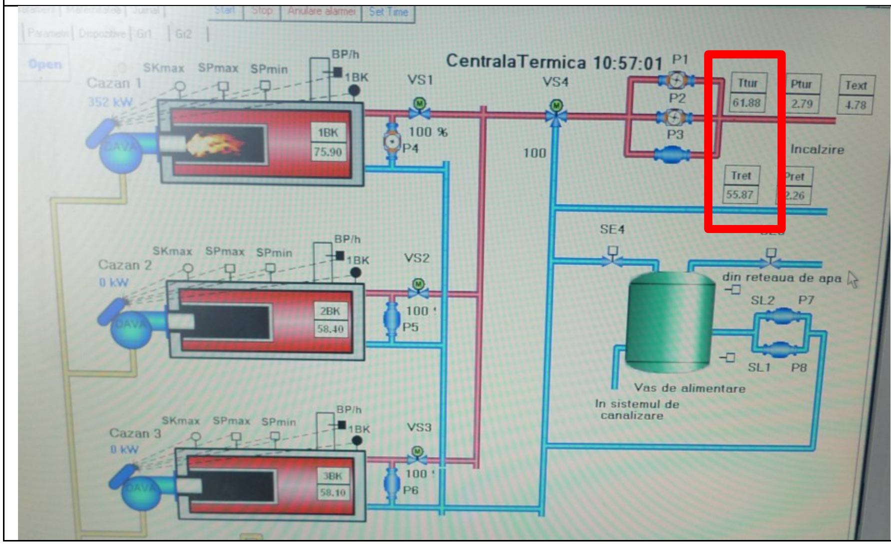
1) Resizing the boiler house to the actual needs of the network or/and focusing on selected heat consumers (selection of key consumers, improvement the network for those consumers, installation of new boilers and heating equipment for the actual needs).
2) Active strategy to reconnect consumers or connect new consumers

The general, the priority is to maintain a satisfactory service to consumer by providing enough heat energy with the required temperatures.

5.3.2 Too low temperature difference between supply water and return water

Most district heating systems are operated with very little temperature difference between supply and return. Often the temperature difference is less than 10°C. Such a small temperature difference leads to massive water volume that has to be circulated, over dimensioned pipes and pumps and high electricity consumption. The picture below shows an existing boiler house in Moldova as an example.

Picture 13: Temperature of the supply water 62°C, temperature of the return water 56°C → ΔT = 6°C



Recommended improvements:

It is recommended to increase the temperature difference between supply and return to ≥ 20°C, this will result in reduced electricity costs and investment costs for pumps and district heating pipes (detailed benefits see table below). This will require an optimization of the internal heating system at the heat consumers and the heat substation. It is recommended to analyse the internal heat system of the heat consumers and try to optimize the system to increase the temperature difference between supply and return. Usually the following measures can be implemented at the heat consumers:

- Replacement of single pipe systems by double pipe systems
- Installation of additional radiators to increase the heating surface
- Installation of low temperature heat surfaces (e.g. floor heating systems)
- Replacement of 4-way valves between flow and return (2-pipe systems)
- Closing of direct connections between flow and return (2-pipe systems)
- Adjusting of the hydraulic flows in the system (hydraulic balancing)

It is recommended to identify critical consumers in a first step and select a few where optimizations are technically and economical feasible.

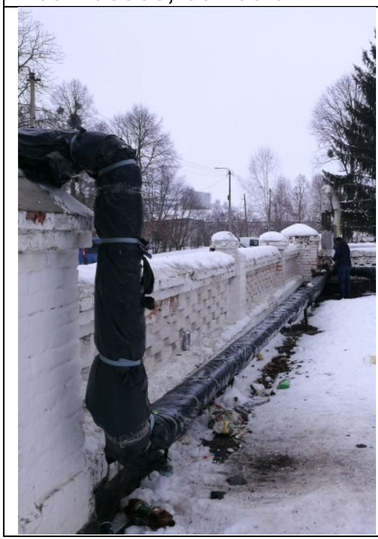
The example below shows the optimization of a heat consumer and the benefit for the district heating system.

	Existing situation	Improved situation
Heat load	350 kW	350 kW
Heat demand per year	560 MWh	560 MWh
Temperature difference ΔT between supply and return	10°C	20°C
Amount of circulated water per year; per hour m^3/h	Per year 6,513 m^3	Per year 3,256 m^3

	Per hour 30,1 m³/h	Per hour 15,05 m³/h
Required main pipe diameter	DN 80 or DN 100	DN 65
Savings	Hydraulic equations show that the reduction of the circulated water amount with 50%, results in a decreased pressure drop (1/4 of the initial pressure drop) and in reduced energy consumption for the circulation (1/8 of the initial energy consumption). In practice, more than 50% of the electricity costs for pumping can be saved!	

5.3.3 *Poor thermal insulation (over ground and underground)*

The district heating pipes are often in a poor technical condition and causes huge heat losses throughout the year.

Picture 14: Poor thermal insulation, massive heat losses, corrosion	Picture 15: 40°C at the heating pipe
	

Recommended improvements:

It is recommended to replace outdated district heating pipes by pre-insulated pipes.

5.4 Heat substation (incl. ancillary equipment)

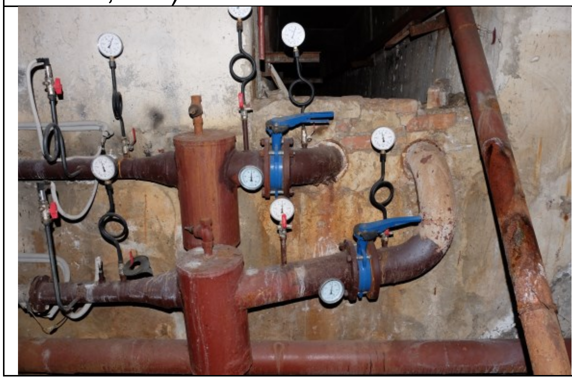
The connection of the district heating network to the consumer can be done as direct connection or as connection with heat exchanger (indirect connection). The table below compares the specifics of each system:

	Indirect	Direct
Type of consumers	All types and sizes	Should be limited to small consumers (single family houses)
Hydraulic separation between district heating network and the internal heating system of the consumer	Yes (no risks)	No → (risk of leakages, contamination of the district heating network with dirt, no clear legal interface between district heating network and the internal heating system of the consumer
Design temperatures	Up to 110°C	Less than 90°C
Design pressures	16 bar (or even higher)	Usually limited to 3 bar
Investment costs		Due to the missing heat exchanger the investment costs are slightly lower compared with an indirect connection

5.4.1 Outdated connection of the consumers to the district heating system

Typically, the connection of consumers shows the following problems:

Problems	Results
Lack of heat meters at consumers	No consumption based billing possible. No incentive for consumers to save heat energy
Lack of hydraulik seperation (no heat exchanger) of the district heating system and the internal heating system of the consumer	No clear legal interface between district heating system and internal heating system of the consumer → risk of leakages, contamination of the district heating network (dirt, corrosion)
No pumps installed at consumers	The pumps in the boiler house are used to circulate the water also in the internal heating system of the consumer. High capacity pumps in the boiler house required, high electricity costs for the district heating system.
Lack of automatic temperature control system at consumers	Temperature in the internal heating system is not separately controlled according to the outside temperature (overheated/underheated areas)
Lack of differential pressure controller at consumers	Noise problems in the internal heating system of the consumer
Very low temperature difference between supply and return water (< 10°C)	The district heating system must circulate a huge amount of water → high capacity pumps needed, high electricity costs

Picture 16: Typical direct connection of a school building to the district heating network (no heat exchanger, no pumps, no heat insulation, no difference pressure control, etc.)	Picture 17: Typical direct connection of a school building to the district heating network (no heat exchanger, no pumps, poor heat insulation, no difference pressure control, etc.)
	

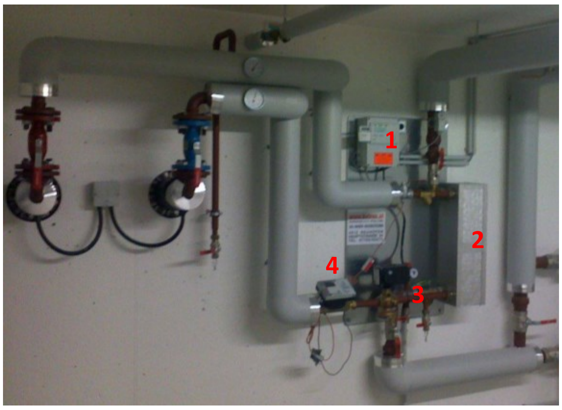
Recommended improvements:

It is recommended to install a prefabricated heat substation for each (larger) consumer to avoid the problems and inefficiencies mentioned in the table above. The heat substation should include the following main components: Heat exchanger, differential control valve/volume flow limiter, heat meter, automatic temperature control system in dependence of the outdoor temperature, option for the connection of a hot water supply system, control system, heat insulation of pipes and components, temperature, pressure sensors and required safety equipment.

The internal heating system of the consumer should include pumps with a variable speed drive (VSD pumps) and an expansion system. The VSD pump is needed to adjust the circulated water flow to the actual needs of the building. A three-port control valve can be installed in the internal heating circuit to ensure the unnecessary return of supply water temperature back to the heat exchanger.

All pipes shall be heat insulated and protected against mechanical damages by applying a coating (e.g. aluminum coating). It is recommended to apply the following insulation thicknesses:

Pipe diameter in mm (outside)	Insulation thickness in mm
< 20	20
21 – 34	30
35 – 50	40
> 50	50

<table>
<tr><td>Picture 18: Example of a modern heat substation with heat exchanger (capacity approx. 70 kW)</td><td>Picture 19: Example of a modern heat substation with heat exchanger (capacity approx. 150 kW)</td></tr>
<tr><td>
1: Control unit
2: Heat exchanger
3: Differencial control/flow volume limiter valve
4: Heat meter</td><td>
1: Control unit
2: Heat exchanger
3: Differencial control/flow volume limiter valve
4: Pump
5: Expansion systen</td></tr>
</table>

6 Design of District heating refurbishment projects

6.1 Sound dimensioning of the pipe network

The design or refurbishment of a district heating networks has to consider many national standards and norms. Most of those standards were developed 20 or 30 years ago and do not consider modern energy efficient practices as modern European standards do. It is therefore recommended to contract a design company that is fully familiar with modern European standards that are relevant for the design of district heating networks. An experienced design company will be able to apply European energy efficiency standards within the framework of the national regulations and standards. Applying such practices can **reduce the investment costs by 30%** compared to old fashioned design practices which are still applied in many countries in the region.

The following principles shall be applied:

6.1.1 Assessment of the existing pipe network

1. Elaboration of an actual map of the district heating network (consumers, heat substation, pipe network incl. diameter, boiler houses incl. capacity)
2. Analysis of the existing consumer situation (heat load in kW, annual heat consumption in MWh)
3. Estimation of the future demand considering potential heat consumers that could be connected in the future and thermal refurbishment of buildings of existing consumers (substantial reduction of the heat consumption)

6.1.2 Calculation and selection of the correct pipe diameter

1. Calculation of the optimized dimension of the district heating pipes. A dedicated calculation software shall be applied (free versions are available online).
2. It is recommended to allow an overall pressure drop for the entire system of 100 – 200 Pascal
3. The system should be designed for a temperature difference between supply and return of at last 20°C (**e.g. supply water 90°C, return water 70°C**). An improvement of the heating system in selected consumer buildings might be required, see chapter 5.3.2.

The following tables provides an overview of the recommended pipe diameters for a temperature difference between supply and return of ΔT 20°C:

Pipe diameter for connection of buildings:

DN	Di	v	m	ΔT: 20 °C	
	mm	m/s	m³/s	P in kW	P in Mcal/h
25	28,5	1,1	2,5	59	51
32	37,2	1,2	4,7	109	94
40	43,1	1,2	6,3	147	126
50	54,5	1,4	11,8	274	235
65	70,3	1,4	19,6	455	391
80	82,5	1,6	30,8	716	616

Pipe diameter for transport pipelines (depending on the actual situation a higher velocity of the water flow is acceptable):

DN	Di	v		m		ΔT: 20 °C			
	mm	m/s		m³/s		P in kW	P in Mcal/h	P in kW	P in Mcal/h
		from	to	from	to	from	from	to	to
100	107,1	1,6	1,9	51,9	61,6	1.207	1.038	1.433	1.232
125	132,5	1,8	2	89,4	99,3	2.078	1.787	2.310	1.986
150	160,3	2,1	2,5	152,6	181,6	3.549	3.051	4.224	3.632
200	210,1	2,4	3,3	300,0	411,9	6.978	6.000	9.581	8.238
250	263	2,7	3,9	528,0	762,7	12.281	10.560	17.740	15.254

DN: norm pipe diameter
Di: inside pipe diameter in mm
v: velocity of the water in m/s
The higher the velocity of the water flow in a pipe system, the higher the flow sound. In transport pipelines a higher velocity of the water flow is acceptable.
m: mass flow of the water in m³/h
ΔT: temperature difference between supply and return flow in °C
P: heat capacity to be transferred in kW
Source: Austrian guideline for district heating systems ÖKL 67, Manufacturer's recommendation

Example:
A new building with 400 kW capacity should be connected to the district heating system.

According to the table the pipe diameter DN 65 is able to transfer up to 455 kW at ΔT 20°C Therefore the required pipe diameter is DN 65.

DN	Di	v	m	ΔT: 20 °C	
	mm	m/s	m³/s	P in kW	P in Mcal/h
25	28,5	1,1	2,5	59	51
32	37,2	1,2	4,7	109	94
40	43,1	1,2	6,3	147	126
50	54,5	1,4	11,8	274	235
65	70,3	1,4	19,6	455	391
80	82,5	1,6	30,8	716	616

6.1.3 Installation practices of district heating pipes

The system must be designed to compensate the thermal stress during the start up of the system but also during regular operation of the system. It is recommended to apply the hot laying with thermal pre-stressing installation method which is a proven European practice for small to medium pipe systems. The district heating pipes will be laid directly in the ground and buried by sand and soil.

The entire pipe design shall be reassessed/checked by the pipe manufacture before the installation. The pipe manufacturer shall confirm that the system is able to compensate the thermal and mechanical stress during start up and the operation of the system.

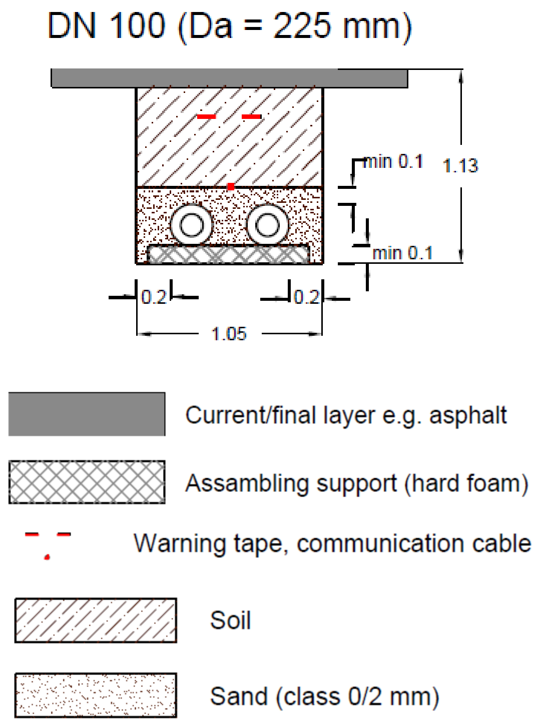
Main installation steps of the hot laying technic are the following:

1) Preparation of the pipe trench
2) Installation of the pipes and couplers, installation of expansion cushions (see picture 25).
3) Preheating the pipe network (or a closed section) to approx. 75 °C with electricity or a mobile heating stove. In the event of an extension or refurbishment of an existing system, the pre-heating will be usually provided from the existing boiler house.

Picture 20: pre-heating with a mobile stove	Picture 21: pre-heating with electricity
	

The hot lying practice will reduce the investment costs substantially as conventual compensation components of the thermal stress such as L-elbow, U-elbow, Z-elbows are not required in most of the situations.

4) Filling of pipe trench during thermal preheating, laying district pipes in a sand bed covered by soil

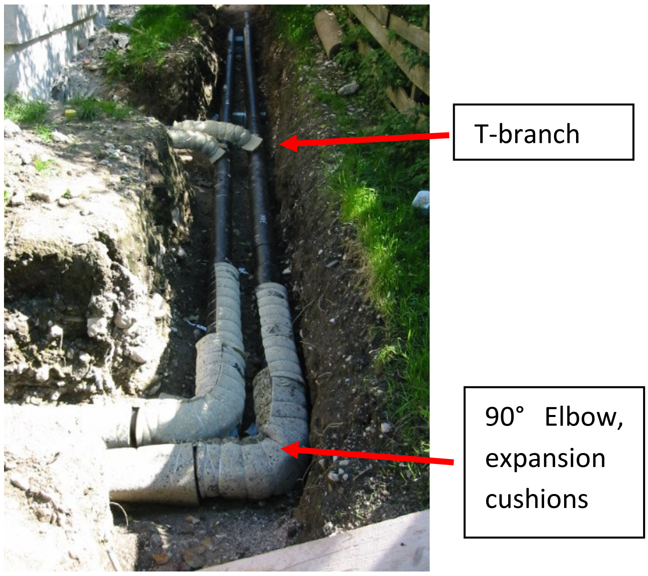
Picture 22: filling of the pipe trench, example DN 100	Picture 23: pre-insulated pipes covered with sand, warning tape and communication cable
	

6.1.4 Branches to consumers, shut off valves, de-aeration valves, construction of shafts

For the connection of consumers pre-insulated T-branch or parallel branches recommended by the pipe manufacturer should be used, the construction of shafts is usually not required.

Shut-off valves for branches and de-aeration valves in the exterior pipe network shall be installed only when absolutely required. For the disconnection of individual consumers (buildings) shut off valves shall be installed at the buildings (shortly after the district heating pipes enter the building), see picture 27.

Shafts for pipe branches are usually not required.

Picture 24: T-branch and parallel branch for connecting consumers	Picture 25: pipe branch (T-branch) and elbow with expansion cushions (hot laying practice), no shafts
	
Picture 26: shafts for valves and for pipe branches should be avoided (costly, corrosion of fittings)	Picture 27: Prefabricated heat substation for a single-family house (under construction), shut off valves and valve for draining the district heating pipes
	 1: Shut off valves 2: Drain valve

As a result, the investment costs of the pipe system can be reduced by approx. 30% when considering the recommended principles.

6.1.5 Recommended standards and guidelines for district heating systems

The district heating system and installation works must comply with the following norms: EN 253, EN 448, EN 488, EN 489, EN 13941, EN 14419, EN ISO 5817 as well as local standards and norms.
Recommended technical rules: German guidelines AGFW FW401, FW446, FW601, FW602
Recommended guidelines: Euroheat & Power Guidelines for District Heating Substations

Medium pipe: Steel pipe according EN 253
Insulation material: Thermal conductivity Lambda ≤ 0.03 W/mK, polyurethane hard foam > 60 kg/m³,

Jacket pipe: Polyethylene high density, according EN 253
Pre-insulated pipes must be equipped with **leak detection wires**.

6.2 Costs indicators of EE measures

Based on practical experience the following cost indicators can be applied for an initial estimation of investment costs. All listed information is available at the Covenant of Mayors – Demonstration projects website (http://com-dep.enefcities.org.ua).

- Natural gas boiler: 30-70 Euro/kW (incl. installation and control system)
- Solid fuel boiler (wood chips) < 500 kW: 200-300 Euro/kW (incl. installation, control system, fuel feeding system)
- Solid fuel boiler (wood chips) 500 – 2,000 kW: 100-200 EUR/kW (incl. installation, control system, fuel feeding system)
- New pre-insulated pipes < DN 100: 120 - 150 Euro/m of pipe trench[9] (pipes, ground works, hot laying technic)
- New pre-insulated pipes DN 100 – DN 200: 150 - 200 EUR of pipe trench[10] (pipes, ground works, hot laying technic)
- Individual heat substation < 100 kW: 100-130 EUR/kW
- Individual heat substation 100 – 300 kW: 50-100 EUR/kW

7 Special requirements of biomass boiler systems

7.1 Project concept phase

The concept phase of a project is of highest importance, mistakes made in the early stages are likely to have substantial cost implications in the following project phases, so it is worth taking time to consider the options carefully.

Usually some of the questions below must be considered:

- What is the current heat load/demand of the district heating system? What will be the future heat load/demand (thermal refurbishment of buildings, connecting new consumers, disconnecting by old consumers)?
- Is the heat load and pattern of the demand of the heat consumers suited to a biomass system? *Biomass boilers work most efficient when they are operated close to their operating capacity (75 – 100 %). Biomass boiler systems for sites with low heat demand or where loads are highly variable must be assessed very carefully.*
- Is there a suitable fuel supplier in the area and at what costs?

[9] 1 m pipe trench consist of 1 m pipe for supply flow and 1 m pipe for the return flow

Access to high quality fuel, preferably from a range of suppliers is vital. Comprehensive fuel standards exist to ensure that boilers are fed properly. Poor quality or incorrectly specified fuel is a common cause of operational problems of biomass systems.

- Is there enough space to accommodate the boiler and a fuel storage?
  Biomass boilers are considerably larger than their fossil fueled counterparts and thermal buffer tank and ancillary equipment will also require more space. Wood fuel is less energy dense than oil or coal so there also needs to be sufficient space for storage.
- Is there access to the site for delivery vehicles and space for them to turn and maneuver?
  A sufficient amount of biomass fuel has to be stored at the site, typically one month supply. It is highly recommended to consider a sheltered fuel storage (roof, concrete or paved surface). Sufficient space for trucks to unload fuel is required.
- Will all legal requirements and other regulations to be applied for the location of the boiler house be met (emission limits, noise, fire protection, chimney height, general safety regulations, ash disposal, etc.)?
- What are the estimated investment costs/operational costs?
- Can the biomass system be operated economical successfully?

In case the project concept was elaborated carefully and assessed positively, the project can be further developed.

7.2 Dimensioning of a biomass boiler

Biomass boiler systems have a different characteristic than natural gas boilers. In general, biomass systems require higher investment costs than conventional (i.e. gas fired) boiler systems, but the operational costs (mainly fuel costs) are lower compared to natural gas or fuel oil.

Natural gas boilers have the ability to modulate their output to cope with different levels of demand. Biomass boilers are less responsive as the heat generation in the combustion chamber cannot be stopped or adapted immediately. Boiler sizing is critical and has implications for every other element in the system (dimensions of pipes, valves, pumps, chimney, etc.). Oversized boilers are less efficient, have higher emissions and will add significantly to the project costs.

The table below shows the main differences of biomass boiler systems compared to conventional systems (natural gas boiler system):

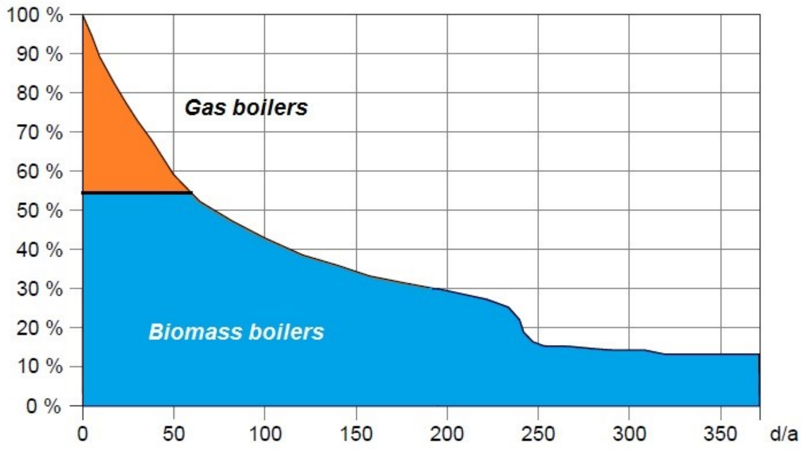
Criteria	Natural gas boiler systems	Biomass systems
Investment costs	low to moderate	moderate to high
Fuel costs	high	low
Boiler staff	low requirements	well trained staff required
Fuel quality	no requirements (standardised fuel)	high quality requirements (water content, size, origin of the fuel, etc.)
Potential to optimise heat production costs	very limited, due to the dependence on the natural gas price	high potential of optimisation of the heat production costs (type of fuel, time of purchasing the fuel, fuel quality, etc.)

Space requirements	moderate	relatively high (boiler size, fuel handling, fuel storage)
Load variation	0 – 100% of max capacity	30 – 100% of max capacity

In boiler planning a distinction must therefore be made between the **base load and peak load.** Usually biomass boilers cover the base load (approx. 50-60% of the maximum heat load of the district heating system) and the peak load will be covered by a conventional natural gas boiler. The main goal is to achieve more than 2.000 full load operation hours of the biomass boiler (annual produced heat energy in kWh/nominal capacity of the boiler in kW). Both boilers should be controlled by a centralized control system (also called load management system), see chapter 7.4.

A thermal accumulator tank (accumulator tank see chapter 5.2.4) is recommended to increase the heat production from the biomass boiler. Such a system will be able to provide 80 to 90% of the entire heat demand by the biomass boiler system. Only high peak loads need to be covered by the natural gas boiler.

The figure below shows a typical load – duration curve (incl. summer operation) and the allocation of the biomass boiler system and the natural gas boiler system.



7.3 Fuel logistics

7.3.1 Choosing the right fuel

The first step is to decide on the type of fuel and its characteristics for the biomass boiler system. The fuel should be available in the region. It is strongly recommended to use international standards such as ISO 17225 to define the fuel characteristics. The type of fuel and its characteristics must be included in the tender documents for the biomass boiler.

The table below shows the classification for wood chips for small to medium biomass boilers based on ISO 17225-4 (Solid biofuels - Fuel specifications and classes - Part 4: Graded wood chips).

Class	Main fraction >60% in mm	Max fine fraction (<3,15 mm) in %	Max coarse fraction in %	Max length of chips in mm	Max area of cross section of chips in mm²
P16	3,15mm ≥ P ≤ 16mm	≤ 15%	≤ 6% bigger than 31,5mm	≤ 45mm	≤ 2 cm²
P31	3,15mm ≥ P ≤ 31mm	≤ 10%	≤ 6% bigger than 45mm	≤ 150mm	≤ 4 cm²
P45	3,15mm ≥ P ≤ 45mm	≤ 10%	≤ 6% bigger than 63mm	≤ 200mm	≤ 6cm²

Experiences for more than 30 years show that the type and **quality of the fuel** is the main cause for operational problems. The most important characteristics for biomass fuels are the origin (type A: virgin woods and chemically untreated wood residues, type B: materials from gardens and chemically treated and untreated industrial by-products and residues) particle size, water content in %, ash content in %, bulk density in kg/loosen m³, chemical components.

For small and medium size biomass boilers (**up to 1 MW capacity**, fuel supply by screw conveyors) the following fuel is recommended (specification according to ISO 17225-4):

- **Wood chips Typ A (virgin wood)**
- **Water content < 35%**
- **Particle class P31**

Picture 28: High quality wood chips (small fine fraction, uniform particle size, source: virgin wood)	Picture 29: Poor quality wood chips (high fine fraction, particle size very different, source: wood residues)
	

Larger biomass boiler systems (> 2 MW capacity) that are equipped with a grate furnace, hydraulic push conveyor and moving floor can usually handle a wide range of biomass fuels (sawdust, wood chips, by products from wood processing industry with various particle sizes) and fuel with a water content of up to 55%.

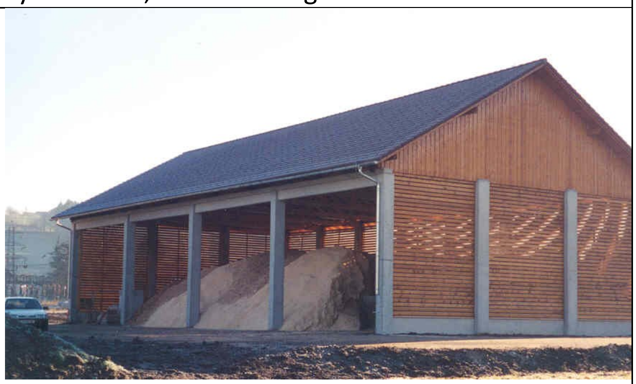
Typical prices for biomass fuel in Ukraine:

Type of fuel	Price	Comments on energy price per MWh
Wood chips	30 – 43 EUR per t	Example 1: Water content 30%, 40 EUR per t → 11,6 EUR / MWh Example 2: Water content 45%, 40 EUR per t → 15,5 EUR / MWh Please note that the water content is a key parameter for the energy content of biofuels.
Agricultural pellets	65 – 80 EUR per t	Example 3: Water content 15%; 80 EUR per t → 18,2 EUR / MWh Please note that the water content is a key parameter for the energy content of biofuels.
Forest based pellets	90 – 120 EUR per t	Example 4: Water content 8%; 110 EUR per t → 22,9 EUR / MWh Please note that the water content is a key parameter for the energy content of biofuels.

7.3.2 Fuel storage

The biomass fuel has to be stored at the boiler house for several weeks. It is recommended to consider a fuel storage supply for at least 1 month of operation as weather conditions in winter can be rough, fuel not available or transport could be difficult. The fuel storage must provide sufficient protection against rain and snow (proper roof, walls should be semi closed at least on 2 or 3 sides), the floor should be paved.

The fuel storage for small boiler systems can be integrated into a building, larger systems need a separate fuel storage.

Picture 30: Fuel storage inside a building (small boiler systems) – 160 m³ storage volume	Picture 31: Fuel storage for larger biomass systems – 1,800 m³ storage volume
	

7.3.3 *Fuel manipulation, fuel supply to the boiler*

Usually the biomass fuel will be delivered by trucks or by a tractor with trailer to the boiler house. After unloading, a tractor with front-loader (or similar vehicle) should be used to move the fuel inside the fuel storage and the fuel bunker of the biomass boiler, and therefore sufficient space should be available for such maneuvres.

Typical fuel feeding system for small biomass boilers (< 300 kW):

Recommended fuel type: high quality wood chips from virgin wood, main fraction 3 – 31 mm, water content < 35% (Classification according to ISO 17225-4: wood chips P31S, A2)

Recommended fuel feeding system: spring blade agitator; screw conveyor (diameter >150 mm) to the boiler.

Advantage: various design options for fuel bunker and boiler; low investment costs

Disadvantages: good fuel quality required (uniform wood chips), vulnerable to stones and soil materials

Picture 32: Fuel bunker, spring blade agitator	Picture 33: screw conveyor to boiler
	 Fuel storage: open canal with screw conveyor to the boiler (in the fuel storage)  From fuel storage to boiler (closed screw conveyor)

Typical fuel supply systems for medium/large biomass boilers (> 500 kW):

Recommended fuel type: wood chips from virgin wood and chemically untreated industrial by-products, main fraction 3 – 45 mm, water content < 40% (Classification according to ISO 17225-4: wood chips P45S, A to B2).

Recommended fuel feeding system: moving floor in the fuel bunker; screw conveyor (diameter >200 mm) to the boiler.

Advantage: various design options for fuel bunker and boiler; moderate investment costs

Disadvantage: screw conveyor is vulnerable to stones and soil materials, high fuel quality required (uniform wood chips).

Picture 34: Fuel bunker, moving floor	Picture 35: Moving floor and screw conveyor to boiler
	

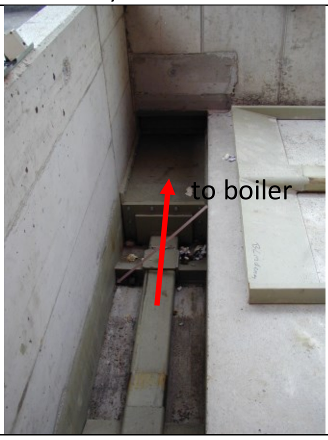
Typical fuel supply systems for large biomass boilers (> 1.000 kW) with grate furnace:

Recommended fuel type: wood chips from virgin wood and chemically untreated industrial by-products, main fraction 3 – 45 mm, water content < 40% (in exceptional cases up to 50%). Classification according to ISO 17225-4: wood chips P45S, A to B2.

Recommended fuel feeding system: moving floor in the fuel bunker; hydraulic push conveyor to the boiler or similar industrial conveyor systems. Please note that fuel feeding systems using chain conveyors comprise of many moving metal parts which are subject to a severe wear (regular check and replacements needed).

Advantage: very robust system; can handle various fuel types incl. individual larger pieces or wood; small stones and soil materials usually do not stop the operation.

Disadvantage: relatively expensive; the fuel bunker is usually situated 90° to the boiler

Picture 36: Fuel bunker, moving floor	Picture 37: hydraulic push conveyor to boiler (robust system, can handle various wood fractions)
	

7.4 Control system of a boiler system comprising of gas boilers and biomass boilers

Biomass boiler systems have a different operational characteristic than natural gas boilers as explained in the previous chapters. In order to combine the advantages of biomass boilers (low fuel costs) and natural gas boilers (low investment costs, operation mode between 0 and 100% of the full boiler capacity) the following principle should be applied:

Base load to be covered by the biomass boiler 50-60% of total heat load

Peak loads (and backup system) to be covered by the natural gas boiler

This requires a control system that controls both boiler systems (also called load management system). The control system has to meet the following requirements:

- Controlling the entire boiler system (biomass boilers, gas boilers). Each boiler can have its subordinated boiler control system, but often the control system of the biomass boiler works as a load management system that manages the gas boiler as well (the control system of the biomass boiler switches the gas boiler ON/OFF as required by the district heating system)
- The control system has to ensure that the biomass boiler will be operated as priority (→ 80-90% of the total heat demand will be covered by the biomass boiler)
- The gas boiler will be switched ON (automatically by the load management system) only if the biomass boiler cannot cover the heat load of the district heating system for a certain period of time (e.g. 1 hour).
- The gas boiler has to be switched ON in case the biomass boiler has a breakdown.

It is recommended to include a thermal storage tank, in which case the load management system will use the temperature sensors of the storage tank for controlling the system, see also Chapter 5.2.4.

8 Procurement of equipment and services

The procurement procedures are crucial as they form the contractual basis for the implementation of the project. Although each country has its own procurement legislation and specific regulations the following principles shall be considered:

- Development of detailed and accurate procurement documents
  The works and services to be procured must be developed in all details and must be described sufficiently. In particular, key technical characteristics of the equipment must be included.
- Harmonisation of all procurement documents
  The information in technical drawings must be in line with the technical descriptions/technical specifications and the bill of quantity. Often those documents contain contradictionary information, which could lead to complaints and delays during the tender procedure.
  In the event of conflicts between the project documents, the following sequence shall be agreed:
    - Contract incl. general terms of condition
    - Technical drawings and schemes
    - Bill of Quantity
- Including general conditions into the tender documents
  It is recommended to include general conditions in the tender documents which could describe some general procedures such as:
    - **Prove, warn and advisory obligation** of the Contractor during project implementation
      The Contractor is obliged to inform the Contracting Authority in written form about circumstances that could lead to defects or damages. This obligation applies not only on the services and works implemented by the Contractor himself, but also on services and works implemented by other companies on the construction site he is aware of.
    - **Survey of the existing situation (surfaces, etc.)**
      The Contractor must take evidence of the construction site prior to the construction works (i.e. foto documentation, description of the defects). The document should be signed (and a copy provided to) by the following parties: Contractor, Project Team or Municipality.
    - **Changes of services and works during the construction – Change Order**
      The Contracting Authority is entitled to change the contracted services and works by a Change Order. The Contractor has to submit his Change Proposal prior to the implementation of the works and services. The Contractor shall include detailed breakdowns of labor and materials for all trades involved and the estimated impact on the implementation schedule. The offer must be approved by the Contracting Authority prior to the implementation of the works and services by the Contractor.
      Works and services implemented without written approval by the Contracting Authority cannot be invoiced.
      For an example of general conditions see Annex G.
- It is recommended to contract only experienced and reliable companies, and include minimum criteria for experience and operational and financial capacity as selection criteria.

9 Operation and maintenance of district heating systems

Customer satisfaction is essential for maintaining and increasing the market position of district heating provider. Guaranteeing a smooth and economically efficient operation of the district heating supply requires regular inspection and maintenance of the main components. Although the boilers, substations and pipes are extremely reliable and have a long technical lifetime, it is recommended that specialists should undertake regular inspections to optimise the operation. Apart from ongoing maintenance work, developing malfunctions will be recognized and eliminated at an early stage.

It is recommended to elaborate a maintenance schedule for the equipment installed. The manufacturers shall provide for the delivered equipment detailed documentation and a maintenance schedule. Furthermore, the manufacturer shall provide sufficient training to the staff for key equipment such as boiler operation, control system, pumps, water treatment equipment, etc.

Example maintenance schedule:

Example maintenance plan:

Component	**What to do**	**Who**	**Interval**
Filter F1	Cleaning		Every 2 weeks
Pressure sensor 1 of heating system	Check pressure		Every week
Water quality in the heating system	Analyse PH value, Oxygen, and Alkaline		Once a year
Ventilation units	Change filters		Once a year
….			

The delivery of a detailed technical documentation (operational manuals, installation scheme, design parameter, control logic, maintenance plan, etc.) and training shall be included in the tender documents to ensure that the contractor provides such documents.