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Data sources: Rogers, E. M. & Shoemaker, F. F. (1971). Communication of Innovation. New York: The Free Press.

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1. General ambition

The European funded D2Grids project aims to define, demonstrate and commercialize a standard and replicable 5th Generation District Heating & Cooling (5GDHC) technology which can increase the share of RES & decrease GHG emissions in North-Western Europe (NWE). The project promotes modular "plug-&-play" components, as well as demand-driven supply of heat and cold at all levels, from early designs to operations.

To achieve this, the D2Grids project will aim to reach 4 objectives:

- Ensure the quality of products supplied by the industry
- Reduce the initial investment requirements (**long-term objective: -20%)**
- Train and educate all support functions (legal, finance, construction, etc.) to 5GDHC networks
- Build trust from potential investors and project developers

5GDHC networks rely on 4 main features:

- Low exergy demand can be supplied by low exergy heat sources: low temperature heat sources at 15-40 °C supply the network (shallow and mid-depth geothermal heat, minewater, riverbed, sea, heat recovery)
- A profusion of demand supplied by a closed heat delivery loop, enabling a better supply and a higher balance between hot & cold needs
- The coupling of electricity and heat grids to create a complete energy system
- New business models and services such as flexibility, transparency, proof of local production, prosumers, etc…

2. General innovation process

Innovations often face the same problems. The steps of an innovation can be visualized in the graphic below. This graphic is designed for product innovations in an existing market. With D2Grids, we are trying to extend the market and increase the market share in the renewable energy market.

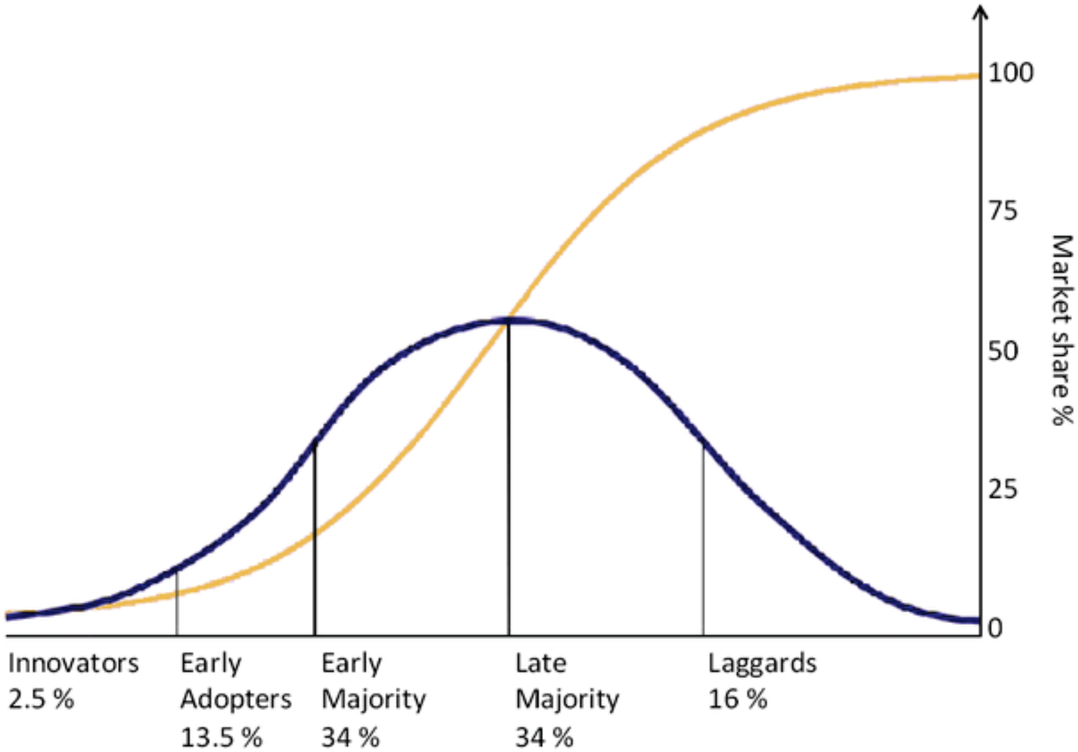

Figure 1: The diffusion of innovations according to Rogers. With successive groups of consumers adopting the new technology (shown in blue), its market share (yellow) will eventually reach the saturation level. The blue curve is broken into sections of adopters.

Innovators (2.5%) – Innovators are eager to try new ideas, to the point where their venturesomeness almost becomes an obsession. Innovators' interest in new ideas leads them out of a local circle of peers and into social relationships more cosmopolite than normal. Usually, innovators have substantial financial resources, and the ability to understand and apply complex technical knowledge. While others may consider the innovator to be rash or daring, it is the hazardous risk-taking that is of salient value to this type of individual. The innovator is also willing to accept the occasional setback when new ideas prove unsuccessful (Rogers, 1971).

Early Adopters (13.5%) – Early adopters tend to be integrated into the local social system more than innovators. The early adopters are considered to be localites, versus the cosmopolite innovators. People in the early adopter category seem to have the greatest degree of opinion leadership in most social systems. They provide advice and information sought by other adopters about an innovation. Change agents will seek out early adopters to help speed the diffusion process. The early adopter is usually respected by his or her peers and has a reputation for successful and discrete use of new ideas (Rogers, 1971).

Early Majority (34%) – Members of the early majority category will adopt new ideas just before the average member of a social system. They interact frequently with peers, but are not often found holding leadership positions. As the link between very early adopters and people late to adopt, early majority adopters play an important part in the diffusion process. Their innovation-decision time is relatively longer than innovators and early adopters, since they deliberate some time before completely adopting a new idea. Seldom leading, early majority adopters willingly follow in adopting innovations (Rogers, 1971).

Late Majority (34%) – The late majority are a skeptical group, adopting new ideas just after the average member of a social system. Their adoption may be borne out of economic necessity and in response to increasing social pressure. They are cautious about innovations, and are reluctant to adopt until most others in their social system do so first. An innovation must definitely have the weight of system norms behind it to convince the late majority. While they may be persuaded about the utility of an innovation, there must be strong pressure from peers to adopt (Rogers, 1971).

Laggards (16%) – Laggards are traditionalists and the last to adopt an innovation. Possessing almost no opinion leadership, laggards are localite to the point of being isolates compared to the other adopter categories. They are fixated on the past, and all decisions must be made in terms of previous generations. Individual laggards mainly interact with other traditionalists. An innovation finally adopted by a laggard may already be rendered obsolete by more recent ideas already in use by innovators. Laggards are likely to be suspicious not only of innovations, but of innovators and change agents as well (Rogers, 1971).

The **5th generation district heating and cooling is now in between the innovators and the early adopter stage**.

Indeed, more and more project similar to 5GDHC are under development but the technology model still face high investment cost and lack of standardization. Our ambition is to mature the market to ensure the increase of the market share.

Our ambition is to mature the market and increase the market share by **evolving towards the end of the early adopters stage.**

3. Long term: mature the market

The total energy demand is roughly divided in 50% electric and 50% heating and cooling [1]. The renewable electricity market (wind energy, solar panels etc.) has already evolved largely the last decade due to support of authorities, subsidies, price reductions, ease of installation, competition, etc.

The heating and cooling of buildings has not evolved in the same way as the electricity market. The heating and cooling market needs to speed up to contribute to the energy transition in the same proportions as the electricity market.

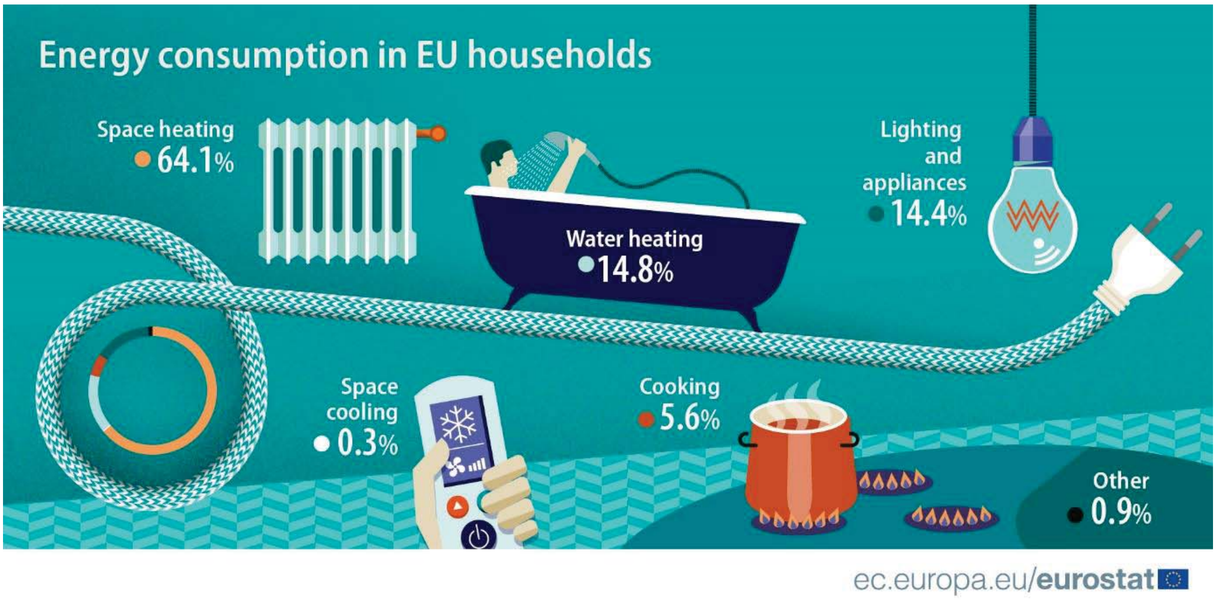

Figure 2: Households use energy for various purposes: space and water heating, space cooling, cooking, lighting and electrical appliances and other end-uses (mainly covering uses of energy by households outside the dwellings themselves). Data on the energy consumption of households broken down by end-use, have been collected and published by Eurostat since 2017.

The potential for district heating and cooling is enormous and the transition towards green energy is an unstoppable movement. The total potential is to a maximum of 3,000 billion euro in Europe based on the current energy consumption.

To ensure the roll out of the 5GDHC technology some barriers have to be crossed:

- Ensuring the quality of products supplied by the industry
- Reduce the initial investment requirements
- Train and educate people for all support functions (legal, finance, construction, etc.) to 5GDHC networks
- Build trust from potential investors and project developers

[1] COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS https://ec.europa.eu/transparency/regdoc/rep/1/2016/EN/1-2016-51-EN-F1-1.PDF

The goal of D2Grids project is to ease the installation and conversion of district heating and cooling networks to the 5th generation principles.

In the project description it is summed up for the technology work package in the following table:

Overview table on project outputs as defined in the work plan					
Programme output indicators	Project contribution to Programme output indicator	Main outputs			Relevance
		Nr	Title	Target	
3.01. Number of adopted or applied low carbon technologies	15.00	T1.1.1	Catalogue of Best Available Technologies	15.00	
3.04. Amount of funding leveraged by the project	35 000 000.00	T2.1.1	Amount of funding leveraged for scaling up pilot investments	35 000 000.00	
CO26. No. of enterprises co-operating with research institutions	50.00	T1.2.1	5GDHC online open access tool	50.00	

3.1. Ensuring the quality of products supplied by the industry

The quality of all the products installed has to be verified and ensured. In creating a 5GDHC network the quality of all the components is crucial. As energy losses are kept at a minimum, any non-conforming product or process can influence the performance of a grid significantly. It is important to correctly describe the required standards, especially where they differ from past practice. When companies have a product that meets these standards, this can receive recognition, e.g. in the form of a label.

For example : ensuring the COP of a heat pump. Or ensuring the preservation of an insulated pipe. More reliability and innovation are awaited from suppliers.

3.1.1. Encourage new developments/studies in 5GDHC

The low temperature district heating network is a combination of various new, or improved technologies. Therefore, new developments need to be encouraged. Based on the knowledge from the pilot projects such as Mijnwater, new technologies will be studied or installed.

The goal is to create a large interest in related topics, such as ideal routing of networks, variable or mobile storage, demand side control, etc.

To broaden the interest in these low temperature networks it is important to develop pilot sites as foreseen within the D2Grids project. They can be the examples demonstrating new ideas and technology to be replicated and further improved at other projects.

To create an environment encouraging innovation, it is important to connect researchers, industry and customers with each other. The network from the existing project partners is already broad and serves as a starting point for further expansion towards other networks.

3.1.2. Standardize products

Input from deliverable D.T1.3.4 Report on the remaining technological challenges: many technologies can profit from standardization.

In deliverable D.T1.3.4 a number of technologies was summed up together with their advantages, disadvantages and technological challenges.

The standardization will initiate a broader market potential. Standardized products will ease entry in the market as they often will lead to price reduction.

The open access tool will facilitate the standardization as suppliers can share information on this platform. Successive technologies needed in the construction of a 5G DHC can check the adaptability of their product to the other components of the network. For example: supplier of substations adapt the connecting diameters to the standard piping diameters.

Standardization will be essential in the deploying of 5th generation networks on a large scale.

An open access tool will be built within this project. The purpose for this is to unite the researchers and the producers to standardize the equipment needed for 5GDHC. For example the connection of the pipe to the substation can be standardized. In this way the producer of substations is always sure to have the right connection to the grid.

3.2. Reduce the initial investment requirements

Nowadays the investment for a low temperature network is still high, so both a reduction of investment cost and production cost is needed. The long term goal is to reach a reduction of 20% of the investments.

3.2.1. Reduce production costs

Standardization of products will reduce the production costs of piping, substations, heat pumps, etc.

By involving the industry in this study they can immediately interact with the researcher centers, investors, consultancy, universities, etc. and pick in on the new technology demands and developments.

In the ideal scenario, the components or building blocks of a 5G DHC will be assembled and produced in a standardized way and applied in a modular way.

3.2.2. Reduce investment costs

By lowering the production costs, the investment cost will follow. Investment cost will also lower once the full risk for installing 5GDHC is reduced.

If the number of 5GDHC increases the interaction of various networks can increase. This will lead to a minimum number of backup.

For the example of Mijnwater in Heerlen, this will mean that if a number of areas are developed with 5GDHC and the interaction of the networks is balanced right, the access to the minewater can be limited or in the end even avoided.

3.3. Train and educate all support functions (legal, finance, construction, etc.) to 5GDHC networks

To move from the innovators to the early adopters it is important to inform and educate the organizations who can be defined as early adopters.

The education is not only necessary on technical expertise, but also for financing or regulating 5GDHC networks.

There is a need to inform local authorities as they can be the catalyzer for starting new networks. They are now often unfamiliar with the principles of district heating and cooling. The advantages in the long-term need to be communicated to the local authorities and municipalities.

If there is a strong demand for district heating and cooling networks the legislation around DHC networks will improve as well.

3.4. Build trust from potential investors and project developers

Trust will automatically increase once the technology has become more common. Therefore, both the pilot projects and the training of stakeholders are very important to prove the technology.

3.4.1. Local authorities

How to convince local authorities to ease the installation of 5GDHC? To get a wide implementation of 5GDHC technology local authorities need to be convinced of the large advantages of this technology. If they join the movement towards 5GDHC, they can ease the implementation by reformulating the regulation or couple some incentives to the implementation.

The regulations can vary in the different areas or regions in North-West Europe.

To bring the knowledge to the local authorities it will be important to organize well prepared workshop, infosessions, etc. The advantages of installing a 5GDHC must be transferred to the local authorities.

3.4.2. Banks

The most direct way to have more investments is to convince the local banks to loan out the money for long term projects. The payback time of DHC infrastructure are usually high around 10 to 20 years. For 5GDHC, early studies may show payback time longer than this. To make sure that bank will be willing to invest in 5GHDC, we must work on effective Business model. These long term investments are not very attractive for banks. The business model for DHC networks needs to be finetuned so these ROI will shorten or we need to convince the banking companies of long terms investments for DHC.

New business models with clear cost structures and contracting to the customers can help this acceleration for investment.

To convince investment by banks, we need to consider:

- Banks will look to protect themselves from downside cases more so than the equity investors. They take less risk and as a result they have a lower cost of capital (interest rate).
- In order to attract debt, business cases must have the ability to offer banks this protection e.g.
    - Long-term contracted revenues with either credit-worthy or highly diversified customers (e.g. long term contracts with large heat customers, or a large number of small customers with shorter term contracts)
    - Good visibility on variable costs -> no nasty surprises that might restrict a project repaying debt
    - Corporate structures which allow banks to enforce security over the assets if debt isn't repaid
- Banks care about the "realistic downside case" as this is the case they will underwrite. They will make conservative assumptions about the project to understand how much debt it can afford to repay.
- Their profit is fixed at FC, even if the project outperforms expectations
- For projects to secure debt investment – projects must demonstrate highly visible and secure future cash flows.

3.4.3. Investors

The overarching goal is to lower one of the biggest barriers to the roll-out of 5GDHC which is lack of investor understanding and engagement.

Moreover, a formal goal to unlock €35m of third-party financing towards the pilot projects build-out has been set.

To warm investors to the idea of low temperature networks we need to know that:

- Equity investors typically take more risk when financing a project, but also receive much more return in the upside case.
- They will also look for visibility on revenues and costs to ensure a feasible downside case; however they will also look to understand sources of upside as they stand to substantially benefit from this.
- For example network growth, reductions in capital costs, higher network efficiencies will all improve project profitability for equity investors.
- Equity investors will underwrite a less conservative business case than banks.
- For projects to secure equity investment – projects must demonstrate a "realistic base case" with good project returns and strong visibility of upsides.

4. Short term

On the short term, within this project, the purpose must be to bring the pilot sites as close as possible to the 5G definition. Therefore, some peer-reviews will be done during the D2Grids project.

4.1. Pilot sites

Pilot visits will be organized in order to communicate directly to the designers and engineers of the pilots. Based on the filled in questionnaire a first review can be done and some feedback can already be given.

The next step will then be to implement the recommendations in an action plan. The advice will be to convert the existing plans as good as possible towards 5G DHC.

4.2. Follower regions

The follow regions included in the project (Parkstad Limburg (NL); North-East France; Luxembourg; Flanders (BE); Ruhr-area (DE); Scotland; East Midlands (UK)) will be advised to make a conceptual design of their network plans. The next step will be to review these plans and to advise the follower regions about the implementation of the 5G principles:

- 2 pipes, at temperature close to the ground temperature, simultaneously supply heat and cold. The temperatures in the pipes are floating temperatures and can therefore vary slightly.
- The possibility of local boosting the temperature for space heating and domestic hot water supply.
- Buildings exchange energy, whereby buildings can extract heat and cold during certain periods of time.
- Coupling to the electricity grid.
- A smart control and safeguarding system to optimize the operation of the network: reduce peaks, reduce temperature variations, guarantee delivery…
- Thermal energy storage, short-term decentralized (at building or area level) and/or long-term (seasonal) centralized. Use of the thermal mass of the buildings themselves.
- Connect to any available sources of renewable energy.