Technology Collaboration Programme
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IEA DHC

International Energy Agency
Technology Collaboration Programme on
District Heating and Cooling

ANNEX TS 6 – ANNEX TEXT

STATUS ASSESSMENT, AGEING, LIFETIME PREDICTION AND ASSET MANAGEMENT OF DH PIPES

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ABOUT THE INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA) is an intergovernmental organisation that serves as energy policy advisor to 28 member countries in their effort to ensure reliable, affordable and clean energy for their citizens. Founded during the oil crisis of 1973-1974, the IEA was initially established to coordinate measures in times of oil supply emergencies.

As energy markets have changed, so has the IEA. Its mandate has broadened to incorporate the “Three E’s” of balanced energy policy making: energy security, economic development and environmental protection. Current work focuses on climate change policies, market reform, energy technology collaboration and outreach to the rest of the world, especially major consumers and producers of energy like China, India, Russia and the OPEC countries.

With a staff of nearly 200 who are mainly energy experts and statisticians from its 28 member countries, the IEA conducts a broad program of energy research, data compilation, publications and public dissemination of the latest energy policy analysis and recommendations on good practices.

ABOUT IEA DHC

The Energy Technology Initiative on District Heating and Cooling including Combined Heat and Power was founded in 1983. It organizes and funds international research which deals with the design, performance, operation and deployment of district heating and cooling systems. The initiative is dedicated to helping to make district heating and cooling and combined heat and power effective tools for energy conservation and the reduction of environmental impacts caused by supplying heating and cooling.

CONTENT

1 DESCRIPTION

Today District Heating (DH) utilities are forced to work on status assessment and lifetime prediction while a large number of pipes in the DH systems are close to the expected service lifetime according to the design.

Consequently, DH organisations have to think about suitable maintenance strategies. Additionally, they must also work on the transformation of their DH systems towards the increased use of renewable energy sources.

To solve these issues, there are several national research projects working on the improvement of knowledge of status assessment, accelerated ageing and models for lifetime predictions.

The annex task shared 6 “Status assessment, ageing, lifetime prediction and asset management of District Heating (DH) Pipes” intends to initiate a collaborative work within the International Energy Agency’s (IEA) Implementing Agreement “District Heating and Cooling including CHP” (DHC) aiming at an initiative to identify holistic and innovative approaches to aging and lifetime prediction of DH pipes.

Regarding preinsulated bonded pipes status assessment, accelerated ageing and lifetime predictions of buried pipes are described in EN 253, EN 448 and EN 13941. The findings of Swedish and German research have led to a complete deletion the relation of lifetime at operative temperature and time of accelerated ageing tests of DH pipes in the European Standard EN 253. A verified replacement of this testing method is currently not available.

As plastic service pipes are used for district heating for more than 35 years, practical experience could be gained from various installations, which are important for existing and new installations. It is expected that plastic pipes will be more and more used in the 4th Generation DH systems and lifetime of up to 100 years can be achieved.

Besides the tasks to improve the knowledge of aging processes and lifetime prediction, there is a need to revise the current standards to gain more realistic results. Asset management tools based on this enable utilities to develop targeted strategies for decarbonising district heating systems in addition to predictive maintenance.

2 SCOPE AND OBJECTIVES

2.1 SCOPE

While the status of buried DH Pipes is difficult to evaluate, the scope of the Annex Task Shared Project should be on buried DH pipe systems. The leading questions are:

- How are obsolete pipes defined?
- How is this measured?

Further investigations, current research results as well as promising approaches should be on:

- Aging processes in DH pipes
- Models and approaches for lifetime prediction
- Documentation of operating conditions
- Testing methods for status assessment and methods for estimating remaining service life of DH pipes
- Additional: Evaluation of DH pipes in existing networks in participating countries

These topics are included in the sub task structures of the TS project for both pre-insulated pipes and the new generation with plastic service pipe.

2.1.1 PIPING SYSTMES

The directly buried heat pipeline

- concrete ducts
- pre-insulated bonded pipes with steel service pipes (mainly Single pipe, if needed Twin pipe)
- Flexible pipes / plastic service pipes

2.1.2 RELEVANT AGING MECHANISMS

Based on the results of the participant forms, the main aging mechanisms are:

- Corrosion of steel caused by oxygen and water:
  - Corrosion under insulation layer
  - Corrosion inside service pipe
- Damage accumulation of service pipes due to low cycle fatigue.
- Degradation of PUR foam (11 times mentioned)
  - thermal aging (7 times mentioned)
  - -thermal oxidative aging (7 times mentioned)
  - additional relevant characteristics:
    - chemical aging (water contact of PUR foam) (4 times mentioned)
    - mechanical aging (fatigue)
    - The shear strength deterioration can due to loss of adhesion cause further damage on the service pipes at bends or T-pieces

2.1.3 CRITICAL COMPONENTS OF THE PIPE SYSTEM

Based on the results of the participant forms, the critical components are:

- Polyurethane foam
- Joining systems for the pipes
  - Joints
  - Welded areas
  - fittings
  - Branch connections (2 times mentioned),
  - reducing pieces

- Steel Pipes
- Components of the piping systems
  - Compensator
  - Elbow
- The pipe assembly itself
- Casing

2.2 OBJECTIVES AND CHALLENGES

Main objectives and challenges are:

- Improve knowledge about aging processes in DH pipes
- Methods for estimating of remaining lifetime of DH-pipes in use need to be developed.
- Models for predicting lifetime need to be developed.
- Besides the models an approach is needed to reduce the amount of pipe samples to evaluate the whole system. The challenges are selecting the representative pipe samples for DH networks and data processing rule for numerous results from each sample
- Better documentation of the operating conditions (annual operating hours per operating temperature)
- Effective technical means for pipeline corrosion detection and establishment of database.
- Access to environmental (e.g. soil, groundwater) and weather data with respect to operating conditions and backward extrapolation/simulation of historic operating conditions where data is lacking/not documented

2.3 BENEFITS

- DH utilities benefit the Sustainable Development Goals (SDG) i.e. Goal 9- Affordable and clean energy, Goal 11- Sustainable cities and communities, Goal 12- Responsible consumption and production, Goal 13- climate action, Goal 17- Partnerships for the goals

- The work serves as a basis for standards and recommendations (support to technical committee and working groups)
- Strengthening “IEA-DHC”TS-Projects as international R&D Platform

2.4 RESEARCHE ISSUES

Based on the results of the participant forms, the main research issues are:

- Aging processes and impact of different parameters, especially operating conditions
- Status assessment
  - Database
  - Methods for testing the relevant material properties
  - Approach for represented testing’s in DH systems
  - Pipeline leakage monitoring system based on resistance and impedance principle
  - Optical fibre leakage monitoring system
  - Buried pipeline detection based on passive micro magnetic technology
- Lifetime predictions
  - Models need to be improved → gain reliable results
  - Approach for missing data
    - Operating conditions
    - starting values of material properties
    - environmental (e.g. soil, groundwater) and weather data
- Asset management
  - Tools for testing at field and handling the amount of information needed for reliable lifetime analysis

- How to adapt tools on specific needs / systems of users
- Improved simulation of aging behavior for better lifecycle analyses and asset replacement scenario evaluations

• Future perspective

- How are developments / transformation of DH systems from the current one to the new generation effects on models (aging, lifetime prediction and asset management)
- How are future operation conditions be used for building new improving existing DH pipe systems

3 MEANS

The discussions during the workshops (online) of the TS 6 project figured out the importance of six sub tasks.

A: Status assessment

B: Aging of DH pipes

C: Lifetime predictions

D: Asset Management

E: Future perspective

F: Dissemination

The connection of the proposed sub tasks are visualized in figure 1. In order to improve the existing methods and modells for asset management of DH pipes, further investigations in status assessment and aging mechanisms of DH are needed. Based on the results models for lifetime predictions have to be improved as well as to be evaluated through further testings in the field. The future perspective of the DH system as well as the piping technologies used need to be taken into account for managing the assets from a system oriented point of view.

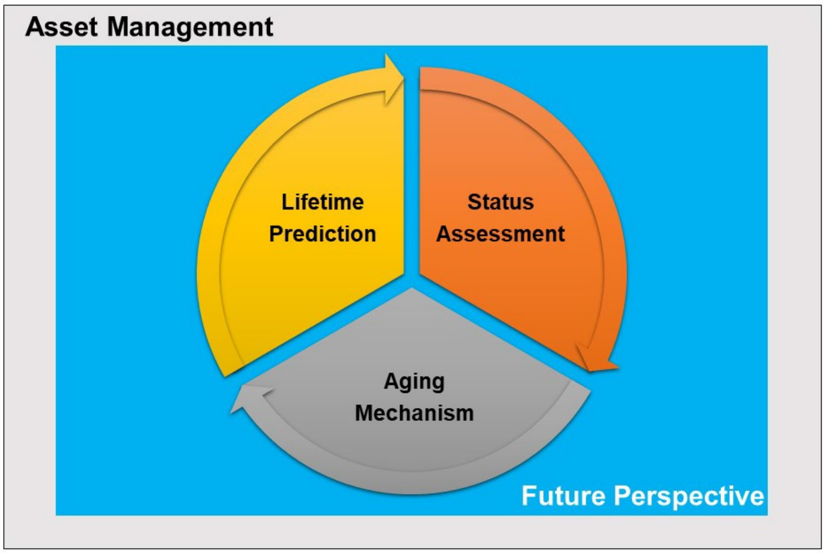

Figure 1: Schematic dependency of the sub tasks

3.1 SUBTASK A: STATUS ASSESSMENT

The status of a DH-pipeline depends on the local load spectrum and the involved material of the system. This involves the pipe materials and the bedding situation in the trench (groundwater yes or no etc.).

- Approach used in DH companies
    - Analyses damage statistics and operating conditions → aging behavior
    - Durability characteristic (operating years, field manufacturing components, etc.)
    - Influence characteristic (diameter, bedding position (crossing river, highway, or railroad, soild, groundwater etc.)
    - Heat losses along a pipe could be simulated with hydraulic models and using also the loss of insulation due to foam aging over time.
- Available technologies for status assessment
    - Thermographic check
    - Surveillance System Resuls
    - Simulation Models → Fatigue Analysis
    - Test method (SP Plug Method or mobile shear test equipment)
    - Chemical and physico-chemical test methods (thermogravimetry, IR-spectroscopy, Raman spectroscopy, dynamic mechanical analysis, etc.)

3.1.1 COLLECTION OF RESEARCH QUESTIONS

The research questions:

- How can we describe the status of a DH-pipe?
- Which physical or chemical parameters can be used as indicators?
- How can we determine these parameters in the field and in the lab?
- Are there already existing methodologies and do they cover all relevant indicators?
- How do different aging processes (e.g. fatigue and thermo-oxidative degradation) interact?
- How can we use a leakage detection system for such purpose?

- Can we develop a holistic method to obtain a realistic status assessment?
- How can real-time simulations and approaches to digitization contribute to improving the status assessment?
- Which monitoring methods / measurement methods are most suitable for the status assessment? Which are reliable? Which are easy to install and maintain? What about non-destructive methods?
- At present, based on the service life of the pipeline and the number of failures in previous years, the experience to determine whether the pipeline should be renovated.

3.1.2 OBJECTIVES

Investigate which types of pipe failures occur in the district heating networks and pertaining the frequency. This work demands the network owners keep a failure register.

Categorize if the failures are related to installation, operation, design or site conditions.

Categorize the ageing mechanisms behind the failures

Evaluate existing methods for status assessment

Limit the work to pre-insulated straight district heating pipes.

Development of a quick and easy to handle field test method for status assessment based on RISE Pipeopsy method. This method allows status assessment by use of the mechanical testing and chemical analysis. Shear strength is measured without heavy equipment and without causing major restoring work by use of RISE Plug method and complementary analysis of the plugs is carried out with Fourier-transform infrared spectroscopy (FTIR) for investigating of degradation of PUR insulation. Further investigation is needed to couple the measured status of pipes with various manufacturing method in order to get an international verification and acceptance to create a standard test method.

Development of trenchless pipeline damage/lifetime detection techniques to make reliable evaluation of the safe operation status, implement risk assessment, and integrity management of the buried pipes.

3.1.3 MAIN WORK ITEMS

- A.1: Give a survey of types of DH networks and their share
- A.2: Pre-insulated bonded pipes
- A.3: Flexible district heating pipes

- A.4: Concrete ducts for district heating
- A.5: Quantify the status of district heating (DH) networks in participating countries

3.1.4 DELIVERABLES

No.	Description	ref. to WI
D.A.1	Collection of methods for status assessment of different DH Pipes (A1, A2, A3) including value/characteristic of the materials; possible usage for lifetime predictions; reliability of the approach/method; possible improvements of test methods increase the reliability of the results	A.2, A.3, A.4
D.A.2	Demo case: report on testings in the field for different types of pipes	A.2, A.3, A.4
D.A.3	Approach for the evaluation of the status of DH pipes in DH grids (f. e. priorisation of pipes based on the security of supply, age of pipes, damage statistics of DH companies…)	A.2, A.3, A.4

3.1.5 CONTRIBUTION

Country	Organisation	ref. to WI
Sweden	Öresundskraft AB	**A**
Germany	HafenCity University	**A.2, A.3**
Sweden	RISE	**A.1, A.2, A.3, A.4, A.5**
Sweden	**Halmstad University**	A.2, A.4
Germany	AGFW	**A.2, A.4**
Austira	Austroflex Rohr-Isoliersysteme GmbH	**A.3**

3.2 SUBTASK B: AGING OF DH PIPES

The ageing of a DH-pipeline depends on the local load spectrum and the involved material of the system. Steady state conditions age the system differently than time dependent changing loads. However, sometime the differences are small and steady state conditions simplify test conditions and calculation.

The focus of the discussions during the initial web meeting as well as the answers of the participant form regarding the aging of the DH pipes are on the service pipe and on the thermal insulation.

In most cases, damage accumulations in the area of low cycles fatigue are used to estimate the ageing of the service pipe. The linear approach according to Palmgren-Miner is widely used.

If steel is used as the carrier pipe material, corrosion is a mechanism that affects the service life. For the degradation of the PUR foam thermal aging and -thermal oxidative aging are well known. Additional relevant mechanism causing chemical and mechanical aging processes are still part of research projects. While there is a need to revise the current standards and recommendations of the pre-insulated bonded pipes, a main focus in this subtask is on the aging of PUR foam.

Degradation of DH pipes due to ageing, determines of the pipe's weakest part.

- Degradation of PUR foam
    - thermal aging and -thermal oxidative aging
    - additional relevant characteristics: chemical aging and mechanical aging
- Corrosion at steel caused by oxygene and external water
- Damage accumulation due to low cycle fatigue

3.2.1 COLLECTION OF RESEARCH QUESTIONS

Service lifetime of district heating pipes is subjected to increasing concerns from all over the world when we approach the estimated lifetime, partly due to considerable uncertainties of testing method for status assessment of the pipe and partly for prediction of remaining lifetime associated to it. Lack of solid evidence bases in real ageing process and enough scientific studies do not allow us to establish a properly and acceptable standard method yet.

Research questions:

- Which processes cause ageing and how can these processes be modeled and accelerated?
- Studied phenomena should be expanded to include other mechanisms than thermo-oxidation of the foam and fatigue on the steel. What mathematical rules does ageing follow?
- Which tests can be carried out under constant conditions and which tests have to consider alternating loads?
- Is there a method that can be standardized?
- How to simulate the natural ageing process in laboratory?
- Is there an improvement in the laying, welding, and joining techniques?
- How can the interrelation of the different aging processes be evaluated and described?
- Is it possible to develop accelerated testing scenarios for determination of the interrelation coefficients?
- Do the lab determined interrelations correlate with in field long term data?
- Which process has the greatest influence on the ageing of pipelines in terms of thermal, thermal-oxidative, mechanical, and chemical ageing?
- How do they affect the DH-system?
- Is there a difference between the different types of piping (e.g., KMR, etc.)?
- Are there available operating strategies (e.g., changing the pipe for return and supply) or laying techniques (e.g., bedding materials) that can slow down ageing processes taking place?
- Does the aging of the PUR foam contribute to corrosion of steel?

3.2.2 OBJECTIVES

From earlier research projects it has been realized that the ageing of DH pipes is a complex scenario.

The PUR foam and its long-term performance is a key component. The foam is the “bridge-builder” between the service pipe and the casing - creating a bonded pipe system. The lifetime of the PUR and its mechanical properties is regarded to be strongly dependant on temperature and oxidation.

The aging load is a combination of temperature and oxidation load. LOGSTOR has been participating in earlier research programmes headed by AGFW and Rise. From these programmes it is realized that temperature and oxidation play a significant role but effects are not really quantified.

The ageing is complex scenario not only involving the PUR foam but needs to include the whole pipe assembly with use of barrier in the casing.

There is a need to develop the accelerated ageing test method of DH pipes which well describes its natural ageing process.

Conventional method was deleted in EN253:2019.

In real operation, the main source of loading in the ageing of PUR is the magnitude of temperature itself and the fluctuation of temperature. (Internal pressure of DH water and outer loading by soil weight is not considerable.)

The magnitude of temperature occurs chemical degradation and the fluctuation occurs mechanical one in PUR foam.

Beside temperature of service pipes, environmental surrounding influences the degradation of PUR due to presence of water vapor, available oxygen where the transmission rates are affected strongly by the temperature of the casing.

Further, the degradation products additionally may contribute to corrosion effects on the service pipe.

In IEA-DHC 12th research project (Effects of Loads on Asset Management of the 4GDH Networks), it researched durability of district heating pipelines exposed to thermal ageing and cyclic operational loads. There is a need to develop its test method into more sophisticated way.

The objective in subtask B is to ensure a key step in understanding ageing mechanisms and interactions with their relationship to remaining service lifetime and their effects on pipe maintenance by undertaking targeted, well-designed, and quality-controlled investigative studies.

The aim is to evaluate:

- Test method for effect of thermal and mechanical ageing in combination
- Laboratory test method and natural ageing regarding process and mechanism

3.2.3 MAIN WORK ITEMS

- B.1: Pre-insulated DH pipe- Develop and get acceptance for a relevant accelerated ageing test method based on combination of thermal and mechanical ageing
- B.2: Concrete and metal pipe- Understand relevant accelerated ageing test method
- B.3: Alternative material for each component in DH pipe- Investigate the ageing mechanism for new marketed material for DH-pipe
- B.4: Effects of ageing tests on status assessment for each kind of DH-pipe material
- B.5: Relevance of ageing tests on the other subtask
- B.6: Effect of new energy sources on ageing of DH-pipe- Influence of new energy sources on ageing mechanism

3.2.4 DELIVERABLES

No.	Description	ref. to WI
D.B.1	Acceptance of need for combination of thermal and mechanical acceleration aging test method Acceptance of relevant load for accelerated mechanical ageing test method as a ground for European and international standardization work	B.1

3.2.5 CONRTIBUTION

Country	Organisation	ref. to WI
Germany	HafenCity University	B.1, B.3
Sweden	RISE	B.1 – B.6
South Korea	KDHC	B.1
Germany	AGFW	B.1, B.4

Austria	Austroflex Rohr-Isoliersysteme GmbH	**B.3, B.4, B.5**

3.3 SUBTASK C: LIFETIME PREDICTION

Prediction of service life, especially for materials expected to perform reliably for many decades, is a challenge. Lifetime prediction of a district heating system has to consider different time dependent phenomena. Deterioration of single parameters can be observed, but it does not show the whole picture. A wide range of mechanisms for the degradation of polymer-based materials, metals and concrete includes thermal degradation, mechanical degradation, oxidation, chemical attack, creep and fatigue. To allow extrapolation of short-time data to predict long-term performance, an appropriate mathematical model must be applied through which the short-term values obtained at elevated temperatures and/or higher stresses can be recalculated to conditions of use. Methodologies that make a combined approach possible are needed.

For prediction of service life of different materials and components, associated input data and different models are needed. Therefore, the most dominant DH pipes are the focus of this subtask:

1. Buried pre-insulated bonded DH pipes:

Currently for the pipe assembly we are considering fatigue of the steel medium pipe, activation rate based on Arrhenius equation and statistical analysis based on damage statistics in order to do a lifetime prediction. The lifetime prediction has until now been assessed through a CCOT evaluation. Research has shown that this model does not reflect the effects of natural aging and the Arrhenius relationship, and the used assumptions as known has not covered the expected real ageing of the pipe assembly. It can be concluded that many factors affect the deterioration of district heating pipes, especially regarding the interface between polyurethane foam and the steel pipe, which makes it very difficult and complex to find a reliable prediction model. Extrapolation of test results from accelerated ageing tests using the Arrhenius equation requires knowledge about the processes involved in natural aging, their activation energies (E_a) and the interrelation of all processes. However, reliable information about E_a for degradation of PUR in DH pipes at operating temperatures is not available in the scientific literature. Lifetime predictions of DH pipes are actually based on accelerated ageing at far too high temperatures. The exposure of DH pipes to thermal aging under the influence of cyclic mechanical loads has only recently begun to be investigated and is even more complex and requires probably new calculation models.

- Standards and recommendations used

- EN 13941
- ASTM E1049-85
- EN 253
- "CCOT still plays a significant role, as it historically has been the method to be used for the assessment. As mentioned in EN253 it is not regarded as sufficient to describe the lifetime of the pipe system as the **"environment"** and the **circumstances** are more complex.

2. Flexible DH Pipes:

- In the flexible pipe systems, different materials are used for the carrier pipe, the thermal insulation and the polyethylene casing. Depending on the materials used, the pipe systems can withstand different operational loads and are therefore suitable for corresponding operating parameters. Standards and recommendations used
    - AGFW FW 420 Teil 1-5
    - EN 15632-2
    - EN 15632-3
    - EN ISO 13670
    - DIN16892
    - DIN 16893

3. Concrete Ducts:

In concrete ducts, the ducts take over the mechanical protection and contribute to the moisture protection of the pipeline due to their design. When sealing the concretes, the joint sealing as well as the connections to structures must be carried out carefully to protect the duct from moisture penetration. Since, in addition to the service pipe, support structures are also made of steel as bearings and expansion compensation elements, corrosion is one of the main factors limiting the service life of the trunking system. In addition, the fatigue of the steel because of temperature changes affects the service life of the pipeline system and compensation elements such as bends and expansion joints.

- Standards and recommendations used
    - DIN EN 1990

- VEB-Wärmeanlagenbau-"DSF": Komplexrichtlinie Wärmenetze. Teil I Wärmeleitungen. 1982.
- DIN AD 2000-Merkblatt B 13; Deutsches Institut für Normung e. V.; Juli 2012.

In order to concretize the work in subtask C we define boundaries as follows:

1. Subtask C will cover only components of distribution network
2. The main focus will be the lifetime prediction of the 3rd generation district heating pipes where rigid PUR foam is bonded in between a steel medium pipe in the centre and an outer casing pipe
3. Elaboration of mathematical models for lifetime prediction of metal and concrete pipes will be include
4. A transition to low temperature district heating opens for the use of new polymer-based media pipes, such as PERT (thermally resistant polyethylene), PP-R (polypropylene random copolymer) and PEX (crosslinked polyethylene). Development of prediction models for use of these materials in DH will be included.
5. Low temperature DH opens also for use of new insulation materials such as EPS (expanded polystyrene) and consequently the need to elaborate new prediction models.

3.3.1 COLLECTION OF RESEARCH QUESTIONS

1) What are the main phenomena responsible for deterioration of DH pipes?
   a) Which mechanisms are service life determinant?
   b) How can they be combined in a holistic model with a reasonable accuracy?
   c) How degradation mechanisms in straight pipes differ from curved pipes and do we have prediction methodologies for DH-pipes that deviate from straight pipes according to EN 253?
   d) How does the design (straight pipe, bending, and adaptor/flange) influence the degradation phenomena?
2) With a view to the digitization of district heating, what are suitable methods for predictive maintenance or failure detection?

3) Is it possible to use existing surveillance systems by a statistical approach for residual lifetime determination?

4) Which data is required for a proper predictive maintenance approach?

5) How can we correlate failure with service life of the pipe in the DH networks?

6) When we predict the lifetime of our DH networks, it should be done by testing a certain amounts of pipe samples to evaluate the whole system. The challenges are selecting the representative pipe samples for DH networks and data processing rule for numerous results from each sample. Besides evaluating the whole network, when we only evaluate the specific sample itself, we also need to reconsider the terminal value of shear strength. 0.12 MPa described in EN253 is based on 0.04 MPa (maximum design value) with safety factor 3 in EN13941:

    a) What are the current methods for testing technical lifetime of pipelines (simulation, test bench, field test/case study)?

        i) As part of which subtask an overview of simulation methods, test facilities, etc. could be collected?

        ii) Which subtask is this question assigned to?

    b) Methods for estimating of remaining lifetime of DH-pipes in use need to be developed and standardized:

        i) Can the two points above also be seen in the context of simulation and testing in the laboratory?

7) To have a proper credibility in lifetime prediction, how many samples would be enough for tests to be representative as the whole network?

8) How to transfer the scientific/laboratory approaches into practical applications with respect to the information available in the field?

3.3.2 OBJECTIVES

- Compilation of information on activation energies and how they have been produced
- Compilation of existing models for lifetime prediction
- Development of new models for lifetime prediction of DH pipes

- Development of new models for prediction of remaining service life of pipes in operation
- Development of a data framework for predictive maintenance
- Combination possibilities of the deterministic and statistic approaches for lifetime prediction
- Determination of the failure's driver on different shape of pipes (straight pipe, bending, and adaptor/flange) in the DH network.
- Development of a calibration method for the terminal value of shear strength of the test samples with respect to the network pipes.

3.3.3 MAIN WORK ITEMS

- C.1 Lifetime prediction of pre-insulated bonded DH pipes
- C.2 Lifetime prediction of new polymer-based media pipes and insulation materials
- C.3 Lifetime prediction of metal and concrete pipes

3.3.4 DELIVERABLES

No.	**Description**	**ref. to WI**
D.C.1	A collection of the state of the art of lifetime prediction methods and models for concrete ducts, pre-insulated, and 4th Gen. DH pipes	C.1, C.2, C.3
D.C.2	Collection of research results in order to identify knowledge gabs	C.1, C.2, C.3
D.C.3	Define border values for lifetime of several DH pipes	C.1, C.2, C.3
D.C.4	Improved calculation models for lifetime predictions	C.1, C.2, C.3
D.C.5	Data framework for predictive maintenance	C.1, C.2, C.3

3.3.5 CONTRIBUTION

Country	**Organisation**	**ref. to WI**
Sweden	Öresundskraft AB	**C**
Germany	HafenCity University	**C.3**
Sweden	RISE	**C.1, C.2**
Germany	AGFW	**C.1, C.3**
South Korea	KDHC	**C.1**

3.4 SUBTASK D: ASSET MANAGEMENT

Definition Asset Management according to ISO 55000

According to the Institute of Asset Management, there are 6 areas in an AM framework (see figure 2):

- Group 1: Strategy & Planning
  Focus on creation of Strategic Asset Management Plan (SAMP) and AM Plans based on AM policies, strategic objectives, and demand analysis
- Group 2: Asset Management Decision Making
  Focus on effective decision making for all stages of asset's life: acquisition/creation, operation and maintenance, end of life (decommissioning, disposal, renewal)
- Group 3: Lifecycle Delivery
  Focus on implementation of AM plans across the whole lifecycle
- Group 4: Asset Information
  Focus on information standards, information sources, information strategy and management
- Group 5: Organization & People
  Focus on AM leadership, organisational structures and cultures, AM competence management as well as procurement/supply chain management

- Group 6: Risk & Review
  Focus on risk assessment and evaluation by looking at resilience, sustainability, asset performance and health, costing & valuation

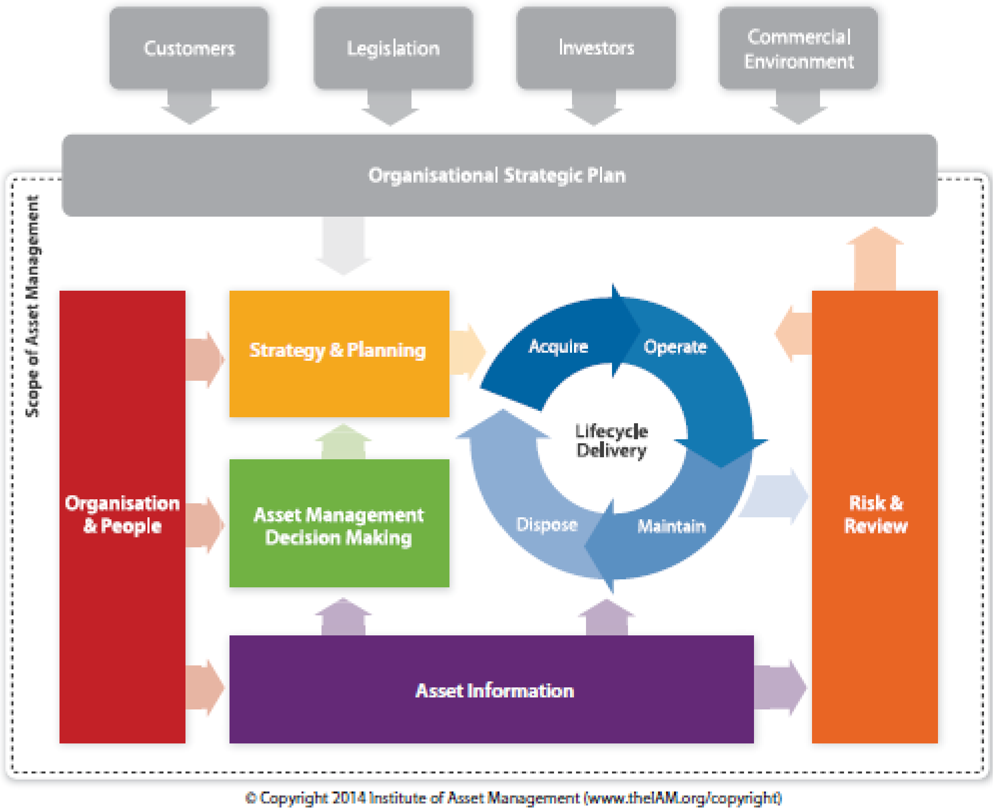

Figure 2: Asset Management Framework[1]

In the transition to industry 4.0, the communication among system components enables new strategies for asset management. A novel approach that commonly is being used in different industries is predictive maintenance. The advantages of the mentioned method not only increase the maintenance quality and system reliability, but also helps the environment via completing the service life of the components. Besides that, the maintenance activities could be very cost effective, and it minimize the unexpected changes in the system.

[1] From: Institute of Asset Management (2015): Asset Management - An Anatomy, Version 3, 84 pages, see: https://theiam.org/media/1486/iam_anatomy_ver3_web-3.pdf

An asset management strategy combining re-active and proactive views based on the importance/risk of assets is recommended. Supply reliability and economic restrictions should be considered as well. In order to improve asset management strategies a better documentation of network operation conditions is needed. Besides that, there is a need to build up reliable failure statistics that can be used for risk-based inspections methods.

Current software programme to support asset strategy simulations considering aging models and a risk-based assessment of single assets.

- Asset Management Strategies (statistics, operating conditions, aging models)
    - documentation of network operation conditions
    - documentation of failures
    - Based on the RBI (risk-based Inspection) method
    - An AM strategy combining re-active and proactive views based on the importance/risk of assets is recommended. Supply reliability and economic restrictions should be considered as well.

When one looks at damages/defects, it is often attributed to specific physical, chemical and other similar failure mechanisms. In this sub task other damages (due to external influences, poor construction/installation quality, ...) should not completely be ignored, even if there are more research questions for the other damages in relation to the other subtasks. In the context of asset simulations, one rather has to look at the whole picture.

For getting an improved asset management an intelligent status assessment is necessary. The existing wire technology or an implemented (light-)fibre technology could be used to determine changes arising from ageing processes aside from leakage detection. The intelligent use of such a (already existing) surveillance technology might push the asset management to a much higher level. In any case “big data” statistics also improve the Asset Management. Using hydraulic models will help to assess supply reliability (overall and for each customer) based on condition (status assessment, aging behaviour) also in order to improve risk assessment of the system and support decisions about maintenance activities.

3.4.1 COLLECTION OF RESEARCH QUESTIONS

In this sub task the following research questions should be answered:

- What are the challenges for AM in the future → DH networks 4.0, 5.0?
- What is required to rebuilt/modernize existing DH networks (2.0, 3.0) with respect to climate change?

- What does “predictive maintenance“ mean for DH pipes in the context of AM? What can be learnt from other industries?
- Which information sources are available to enable good AM-related decisions?
- What are tools for predictive maintenance?
- Which maintenance activities/measures, especially predictive maintenance actions, can be used in AM for DH pipes and how do they affect and/or extend service life?

3.4.2 OBJECTIVES

AM is defining the frame for all other sub tasks (see figure 1). Thus, an AM system for DH pipes should be described considering all other sub tasks

- A: Status assessment
- B: Aging of DH pipes
- C: Lifetime prediction
- E: Future perspectives

The AM system will include the description of inputs, outputs, relationships and interfaces between these sub tasks. This incorporates an overview of AM tools and methodologies for DH pipes.

It should be investigated how renewable energies respectively decentralized energy supply influences AM for DH pipes (effect on aging/lifetime?). This comprises also studies on the supply reliability of DH networks.

Another goal is the determination of carbon footprint of DH pipes over lifetime.

As part of an AM system for DH pipes a KPI system should be established with focus on technical, ecological, and economic indicators.

As part of the work in this Annex TS6 it is important to create links to other currently ongoing annexes, e.g., TS4 “Digitalisation of District Heating and Cooling” and TS5 “Integration of Renewable Energy Sources into existing District Heating and Cooling Systems”

3.4.3 MAIN WORK ITEMS

The following work tasks will be carried out to achieve the goals of Subtask D:

- D.1: Define AM processes within an AM framework for DH pipes and their relationship/interfaces; Describe data requirements, technologies/tools, inputs and outputs; show examples from other sectors and/or countries
- D.2: Develop a KPI system for DH pipes
- D.3: Assessment of carbon footprint for DH pipes over lifetime
- D.4: Improve asset simulations by incorporating results from status assessment, aging, lifetime prediction and future perspectives, demonstration for one example tool
- D.5: Further develop the IKOS [2] concept by considering supply reliability in AM simulations and the influence of decentralized renewable energy sources

3.4.4 DELIVERABLES

No.	Description	ref. to WI
D.D.1	Report on AM system for DH pipes	D.1
D.D.2	Report on KPI system for DH pipes	D.2
D.D.3	Methodology to assess carbon footprint for DH pipes over lifetime	D.3
D.D.4	Example AM simulation	D.4
D.D.5	Example IKOS simulation	D.5

3.4.5 CONTRIBUTION

Country	Organisation	ref. to WI

[2] IKOS: IKOS is an abbreviation of the German phrase „Instandhaltungskosten optimieren und synchronisieren“ which can be translated by the terms „Maintenance – Cost – Optimization – Synchronization”. IKOS was a research project within the Vattenfall R&D program TTP DS (Thermal Technology Program Distribution Systems) for the last 15 years.

Germany	HafenCity University	**D.3**
Sweden	RISE	**D.2**
Sweden	**Halmstad University**	**D**
Germany	3S Consult	**D.1 – D.5**

3.5 SUBTASK E: FUTURE PERSPECTIVE

For future heating networks, the reduction of the operating temperatures will determine the developments. Construction technology and DH-pipe systems will change with new requirements and different load spectra of future DH-systems. New materials, connection methods and backfilling will be used, which lead in combination with different loads to different ageing phenomena, changes in lifetime and the subsequent predictions and asset management.

It can be assumed that the reduction of the operating temperature will have a positive effect on the service life of existing pipelines. Similarly, the changes in operating temperature will have a similar effect on the pipe materials to be used.

How the transformation process of the heating networks to a larger number of volatile renewable energies will affect the life span of existing pipelines cannot be estimated at present. Further investigations are necessary to avoid endangering existing networks as the backbone of the heat supply and as a component of a successful decarbonization of the district heating systems.

With regard to status assessment, aging and lifetime prediction, the development of the digitalization of the district heating system is expected to have further positive effects. The availability of real time data will allow an improved and precise life cycle assessment. Currently, the possibilities and the degree of digitalization of future heating networks are difficult to estimate. However, it can be assumed that existing networks without digital elements will continue to be operated and will require greater attention from the perspective of remaining service life estimation. In a more digitalized DH system, the heat and temperature losses along the pipes could be used for status assessment.

Transferability of the gained experience from the 3rd gen DH networks might be key point to make future networks more secure, more reliable, and easy to maintain. Therefore, a knowledge transform framework would be advantageous to be planned for future developments.

It is very relevant question and will be more and more crucial when we talk about circular economy. It is a future research area, and it is important to determinate the quality of different recycled material which has potential to use in DH system.

3.5.1 COLLECTION OF RESEARCH QUESTIONS

- Which are the modern trends in DH to be considered for a general future asset management?
- Who do we have to modify the existing models for these new conditions?
- Is it possible to transfer the gained knowledge on aging of DH Pipes towards new DH pipes using different materials (for example new PUR foam)?
- The replacement and recycling of (old) pipelines could be very exciting, but maybe that is beyond the scope?
- What about hybrid energy network (possibly seen as part of a transformation process?)
- Maybe we should differentiate between transformation and digitization? Maybe also give a reference to Annex TS4?
- Transformation, digitalization and hybridization of DH (C) have a strong link to the annex but play only a minor role while working on it? Then maybe insert the corresponding activities in chapter 5 RELATED ACTIVITIES (Annex TS 2, TS3 and TS4?)
- How does the feed-in of volatile energy sources influence the piping in a future district heating system? How can older systems be upgraded for feeding in fluctuating energies? Is this even necessary?
- What influence does lowering the temperatures in the district heating system have on ageing?
- What should the future regulations for networks supplied by renewables sources look like?
- Are the current developed ageing models useful for 4th gen DH pipes?
- What are the possible statistical approaches for estimating service life of the 4th gen pipes?

3.5.2 OBJECTIVES

The reduction of DH network temperatures will have an impact on the service life of existing DH pipes.

- The reduction of DH network temperatures
  - Lower operating temperatures will be beneficial for the lifetime of the DH-systems. But still status assessment and lifetime prediction are important for maintenance
  - key advantage, especially for plastic systems (future Pipe systems)
  - Higher insulation series are to be expected as well as more twin pipe systems. All factor towards a more energy efficient system
- Transformation of DH (RES, new technologies [5G/machine learning])
  - transformation of DH and/or/both the feed-in of volatile/ fluctuating energy sources will have a major impact → not only pipes incl. fitting but also interaction between pipes/soil
- Transformation, digitalization and hybridization of DH (C) have a strong link to the annex but play only a minor role while working on it? Then maybe insert the corresponding activities in chapter 5 RELATED ACTIVITIES (Annex TS 2, TS3 and TS4?)
  - RES and the feed-in of volatile/ fluctuating energy sources (renewable energy)
  - more intelligent DH-systems / pipes will help the utilities to make timely and accurate decisions
  - apply the latest technologies such as big data analysis and machine learning

The transformation process of DH networks should also take into account assessment of environmental performance indicators, e.g., carbon footprint, need/use of resources to hopefully find the best transformation “path”.

In a more digitalized DH system, the heat and temperature losses along the pipes could be used for status assessment. At the moment these data are only available at specific points of the DH grid or as assumptions in connection with the delivered heat to the customer. In order the use these indicators for status assessment more real time data needs to be available.

3.5.3 MAIN WORK ITEMS

- E.1: Effect on future operation mode to lifetime of DH-System in general
- E.2: Effects of digitalisation on district heating systems
- E.3: Assessment of environmental indicators to identify the best transformation path

3.5.4 DELIVERABLES

No.	Description	ref. to WI
D.E.1	Documentation of on technical options with regard to future operation mode	E.1
M.E.1	Fact sheets as overview technical options and ongoing research with regard to future operation mode	E.1
D.E.2	Documentation of on technical options with regard to digitalisation	E.2
M.E.2	Fact sheets as overview technical options and ongoing research with regard to digitalisation	E.2
D.E.3	Fact sheets as overview technical options and ongoing research with regard to environmental indicators	E.3
M.E.3	Documentation of results with regard to environmental indicators	E.3

3.5.5 CONRTIBUTION

Country	Organisation	ref. to WI
Sweden	Öresundskraft AB	**E**
Sweden	RISE	**E.1, E.2**
Germany	AGFW	**E.1**

Austira	Austroflex Rohr-Isoliersysteme GmbH	**E.1**

3.6 SUBTASK F: DISSEMINATION

The main objective of Subtask F is the dissemination of the project results. This is to be achieved through the targeted dissemination of information to the international district heating sector. Target groups are research institutes, district heating supply companies, experts and engineering offices, component manufacturers and standardisation bodies.

The Dissemination strategy consists of four work items:

- Raising the awareness of the project, attracting further partners.

- Communication

- Interaction

- Documentation of the results

3.6.1 WORKITEMS

- Work Item F.1: Rising the awareness of the project
    - Social media like LinkedIn will be used to spread the information of the TS 6 project. All social media activities direct the interested persons to the official IEA DHC TS 6 webpage (landing page) where they can find further information on the IEA DHC TS and other IEA DHC activities.
    - Create an official IEA DHC TS 6 webpage (landing page)
    - Publications in relevant international magazines
    - Presentations on relevant conferences and workshops
    - Get in touch with relevant standardization bodies
- Work Item F.2: Communication (webpage)
    - The webpage will be used as a platform to share relevant information with the district heating community. Interested people will find the contacts of the

subtask leaders as well as results, presentations, and information about TS 6 events on the webpage.

- The content of the webpage will be updated regularly.

- Work Item F.3: Interaction (workshops, conferences, meetings)
  - It is planned to join relevant conferences like the IEA DHC Symposium or the EHP congress.
  - The IEA DHC TS 6 partners will meet online regularly, and it is planned to meet in personal twice a year. It is planned to organize workshops around these official TS 6 meetings, where results will be presented to interested people.
- Work Item F.4: Documentation (papers, articles, presentations, final report)
  - It is planned to publish first result of the TS 6 project in papers and journals.
  - Besides that the TS 6 Subtask Leader will check if it is possible to upload/publish presentations of meetings on subtask level on the official webpage.
  - It is planned to create a final report based on all results of the TS 6 project.

4 TASK MANAGER AND LEADS

Currently the first draft of the TS 6 annex text was elaborated and improved by

- Stefan Hay, German Heat & Power Association – AGFW e.V (AGFW)
- Associate Prof. Dr. Nazdaneh Yarahmadi, RISE Research Institutes of Sweden - Division Built Environment (RISE)
- Prof. Dr.-Ing. Ingo Weidlich, HafenCity Universität Hamburg – Infrastructure Engineering (HCU)

in cooperation with the participants of the TS 6 workshops. Stefan Hay has done the coordination of the TS 6 so far and is ready to take on the role of Task Manager.

During the preparation phase so far, the following experts have agreed to take the lead or co-lead in the subtasks:

Subtask A: Status Assessment of DH Pipes

- Lead: Heiko Below (IMA) & Andreas Leuteritz (IPF)
  Co-Lead: Jan Henrik Sällström (RISE)

Subtask B: Aging of DH Pipes

- Lead: Nazdaneh Yarahmadi (RISE)
  Co-Lead: Andreas Leuteritz (IPF)

Subtask C: Lifetime Predictions of DH Pipes

- Lead: Ignacy Jakubowicz (RISE)
  Co-Lead: Pakdad Langroudi (HCU)

Subtask D: Asset Management of DH Pipes

- Lead: Ingo Kropp (3S-Consult)
  Co-Lead: Andreas Büchau (Vattenfall Berlin Wärme AG)

Subtask E: Future Perspective of DH Pipes

- Lead: Anna Kallert (Fraunhofer IEE)
  Co-Lead: Alberto Vega (RISE)

Subtask F: Dissemination (Task Manager supported by the Subtask Leaders)

5 RELATED ACTIVITIES

6 TIME SHEDULE

Activities that will be carried out in the next 6 months

- Start working phase (1st April 2022)
- Virtual kick-off meeting (25th April 2022)
- Organize the collaboration on subtask level in detail, elaborate time plans with the contributing partners
- Find a possibility for a face-to-face meeting
- Spread the idea of TS 6 connect to / organize further workshops for the DH companies
- Connect the TS 6 project with other IEA DHC Task Shared Annexes (TS 4, TS 5) as well as other IEA initiatives like IEA SHC

2020	2021		2022		2023		2024		2025	
x	x	x	x	x	x	x	x	x	x	x
Defin	Preparation		Working Phase						Reporting	

Figure 3: Time schedule

7 FUNDING

8 PARTICIPANTS

The following organisations already send additional content or contributions to support the preparation of this TS Project:

- Beijing District Heating Group (China District Heating Association), China
- Fraunhofer-Institut für Energiewirtschaft und Energiesystemtechnik IEE, Germany
- Korea District Heating Corporation (KDHC), Korea
- AUSTROFLEX Rohr-Isoliersysteme GmbH, Austria
- LOGSTOR, Germany and Denmark
- RISE Research Institutes of Sweden - Division Built Environment, Sweden
- HafenCity Universität Hamburg – Infrastructure Engineering, Germany
- 3S Consult GmbH, Germany
- Leibniz-Institut fuer Polymerforschung e.V. (IPF Dresden), Germany
- Halmstad University, Sweden
- Öresundskraft AB, Sweden

The following organisations wants to be involved as observer of this TS Project:

- Powerpipe Systems AB, Sweden
- Vattenfall Berlin Wärme AG, Germany
- Energy Institute Hrvoje Pozar, Croatia

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