Part C

WATER JOINT PROGRAMMING INITIATIVE

WATER CHALLENGES FOR A CHANGING WORLD

2018 JOINT CALL
Closing the Water Cycle Gap

"Sustainable technology for the staged recovery of an agricultural water from high moisture fermentation products"
"RECOWATDIG"

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1. EXCELLENCE

1.1. Introduction

Given the growing demand from human activities and climate change issues, many regions, primarily in the south, face difficulties in providing enough fresh water to satisfy demand. It is estimated that in 2025 5.5 billion people (2/3 of the population) will live in areas exposed to so-called water stress. This means that the amount of renewable water resources (the so-called Falkenmark index) per person per year will be below 1700 m^3. About 1.8 billion people will live in areas with a significant water shortage (Falkenmark's value <1000 m^3 per person per year). Currently, the reclamation and re-use of water is much smaller than its potential, although more energy is needed to obtain and transport fresh water and this solution has more serious environmental impact. In addition, the year-round water shortage affects 1/3 of the EU's territory, and the lack of water is still a serious problem for many EU Member States[1]. Increasingly unpredictable weather conditions, including severe droughts, may also affect the amount and quality of freshwater resources. Agricultural irrigation is by far the largest application of reclaimed water worldwide, so proposed experiments may result in the production of water that can be used, among others, for crop irrigation. Moreover, the new water source will lead to savings for the economy, the environment and will contribute to better management of the most valuable resource, which is water.

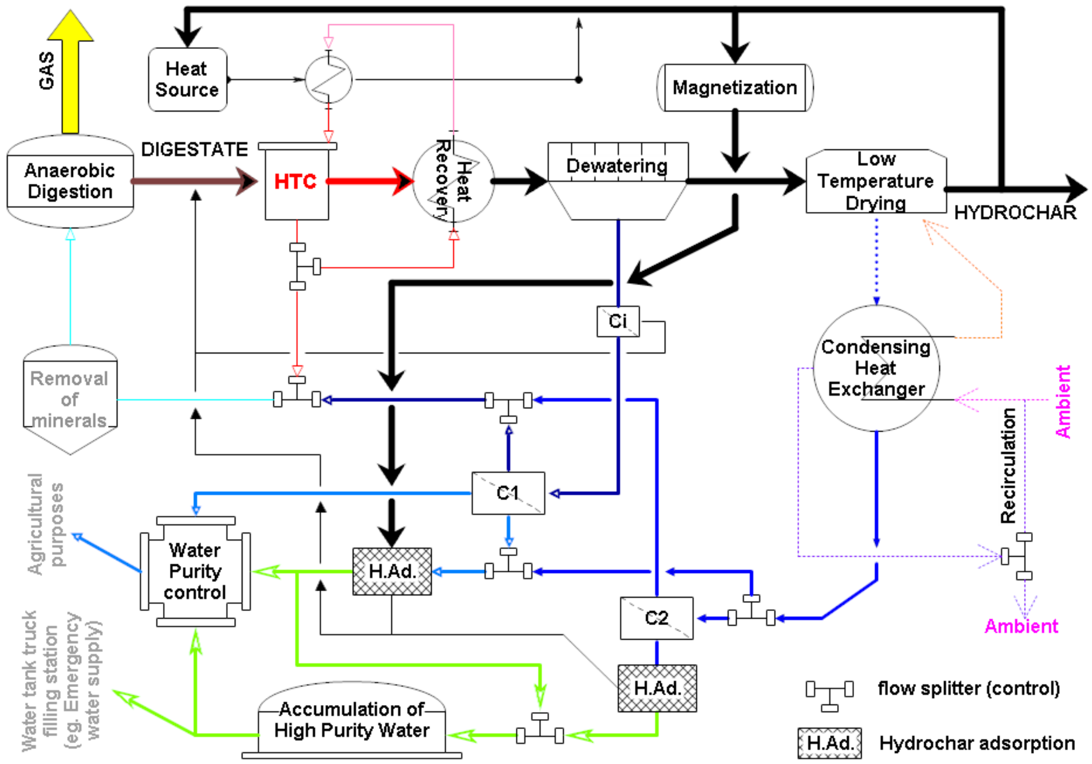

Figure 1: Flowsheet of the proposed installation: Ci – initial (non-thermal) treatment; C1 – pressurized membrane processes/forward osmosis; C2 - nano-filtration (areas marked with grey colour are excluded from the scope of the proposed project)

One of the activities ensuring further food production without exposing the natural environment to a water shortage at the same time should be the increase of water usage efficiency. Agriculture affects both the quantity and the quality of water available for other purposes. Irrigation of crops is one of the areas of agriculture in which significant improvement can be achieved through the introduction of new practices and strategies for the water recovery from treated wastewater. Therefore a direct competition for available water reservoirs should be avoided, especially if alternative sources of agricultural water are available. Sustainable Development Goals proposed by UN, as well as the international agreement signed in Paris during COP21 are currently important drivers of the international research

[1] Water reuse: Commission proposes measures to make it easier and safer for agricultural irrigation, European Commission, Brussels, 28 May 2018

and development efforts in order to achieve the highest possible sustainability of the human activities. Project described in this proposal addresses these needs by research and development, aimed at obtaining a technical design of an installation for the staged recovery of an agricultural water from high moisture fermentation products. The general flowsheet of the concept is depicted in the Figure 1. Proposed technology will be modular and transportable, i.e. technical design will include containerization of all of the modules. Project proposes innovative, transdisciplinary approach, by enabling an access to the potential water resources, currently neglected, i.e. water present in solid fermentation products with high moisture content. Moreover, project is aiming to achieve high synergy by integrating the water recovery with improved heat balance of the drying process and additional utilization of the latent heat, that could be recovered during the water condensation. Furthermore, project proposes to apply the hydrothermal carbonization (HTC), thus bringing the potential for synergy, due to positive effects in terms of dewaterability, sanitization and recovery of organics for the anaerobic digestion. Purification of the water from two separately obtained streams will be achieved by the use of different types of membrane processes as well as sophisticated carbon based materials, such as magnetic chars and nanotubes, selected in a way, that will optimize the use of the electricity by the installation as well as CAPEX and maintenance cost. The use of electricity will be further optimized by implementation of accumulation of pure water, allowing to minimize the cost of electricity by using it during off peak hours. This will make the proposed technology "smart grid ready". It will also allow better management and ensure the availability of this precious resource in case of the emergency situations, for example water for firefighting squads during wildfires. An additional benefit of the proposed technology of water recovery from digestate will be the reuse of the resulting concentrate: it will be recycled to the waste processing as a technological liquid to the fermentation chamber, which will increase the hydration in the digestion chamber. Due to the use of concentrate it will be a waste-free technology (zero liquid discharge technology). Finally, the proposed installation will allow to turn digestate into a valuable and marketable product.

1.2. State-of-the-art and relation to the work programme

Previous research in this area included aimed at obtaining high purity water. According to literature sources for the purification of post-fermentation liquid, after preliminary cleaning (removal of ammonia, precipitation of struvite), ultrafiltration and reverse osmosis processes were used. Thus traditional technology is focused mainly on the production of drinking water. Change of the focal point proposed in this project will allow to save precious resources of potable water by tapping to typically neglected source of agricultural water. Due to the fact that the proposed research aims at obtaining the water for agricultural purposes, reverse osmosis is going to be replaced with nanofiltration after micro- and ultrafiltration for both purification of both streams: the liquid digestate and post-condensation water. Nanofiltration is one of the most up-to-date techniques that uses nanotechnology in the membrane water purification process. Currently, it is one of the most intensively developed membrane technologies. Like in reverse osmosis, using nanofiltration process, it is possible to get very high quality water, however, not completely demineralised. A nanofiltration membrane removes multivalent ions, many micropollutants, inorganic compounds as well as pesticides, heavy metals and nitrates. The nanofiltration membrane is capable of retaining organic compounds with a molecular weight greater than 200-300 Da and multivalent salts [2]. The water obtained in this way is microbiologically safe and suitable for use immediately after the completed process. Unlike reverse osmosis, nanofiltration requires lower operating pressures. An additional advantage is the fact that nanofiltration membranes have longer lifespan compared to reverse osmosis membranes, which translates into lower OPEX. Furthermore, taking into account the possibility of volatile organic compounds presence in the permeate after nanofiltration, it is proposed to use an adsorption process as the final step of water purification. The constant search for new adsorption materials led to usage of the magnetic biochars[3] and carbon nanotubes[4] for water and wastewater treatment. Huge interest in this material is related to their unique properties which have fundamental importance for their potential technological applications. Due to these special properties, it can be assumed that the efficiency of the process will be much higher than that for other sorbents, thereby allowing to obtain high quality water. Unfortunately, there is still no information on the use of carbon nanotubes in the process of recovery of water from biogas plant wastewater, which makes the undertaken research a possible significant contribution to the water reclamation technology. New processes are still being sought, which, with a lower energy consumption, would effectively remove

[2] Evelyne Monfet, Geneviève Aubry, and Antonio Avalos Ramirez, "Nutrient Removal and Recovery from Digestate: A Review of the Technology," *Biofuels* 9, no. 2 (2017): 247–62, doi:10.1080/17597269.2017.1336348.
[3] K. R. Thines et al., "Synthesis of Magnetic Biochar from Agricultural Waste Biomass to Enhancing Route for Waste Water and Polymer Application: A Review," *Renewable and Sustainable Energy Reviews* 67 (2017): 257–76, doi:10.1016/j.rser.2016.09.057.
[4] Rasel Das et al., "Multifunctional Carbon Nanotubes in Water Treatment: The Present, Past and Future," *Desalination* 354 (2014): 160–79, doi:10.1016/j.desal.2014.09.032.

impurities from water solutions and thus would enable the recovery of water from waste streams. Undoubtedly one of such processes may be the process of forward osmosis proposed in the research. Currently, this process is increasingly used in many fields of water and wastewater treatment. However, a small number of literature reports on the recovery of water from wastewater testifies to the rare usage of this process. Due to the numerous advantages of forward osmosis, it seems advisable to conduct research in this area. Thanks to this process, the recovered water could be used for crops irrigation, preparation of the fertilizer solution[5] or for the livestock. All proposed activities in the project will contribute to the development of highly effective technologies that will reduce water scarcity through the usage in agriculture water recovered from the anaerobic digestion (AD) of organic wastes. State-of-the-art biogas plant has a substantial land requirement for the storage of digestate, typically 8 ha/MW of installed power, which introduces significant costs[6]. Since digestate is rich in nutrients, land spreading is used as a utilization option. However, European Nitrates Directive (91/676/EEC) is a significant obstacle for wider implementation of this practice[7]. Currently there are several commonly applied techniques for digestate management with solid-liquid separation being one of the possibilities. Thermal drying is considered as one of the options that, along with a subsequent pelletizing, might lead to a significant decrease in the volume of the digestate [2,3]. Nonetheless, it comes at a cost of the use of valuable energy, e.g. using a part of the produced biogas[2], with open air drying being the only energy saving option. The recovery of water after drying is typically neglected. There is a potential for the recovery of the nutrients in the digestate, with some synergy potentially existing between this stage and aforementioned purification of water. This is due to the fact that the ammonia stripping and struvite precipitation are necessary anyway[2,8] and from the lifecycle point of view are a good alternative to the Haber-Bosh process with energy consumption of 37 GJ per ton of ammonia[5]. The research on the hydrothermal carbonization (HTC) so far has been focused mainly on its use as a thermal treatment for upgrading low quality solid fuels[9]. HTC of the digestate has a significant potential as it could improve its subsequent dewatering [10], partially remove organic and inorganic material, decrease the overall solid mass, sanitize the digestate, change its properties and eliminate problems related with emissions of odours from the installation. Some amount of studies has already presented successful use of the HTC liquid as a feedstock for anaerobic digestion[11,12]. However, significant gap still exists in terms of a comprehensive analysis of the simultaneous influence of the process on both dewatering and feasibility of the liquid for anaerobic digestion. Further processing of the liquid fraction in order to its purification prior to discharge into the environment is often implemented with membrane separation[13]. It is often considered in this case as the only feasible method to purify water to such degree. It allows, beside water purification, recirculation for the recovery of the nutrients. Beside advantages mentioned above, application of membranes is still novel (although applied on large-scale), expensive (high investment costs, energy consumption and maintenance costs), requires large amount of chemicals for membrane cleaning and is commonly considered as having high potential for optimization and improvement. Biomass, turned to biochar in general can improve the quality of the soil [14], which is true also for hydrochar. However, biochar offers some benefits in terms of serving as an additive for the anaerobic digestion by creating a habitable surface area for microbial cells[15], being a conductor of electron transfer among the species, sorbent for inhibitors and

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[5] Laura Chekli et al., "Fertilizer Drawn Forward Osmosis Process for Sustainable Water Reuse to Grow Hydroponic Lettuce Using Commercial Nutrient Solution," *Separation and Purification Technology* 181 (June 30, 2017): 18–28, doi:10.1016/J.SEPPUR.2017.03.008.
[6] P. Vilanova Plana and B. Noche, "A Review of the Current Digestate Distribution Models: Storage and Transport," in *Proceedings of the 8 International Conference on Waste Management and The Environment (WM 2016)*, vol. 202, 2016, 345–57, doi:10.2495/WM160311.
[7] Ian Vázquez-Rowe et al., "Environmental Assessment of Digestate Treatment Technologies Using LCA Methodology," *Waste Management* 43 (2015): 442–59, doi:10.1016/j.wasman.2015.05.007.
[8] Elin Törnwall et al., "Post-Treatment of Biogas Digestate-An Evaluation of Ammonium Recovery, Energy Use and Sanitation," *Energy Procedia* 142 (2017): 957–63, doi:10.1016/j.egypro.2017.12.153.
[9] K J Moscicki et al., "Commoditization of Wet and High Ash Biomass : Wet Torrefaction — a Review," *Journal of Power Technologies* 97, no. 4 (2017): 354–69.
[10] Liping Wang, Lei Zhang, and Aimin Li, "Hydrothermal Treatment Coupled with Mechanical Expression at Increased Temperature for Excess Sludge Dewatering: Influence of Operating Conditions and the Process Energetics," *Water Research* 65 (2014): 85–97, doi:10.1016/j.watres.2014.07.020.
[11] Kine Svensson et al., "Post-Anaerobic Digestion Thermal Hydrolysis of Sewage Sludge and Food Waste: Effect on Methane Yields, Dewaterability and Solids Reduction," *Water Research* 132 (2018): 158–66, doi:10.1016/j.watres.2018.01.008.
[12] M. A. De la Rubia et al., "Effect of Inoculum Source and Initial Concentration on the Anaerobic Digestion of the Liquid Fraction from Hydrothermal Carbonisation of Sewage Sludge," *Renewable Energy* 127 (2018): 697–704, doi:10.1016/j.renene.2018.05.002.
[13] W. Fuchs and B. Drosg, "Assessment of the State of the Art of Technologies for the Processing of Digestate Residue from Anaerobic Digesters," *Water Science and Technology* 67, no. 9 (2013): 1984–93, doi:10.2166/wst.2013.075.
[14] Johannes Lehmann, "A Handful of Carbon," *Nature* 447, no. 7141 (2007): 143–44, doi:10.1038/447143a.
[15] Michael O. Fagbohungbe et al., "The Challenges of Anaerobic Digestion and the Role of Biochar in Optimizing Anaerobic Digestion," *Waste Management* 61 (2017): 236–49, doi:10.1016/j.wasman.2016.11.028.

reactant in the labile carbon methanization[16]. Positive effects of the addition of hydrochar to the anaerobic digestion have already been mentioned by the literature [17],[18] for digestate coming from AD of food waste or dead pig carcasses. Proposal addresses the issue in a holistic and multidisciplinary manner. It builds on the knowledge in the areas of water purification, anaerobic digestion, material science and engineering as well as thermal processes such as hydrothermal carbonization and drying. Proposal aims at addressing the challenges investigated individually in the respective fields, mentioned above, by maximizing the potential for synergy between different technologies, developed within the respective fields.

1.3. Objectives and overview of the proposal

The primary goal of the project is to develop a technical design of the modular and transportable installation for the staged recovery of an agricultural water from dewatering and drying of high moisture fermentation products. Each of the modules will be designed to fit into standard containers along with all the auxiliary devices, thus making the whole installation work according to Plug and Produce (PnP) principle. The most important objective is the determination of the optimum configuration of the water reclamation module. In order to recover water from both sources, it is proposed to use pressure membrane processes. The use of the ultrafiltration process will allow the retention of residues of organics, nutrients, colloids, and microorganisms. The nanofiltration process will separate multivalent ions and high molecular weight organic compounds. Low molecular weight organic compounds will be separated, using produced hydrochar, as well as other carbon based materials, e.g. carbon nanotubes, in an adsorption process. Both polymer and ceramic membranes with various molecular weight cut-off will be used in the research. Separation and transport properties of the tested membranes will be determined. The second objective is to determine the optimum set of parameters for the HTC process. Optimization will be performed in a context of factors, such as: suitability of the liquid for subsequent digestion; dewaterability of the obtained hydrochars; suitability of the produced hydrochars for the use as soil amendments; suitability of the produced hydrochars and magnetic hydrochars for the use as adsorbent for water purification; suitability for the use of hydrochars as a solid fuel. The third objective is optimization of the subsequent drying by using low quality heat. Here, the optimum parameters aiming for maximalization of the recovery of the evaporated water through condensing along with maintaining sensible efficiency and the size of the module feasible enough for the containerizing process, will be researched. All objectives will be related with modelling of all the main processes in the installation. Furthermore, efforts will focus on determination of the maximum productivity of the installation that would still allow to maintain its modular and transportable nature, turning by-products into useful/marketable products (e.g. magnetic biochar) and the optimum size of the accumulation tank that would allow to maximize the use of a cheap, off-peak electricity.

1.4. Research methodology and approach

Project outlined in this proposal will take an interdisciplinary approach, i.e. methods known from the field of water and wastewater purification will be combined with methods typical for the fields of solid fuel processing and advanced material science. Proposed research will concern the recovery of water from two sources related to the digestate processing: ☑liquid fraction after hydrothermal treatment of the digestate; ☑post-condensation water collected after the drying process of the solid digestate fraction. Because of the different origin, properties of the water from these sources will likely vary. However, there is a lack of literature data for the water from this specific source. In order to recover water from the liquid fraction after digestate dehydration, it is proposed to apply integrated membrane process composed of pre-treatment stage and the membrane process of actual purification after the initial phase. The technology of complete purification proposed in this way will allow to purify the digestate liquid fraction and obtain water that may be applied, among other, in agricultural production. Research methodology and approach is depicted at the diagram (Figure 2). Both polymer and ceramic membranes with various molecular weight cut-off will be used in the research. Separation and transport properties of the tested membranes will be determined. Among other factors, the effect of membrane type, its molecular weight cut-off, trans-membrane pressure and membrane operation time on the quality and the permeate volume flux as well as membrane susceptibility to fouling will be investigated. As an alternative to water recovery using pressure-driven membrane processes, a forward osmosis[19]

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[16] Fábio Codignole Luz et al., "Biochar Characteristics and Early Applications in Anaerobic Digestion-a Review," *Journal of Environmental Chemical Engineering* 6, no. 2 (2018): 2892–2909, doi:10.1016/j.jece.2018.04.015.

[17] Ying Zhou, Nils Engler, and Michael Nelles, "Symbiotic Relationship between Hydrothermal Carbonization Technology and Anaerobic Digestion for Food Waste in China," *Bioresource Technology* 260, no. March (2018): 404–12, doi:10.1016/j.biortech.2018.03.102.

[18] Jie Xu et al., "Effect of Hydrochar on Anaerobic Digestion of Dead Pig Carcass after Hydrothermal Pretreatment," *Waste Management* 78 (2018): 849–56, doi:10.1016/j.wasman.2018.07.003.

[19] Sherub Phuntsho et al., "A Novel Low Energy Fertilizer Driven Forward Osmosis Desalination for Direct Fertigation: Evaluating the Performance of Fertilizer Draw Solutions," *Journal of Membrane Science* 375, no. 1–2 (2011): 172–81, doi:10.1016/j.memsci.2011.03.038.

process using non-porous asymmetric membranes made of hydrophilic polymers is proposed. In this process, conducted under atmospheric pressure, the water will pass through the synthetic membrane from the liquid phase of the digestate to the concentrated receiving solution. The driving force of the process will be produced in a natural way and will result from the difference in the osmotic pressure of solutions on the two sides of the membrane. The process may take place until the hydraulic and osmotic pressure are equal. In this case, a fertilizer concentrate will be used as the receiving solution. The water from the digestate moving through the membrane will therefore be used to dilute this concentrate with initial concentration being too high for direct application to the plant fertilization.

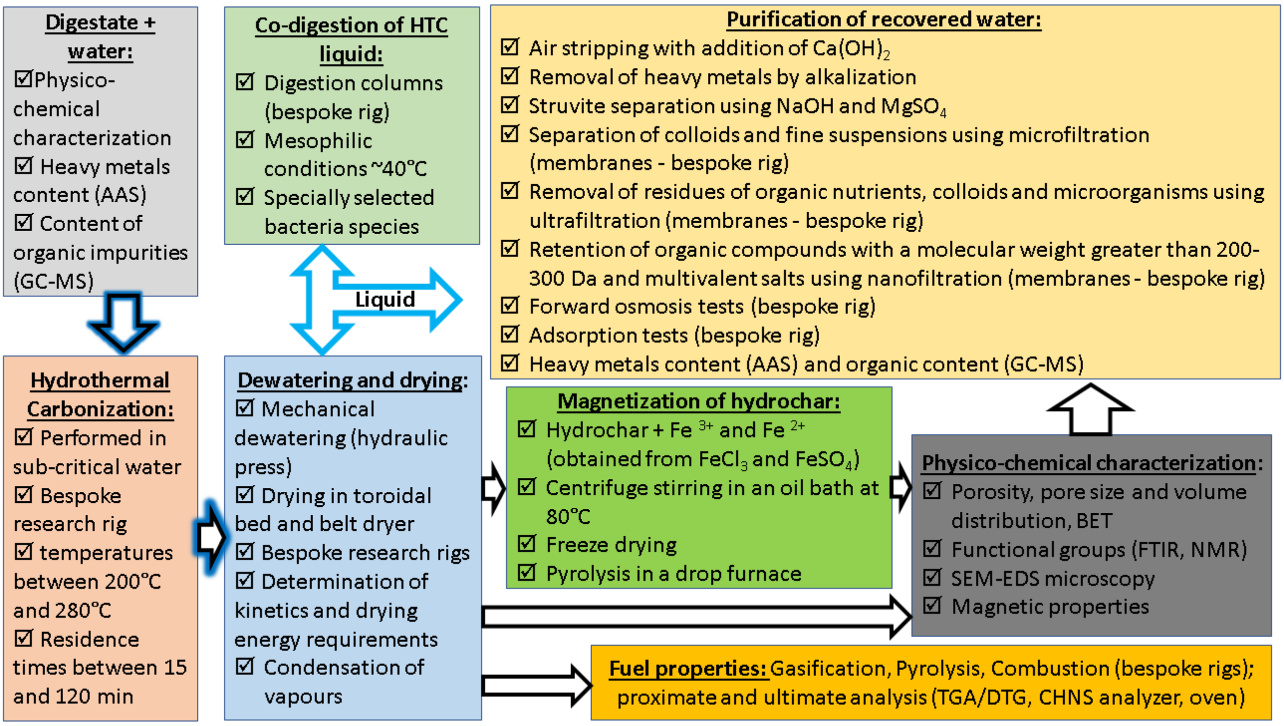

Figure 2: Research methodology and approach adopted for the research proposal

Due to the fact that it is likely that the permeate after the nanofiltration process may contain low molecular weight fractions of volatile organic compounds, it is proposed to apply adsorption process as a post-treatment stage. These methods are highly appreciated due to their efficiency, simplicity and relatively low process costs. The proposed adsorbent materials for further permeate purification are, among others, hydrochars, magnetized hydrochars and multi-walled carbon nanotubes. They are characterized by unique properties, among others: large surface area, high mechanical durability and adsorption capacity[20,21].

1.5. Originality and innovative aspects of the research (ambition)

The proposed research aims to recover water from the anaerobic digestion of the organic waste, which is typically located in the rural areas living off the agriculture. It will focus on the reclamation of water from the liquid fraction obtained after digestate dewatering and post-condensation water from drying process of the solid digestate fraction, which will be turned into a marketable product. The recovered water from both sources can be reused for agricultural irrigation. As a result, farmers will have access to a sustainable water supply for cultivation. The proposed technology guarantees that any additional hazards will be eliminated and the recovered water will be safe. As a result, consumers will be sure that the products they consume are safe and companies will have more development opportunities. An additional benefit of the proposed technology of water recovery from digestate may be the reuse of the resulting concentrate after membrane processes: it may be recycled to the fermentation chamber, and thus correct the water content of the fermented mass. Thanks to the use of concentrate, the proposed process may be a waste-free technology (zero liquid discharge technology), in compliance with the rules of the circular economy. The novelty of the proposed solution could be summarised as follows:

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[20] B. Mella et al., "Utilization of Tannery Solid Waste as an Alternative Biosorbent for Acid Dyes in Wastewater Treatment," *Journal of Molecular Liquids* 242 (2017): 137–45, doi:10.1016/j.molliq.2017.06.131.

[21] Maria-Magdalena Titirici and Markus Antonietti, "Chemistry and Materials Options of Sustainable Carbon Materials Made by Hydrothermal Carbonization.," *Chemical Society Reviews* 39, no. 1 (2010): 103–16, doi:10.1039/b819318p.

- ✓ Containerised (transportable) system for the purification of the water from digestate, utilizing drying and condensation, that will allow quick and efficient deployment and integration with an existing infrastructure, thus achieving CAPEX at a competitive level, by reducing the required assembly time.
- ✓ Modular technology designed as a PnP solution, allowing straightforward integration with an existing infrastructure of the plant, with a possibility of further integration of modules, achieving their commercial readiness (HTC).
- ✓ Cost efficient purification of water, which will involve optimization of OPEX by utilization of membranes requiring lower pressure (in comparison with state-of-the-art solutions) and utilization of a part of the hydrochar stream and magnetic hydrochar for filter columns.
- ✓ Sustainability of the technology by utilization of a low grade heat (latent heat of vaporization) for drying and a part of the hydrochar stream as a fuel for the heat source for the hydrothermal carbonization.
- ✓ The unique solution to make the hydrochar as magnetic biochar for waste water application, with a high potential for patentability, will be developed by KTH[22] basing on KTH's exiting knowledge and facilities.
- ✓ Zero waste and zero liquid discharge technology, thanks to recirculation of the reject liquid back to the anaerobic digestion and turning solids into a sellable product (soil amendment, magnetic hydrochar - sorbent).
- ✓ "Smart grid ready" – possibility for active management of the demand side and use of the electricity with marginal price by including the water accumulation unit.
- ✓ Enabling sustainable management of water resources by using streams that are presently neglected.

1.6. Clarity and quality of transfer of knowledge for the development of the consortium partners in light of the proposal objectives

Within the project team transfer of knowledge will be multidirectional due to interdisciplinary character of the project and the composition of the consortium. As a key user of the technology ZGO Gać sp. z o.o. will deliver detailed information about the problems that need solving and all the operational issues, thus giving an understanding of the consumer needs at the market and possibilities for improvements in terms of operational costs. Thanks to HoSt, which is a technology developer, partners will gain knowledge of the commercial reality and the information that is needed by the producers to improve their products and decrease investment costs of offered installations. Interdisciplinary academic team composed of experts in the fields of water cleaning technologies, thermal and process engineering as well as process modelling and chemistry will be able to effectively answer the needs of the industrial partners. Moreover, collaboration and joined submission of articles will give the academics opportunity to share their knowledge and experience also gaining a new insight by looking from the perspective of experts from different fields. The RECOWATDIG consortium recognises that management of knowledge and securing Intellectual Property Rights (IPR) are fundamental for effective cooperation, avoiding information bottlenecks related to confidentiality or competitiveness and enhancing the exploitation potential of results. The IPR provisions as the licensing models will be outlined in the Consortium Agreement. The Consortium Agreement will be signed by all partners before start of the project. The CA carefully identifies the Knowledge (generated during the project) and pre-existing know-how and will address: ☑Confidentiality – the CA carefully governs issues related to the disclosure of confidential information in accordance with applicable laws and EC regulations; ☑Ownership of knowledge; Legal protection of results; Access rights to Knowledge and Pre-existing know-how; ☑The dissemination and exploitation of knowledge will be in compliance with regulations affecting IPRs and reflect the requirements; ☑Results of the study will follow policies of open access concerning scientific publications and peer-review availability

1.7. Quality of the consortium partners and collaborative arrangements. Capacity of the consortium to reinforce a position of leadership in the proposed research field

Consortium presents a perfect collaborative arrangement for the purpose of the development of an innovative technology as it consists of a technology developer (HoSt), a key user (ZGO) and academics (WUST, UT, KTH, AGH) being leaders in their respective fields with proven records of previous projects and publications. All of the academic partners have taken part in many international project, which included co-operation with industrial partners. All of their respective laboratories have state-of-the-art equipment. All academic partners are internationally renowned. HoSt is a company with long traditions and proven track record in the field of anaerobic digestion, with many farm scale and industrial scale biogas plants in its portfolio. HoSt is also a leader in innovative solutions in the

[22] Abbreviations used in this document: WUST – Wroclaw University of Science and Technology (PL);ZGO (pl. Zakład Gospodarowania Odpadami Gać) – Industrial Partner, owner of the anaerobic digestion system (PL); HoSt - Industrial Partner, supplier of industrial solutions for anaerobic digestion plants (NL); UT – University of Twente (NL); KTH – KTH Royal Institute of Technology, Stockholm (SE); AGH – AGH University of Science and Technology, Krakow (PL)

field of anaerobic digestion, offering containerised membrane filtration installations for upgrading biogas to biomethane, which is currently a novelty on the market. Zaklad Gospodarowania Odpadami Gać sp. z o.o. is a consortium with partially private and public ownership, with involvement of local councils (Ślęza-Oława, Jelcz-Laskowice). The company is experienced in participating in regional development project, funded by EU, as well as in the co-operation with big academic centres (WUST). ZGO Gać is a local leader of innovation. Due to these reasons consortium is fully capable of reinforcing leadership of the respective partners in the field.

2. IMPACT

2.1. Impact of the proposal

Proposed project is contributing to the practical implementation of the UN Sustainable development goals, namely SDG6 and SDG13, as well as to the implementation of the conclusions of COP 21 Paris agreement, in a cost-effective way, by developing a modular and transportable installation for the purification of the water from the digestate for agricultural use (livestock drinking water and irrigation). Moreover, execution of the research will enable the development of the installation in a way that will allow, in the near future, to integrate emerging technologies, reaching their commercial maturity. Proposed project is in good agreement with a sub-theme 2.2 – The reuse of water. Project is contributing to the goals of the Horizon 2020. Unique approach towards the optimization of the energy use, by the proposed technology, is in line with the concept of greening of the economy. Research and innovations proposed in the project will contribute towards decarbonization of the economy (SC5-07-2017) by maximizing the synergy between increased energy efficiency, through use of waste, low quality heat and optimization of the use of electricity via accumulation of the purified water. The latter will also help to include more intermittent energy sources (e.g. solar, wind) into the energy grid by stabilizing it on the demand side, according to the principles of a smart grid (H2020-SCC-2016/17). For example, electricity necessary for the pumps needed for membrane purification modules will be consumed primarily during periods with high availability of the solar and wind energy and off peak hours. Utilizing underappreciated water resource (water in the digestate) will contribute towards closing of the water gap (SC5-33-2017). Moreover, ability of the installation to produce hydrochar (a potential substitute for activated carbon), could help on the way towards new solutions, for sustainable production of raw materials (SC5-13-2016-2017). Another potential use of hydrochar, as a soil amendment, could help in achieving sustainable food security, as envisioned in H2020-SFS-2017-2018. Recirculation of the water, containing hydrocarbons, back to the anaerobic digester, thus making the technology, zero-waste (zero-discharge) is in line with the goal of achieving circular economy(H2020-IND-CE2016-17). The research proposed in the project is transdisciplinary and combines basic and applied approaches.Impact of the research performed within the frames of the proposed project is as follows: ☑Effective participation of the leading academic organizations along with technology developer and key user of the technology, by innovative way of building on the state-of-art-solutions, through unorthodox connections between the pieces; ☑Development and strengthening of the connections between the industry and the academia, leading to better understanding of the problems, that need to be solved by on-going research activities; ☑Fostering of the further interdisciplinary co-operation between the involved academic partners; ☑Spreading the awareness of the novel possibilities of economic optimization of the cost of the original solutions, through standardization and modular build, allowing rapid deployment of the units and savings, through mass production.

Increased availability of the water due to its recovery from the digestate will decrease pressure on available resources of potable water in rural areas, where frequent droughts are a problem, thus improving the wellbeing of local population. Accumulation of water, included in the design, could potentially help to save people's lives, when used by firefighting squads during fires, which are more likely during natural disasters such as droughts. Improvements in the quality of the soil due to application of hydrochar as soil amendment will have a positive influence on the agricultural sector by increased yield during crops. Containerised system will give additional commercial opportunities for the technology developer, due to a possibility to sell units to more distant markets, with special emphasis on third world countries, where projects tend to be expensive during erection of the installations due to low availability of highly skilled workforce. Thus pre-assembled, containerised installations, with low investment cost, might become an opportunity for inhabitants of underdeveloped countries to save their precious, often scarce, water resources. Self-sustainable character of the installation and implementation of the accumulation will open new markets in remote, off-grid locations such as underdeveloped countries and islands (Caribbeans and South Pacific regions). Overall designed technology will be a step forward towards worldwide implementation of the circular economy.

2.2. Expected outputs

The main expected output will be a technical design of containerised installation for recovery of agricultural water from the digestate. As the concept of the proposed installation is novel developments will shift in TRL levels from 1 to 6. It is expected that, in order to protect the Intellectual Property Rights, patents for the developed technology will also become outputs of the project. Techno-economic model of the process will also be among the outputs. Since proposed solutions are highly innovative research work, performed throughout the lifespan of the project, will be suitable for publication at the internationally renowned conferences and in the high impact scientific journals. Deliverables, produced during the lifetime of the project will also be published after considering protection of the IPR. These outputs will be ensured by a dissemination and exploitation strategy.

2.3. Exploitation and communication activities (measures to maximise impact)

The dissemination strategy is to raise the awareness about the outcomes of the project and the developments that would be achieved within the proposed project. In order to enhance the impact of the project activities and results, academics, research institutions, scientific and industrial experts as well as NGO's and local authorities will be involved. All dissemination tools available will be used to disseminate innovations and results concerning the research activities, for spreading contents to as much as possible people. Events fitting to the thematic area will be carefully chosen for participating and promoting project topics. Dissemination inside the consortium will be carried out through three main information channels: project meetings and reports, web based information system. Dissemination outside the Consortium will be in the primary interest of the Consortium in order to create awareness about the project results and technological breakthroughs to the scientific and business communities. All dissemination tools available will be used to disseminate innovations and results concerning the research activities, for spreading contents to as wide audience as possible. Dissemination of project results will be done through the following communication channels: Web page (public); brochures and posters; publishing of scientific papers; participation in the seminars, conferences, workshops related to the scope of the project; organizing of an open workshop at the end of the project; social media (Research Gate, Linked In). According to the strategy dissemination will aim to maximize impact by giving preference to the communication channels free of charge for the final users, such as journal articles published in the Open Access.

2.4. Market knowledge and economic advantages/return of investment

There is a substantial customer base for the proposed installation, as there is currently more than 17 600 biogas and 500 biomehtane plants operating in Europe [23], producing more than 18 billion m^3 of biogas and more than 1200 million m^3 of biomethane [24]. In this environment agricultural water, due to recent droughts, becomes increasingly scarce resource. Having the proposed technology as a supplementary technology for the biogas plant in the portfolio of the technology developer (HoSt) might open additional commercial opportunities in the rural areas around the world, where water is scarce, soil quality is poor and agricultural residues are available (Africa, Caribbean and Sout Pacific region). Worldwide biogas market size is estimated to exceed 32 billion USD by 2023 [25], whereas waste derived biogas market is estimated to be worth 10.1 billion USD by 2022 [26]. Moreover, there is a huge worldwide potential for biochar, due to problems with quality of the soils and content of organic matter [27]. Global soil treatment market is expected to exceed 39.5 billion USD by 2021 [28].

3. IMPLEMENTATION

3.1. Overall coherence and effectiveness of the work plan

Works plan can be divided into packages, as depicted in the Figure 3. It consists of two mayor groups, namely experimental part and design part, as well as auxiliary work packages. One focuses on management, with main concern being all the administration activities, including Project Quality Assurance, Risk Contingency and Data Management Plan. Second auxiliary work package focuses on the dissemination activities. Detailed description of work packages, tasks, milestones and deliverables can be found in the tables in this paragraph.

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[28] Market Research Store, "Global Soil Treatment Market Set for Rapid Growth, To Reach USD Around 39.50 Billion by 2021," accessed July 28, 2018, https://www.marketresearchstore.com/news/global-soil-treatment-market-222.

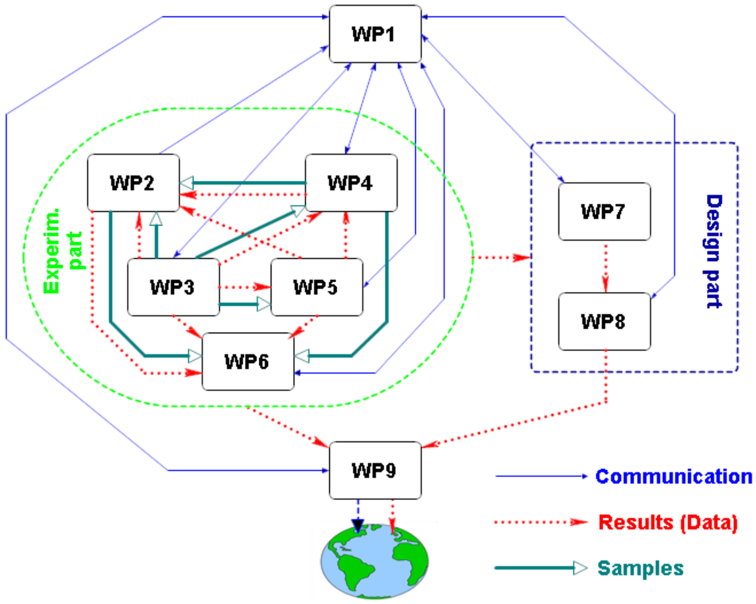

Figure 3: Connections between the work packages in the proposal

WP Number	WP Title	Duration (months)	Starting Month	End Month	WP Description
WP 1	Project Management	36	1	36	WP is intended to integrate all management, communication and compulsory reporting tasks of this project, described in details in paragraphs 3.2, 3.3 and 3.4 of this document. • WP Leader: WUST; Involved Partners: all
WP 2	Hybrid membrane purification of the recovered water for the agricultural use	24	1	24	The aim of this WP is to determine a set of parameters for the membrane purification system necessary to achieve satisfactory quality of the water after each of the purification stages, thus enabling its subsequent use in the agriculture. Works will start with the preparations of laboratory setups, e.g. for conducting membrane pressure filtration processes using polymer and ceramic membranes, forward osmosis process or a setup for carrying the adsorption process, using hydrochars and magnetic biochars, located at WUST and KTH as well as purchases of the necessary consumables in order to ensure accomplishing all the goals in a timely manner. ZGO will provide the water samples in order to determine a reference case scenario (“business as usual”). Samples of permeates as well as samples of liquids from dewatering performed within the scope of WP3 and drying performed within the scope of WP4, will be tested by WUST. • WP Leader: WUST; Involved Partners: KTH, UT, ZGO.
WP 3	Improvement of the dewatering properties of the digestate and its sanitization via HTC	18	1	18	Activities performed within this WP will serve the purpose of the determination of the parameters of HTC that will allow to maximize the mechanical dewatering capability of the treated digestate. Works will start with the preparations of the laboratory scale HTC and mechanical dewatering rigs at UT and WUST and purchases of the necessary consumables in order to ensure accomplishing all the goals in a timely manner. Most of the tests shall be performed at UT and results of testing of the obtained samples will allow to narrow down the amount of tests on a bigger rig, located at WUST. ZGO will provide necessary samples of the digestate. • WP Leader: UT; Involved Partners: WUST, ZGO, KTH
WP4	Sustainable recovery of	22	1	22	The goal of this WP is to optimize drying parameters of mechanically dewatered hydrochars in order to:

	water from low temperature drying of hydrochars, using condensing heat exchanger				✓ Maximize recovery of the water during condensing. ✓ Achieving the lowest possible energy consumption for drying. Works will start with the preparations of the drying rigs at WUST and purchases of the necessary consumables in order to ensure accomplishing all the goals in a timely manner. ZGO will provide the digestate samples in order to determine a reference case scenario (drying of digestate without HTC). Rest of the samples will be delivered after the tests performed within the scope of work of WP3. • WP Leader: WUST; Involved Partners: ZGO, UT, KTH
WP 5	**Determination of the physical, structural and chemical properties of hydrochars produced from digestate**	**22**	**3**	**24**	Physical, structural and chemical properties of the hydrochars, produced from digestate during WP3 and dried during WP4, will be determined within the scope of this WP. Among these properties one can distinguish: o Presence of functional groups o Porosity and pore size and volume distribution o Magnetic properties the hydrochars Determined properties will be used as a starting point for the subsequent modelling. ZGO will provide the water samples in order to determine a reference case scenario ("business as usual"). • WP Leader: AGH; Involved Partners: KTH, WUST, UT, ZGO
WP 6	**Use of by-products from water recovery and purification stages**	**27**	**1**	**27**	Activities performed during this WP will serve the purpose of assessment of different utilization routes for by-products of water recovery and purification stages. Some of the utilization routes will serve the purpose of the installation itself, whereas others will lead to turning residues into marketable products, potentially leading to improvements in the economic performance of the installation or some gains from the environmental point of view. Important activity of production of magnetic hydrochars will serve all the purposes, mentioned above. Activities will involve: (1) Production of magnetic hydrochars (used in WP2); (2) Determination of the improvement of the gas yield of the anaerobic digestion process using HTC liquid reject stream and hydrochars; (3)Assessment of the potential use of surplus hydrochar as a soil amendment (marketable product); (4) Determination of the fuel properties of hydrochars and the level of consumption ensuring self-sustainability of the whole installation. A suite of experiments will be performed using research infrastructure and analytical equipment located at KTH, WUST and AGH. ZGO will provide necessary information about their anaerobic digestion process. • WP Leader: KTH; Involved Partners: AGH, UT, WUST, ZGO
WP 7	**Model of the proposed installation for recovery of clean water from the digestate, techno-economic and sustainability assessment**	**14**	**16**	**29**	Developing of the model of the proposed installation will be crucial in terms of assessing:☑Mass, energy and exergy balance of the proposed installation;☑Sustainability of the proposed installation;☑Economic feasibility of the concept;☑Reaping the benefits of a "smart grid ready" status, through accumulation of purified water. Results from the modelling stage will be crucial in the subsequent technical design stage. Academic partners will supply the results of their respective tests, whereas industrial partners will play an advisory role in terms of the techno-economical modelling. • WP Leader: KTH; Involved Partners: all partners
WP 8	**Technical design of a containerized installation for drying, condensation and purification of water from a digestate**	**12**	**24**	**36**	Technical design will be developed, based on the results from previous Work Packages: Achieving optimum CAPEX of the proposed installation by: ☑Sizing of all the elements for fitting into containers (modules);☑ Determination of the deployment and connections between each of the modules allowing to fit them into the specific floor plan; ☑Optimization of the erection time of the installation, by finding the optimum deployment (minimalization of the man-hours on site). Achieving optimum OPEX of the proposed installation by:☑Sizing of the accumulation tank, enabling the use of cheap off-peak electricity; ☑Demand side energy management, thus maximizing the cost efficiency

					of such installations, located in the remote (off-grid) areas, where the sale of surplus electricity is not possible; ☑Maintenance strategy. Guidance from industrial partners as well as data supplied by WUST and models made by KTH will be used to complete the technical design. • WP Leader: HoSt; Involved Partners: UT, ZGO, WUST, KTH
WP 9	**Dissemination and exploitation of results**	**36**	**1**	**36**	This Work Package will be dedicated to the dissemination and exploitation of the results obtained through work performed in other WP's. The goal of this WP is raising awareness of the project results among:☑Academic community;☑ Potential users of the technology;☑ Authorities on various levels, with special emphasis on the authorities of the regions with scarce water resources and severe competition between the use of existing reservoirs for agriculture and consumption by the population;☑ NGO's and aid organization focused on the development of the areas with scarce water resources and severe competition between the use of existing reservoirs for agriculture and consumption by the population. An exploitation plan will be submitted, as outlined in section 2.3. Preparation of the project website also falls within the scope of this WP. • WP Leader: WUST; Involved Partners: all

WP Number	Task Number	Task Leader	Involved Partners	Task
WP1	**T1.1**	WUST	All partners	Coordination and communication
WP1	**T1.2**	WUST	All partners	Progress monitoring and reporting
WP1	**T1.3**	WUST	All partners	Quality management, risk analysis and contingency planning
WP1	**T1.4**	WUST	All partners	Financial Administration
WP2	**T2.1**	WUST	ZGO, UT	Analysis of the liquid fraction after digestate dewatering and post-condensation water after drying of the solid digestate fraction.
WP2	**T2.2**	WUST	ZGO, UT	Initial cleaning of the liquid fraction after the digestate dewatering, by removal of ammonia, precipitation of struvite, sedimentation and rapid filtration.
WP2	**T2.3**	WUST	ZGO	Application of pressurized membrane processes such as microfiltration (MF) ultrafiltration (UF) and nanofiltration (NF) for the purification of the liquid fraction of digestate.
WP2	**T2.4**	WUST	ZGO, UT	Application of a nanofiltration process to purify water after condensation.
WP2	**T2.5**	KTH	WUST	The adsorption kinetics of impurities in the permeate after nanofiltration for magnetic hydrochar as well as other advanced carbon materials (e.g. nanotubes) on removal impurities from the permeate stream
WP2	**T2.6**	WUST	ZGO	Determination and explanation of differences in transport and separation properties of polymeric and ceramic membranes of comparable pore size and identification of problems related to their operation (membrane fouling).
WP2	**T2.7**	WUST	ZGO, UT	Determination of the forward osmosis process effectiveness as an alternative replacing pressure-driven membrane processes.
WP3	**T3.1**	UT	WUST	Hydrothermal carbonization of the digestate under various process conditions
WP3	**T3.2**	UT	WUST	Mechanical dewatering of hydrochars after HTC of digestate
WP3	**T3.3**	KTH	WUST, UT	Mass and energy balance of the hydrothermal carbonization of digestate
WP3	**T3.4**	UT	WUST, KTH	Determination of optimal parameters of HTC process for mechanical dewatering of the obtained hydrochars
WP4	**T4.1**	WUST	UT, ZGO	Drying of the mechanically dewatered hydrochars using toroidal bed dryer rig
WP4	**T4.2**	WUST	UT, ZGO	Drying of the mechanically dewatered hydrochars using belt dryer rig
WP4	**T4.3**	KTH	WUST, UT	Mass and energy balance of drying of the hydrochars produced of the digestate, with special emphasis on water balance
WP4	**T4.4**	WUST	UT, KTH	Determination of optimal parameters of drying of hydrothermally treated digestate for maximum recovery of water through subsequent condensing
WP5	**T5.1**	AGH	WUST, UT, ZGO	Porosity, pore size and volume distribution for solid digestate and its respective changes due to HTC, various drying systems and magnetization
WP5	**T5.2**	AGH	WUST, UT, ZGO	Determination of the chemical composition and the presence of functional groups in hydrochars produced via HTC

WP5	**T5.3**	KTH	UT, WUST, AGH, ZGO	Characterization of the properties of magnetic biochars produced from HTC treated digestate (X-ray, BET, SEM and the magnetic properties)
WP6	**T6.1**	WUST	AGH, ZGO	Utilization of HTC reject streams from membrane purification and hydrochars for improvements in biogas production
WP6	**T6.2**	KTH	AGH	Assessment of the potential use of surplus hydrochar as a soil amendment
WP6	**T6.3**	WUST	UT, KTH, AGH	Combustion, gasification and pyrolysis of hydrochars produced from digestate for the subsequent use of the chemical energy
WP6	**T6.4**	KTH	WUST	Optimization of the preparation the magnetic hydrochars.
WP7	**T7.1**	KTH	WUST, UT AGH,	Mass, energy and exergy balance of the different variants of the proposed installation.
WP7	**T7.2**	KTH	HoSt, ZGO, WUST	Techno-economic, environmental and sustainability assessment of the optimum variant of the proposed installation
WP8	**T8.1**	HoSt	WUST, UT, KTH	Technical design of the installation for recovery of agricultural water from the digestate
WP8	**T8.2**	ZGO	HoSt, KTH, WUST, UT	A retrofitting study for existing installation at ZGO Gać
WP9	**T9.1**	WUST	All partners	Project website
WP9	**T9.2**	WUST	All partners	Publishing of the project reports
WP9	**T9.3**	WUST	All partners	Conferences and journal publications
WP9	**T9.4**	WUST	All partners	Organization of the final workshop

WP Number	**Milestone Number**	**Month**	**Milestone Description**
WP1	**M1.1**	**2**	Distribution of Project Quality Assurance, Risk Contingency and Data Management Plan, with templates (for financial and technical reporting, etc.) to partners
WP1	**M1.2**	**12**	Completion of the annual report for the1-st year of the project
WP1	**M1.3**	**24**	Completion of the annual report for the 2-nd year of the project
WP1	**M1.4**	**36**	Completion of the final report
WP2	**M2.1**	**10**	Completion of the required modifications of the test rigs for testing of different membranes
WP2	**M2.2**	**14**	Determination of the physico-chemical properties of all the samples of liquid fraction after digestate dewatering and post-condensation water after drying of the solid digestate fraction.
WP2	**M2.3**	**16**	Determination of optimal parameters for each of the purification stages (MF,UF,NF) of the water recovery process from the liquid digestate fraction.
WP2	**M2.4**	**18**	Determination of optimal parameters for each of the purification stages (MF,UF,NF) of the water recovery process from the post-condensation water after drying of the solid digestate fraction.
WP2	**M2.5**	**23**	Determination of feasibility of using advanced carbon materials (hydrochars) for purification of water recovered from the digestate
WP3	**M3.1**	**6**	Completion of the required modifications of the HTC test rigs at UT and WUST
WP3	**M3.2**	**15**	Finishing a complete suite of HTC and dewatering tests
WP3	**M3.3**	**17**	Determination of the HTC process conditions optimal for dewatering of the obtained hydrochars
WP4	**M4.1**	**8**	Completion of the required modifications of the toroidal bed and belt drying rigs
WP4	**M4.2**	**19**	Completion of the suite of drying experiments in toroidal bed and belt drying rigs
WP4	**M4.3**	**21**	Determination of maximum possible amount of condensed water from drying along with corresponding process conditions
WP5	**M5.1**	**22**	Known physical, structural and chemical properties of all the samples generated in previous WPs
WP6	**M6.1**	**25**	Determination of the parameters of HTC process and proportions of the biochar added to digestion resulting in the highest yield of biogas using HTC liquid
WP6	**M6.2**	**26**	Completion of the assessment of the suitability of hydrochars as a fuel/feedstock for combustion, gasification and pyrolysis
WP6	**M6.3**	**27**	Determination of the optimum parameters of the production of magnetic hydrochars
WP7	**M7.1**	**28**	Completion of the PFD (Process Flow Diagram) along with detailed mass, energy and exergy balance of the installation
WP7	**M7.2**	**29**	Completion of the techno-economic, environmental and sustainability assessment
WP8	**M8.1**	**33**	Completion of the PI&D (Piping and Instrumentation Diagrams) for all of the containers
WP8	**M8.2**	**34**	Completion of the retrofitting study for existing installation at ZGO Gać

WP9	**M9.1**	**8**	Fully functional project website online
WP9	**M9.2**	**35**	Preparations for the final workshop finished

WP Number	Deliv. Number	Month	Deliverable Description
WP1	**D1.1**	**2**	Project Quality Assurance, Risk Contingency and Data Management Plan, with templates (for financial and technical reporting, etc.)
WP1	**D1.2**	**12**	Annual project report (1-st year)
WP1	**D1.3**	**24**	Annual project report (2-nd year)
WP1	**D1.4**	**36**	Final project report
WP2	**D2.1**	**14**	Physico-chemical properties of liquid fraction from HTC of the digestate
WP2	**D2.2**	**16**	Multistage purification of liquid fraction from HTC of the digestate: optimal configuration and parameters of MF, UF, NF and FO membranes
WP2	**D2.3**	**19**	Multistage purification the post-condensation water after drying of the solid digestate fraction: optimal configuration and parameters of NF membranes.
WP2	**D2.4**	**20**	The use of advanced carbon materials (hydrochars, magnetic hydrochars, nanotubes) for purification of water recovered from the digestate
WP3	**D3.1**	**17**	Optimization of HTC process for maximum dewatering of the hydrochars produced from the digestate
WP4	**D4.1**	**21**	Drying and vapour condensation: comparison of results for two variants of dryer and optimization of drying of hydrothermally carbonized digestate for maximum water recovery from condensation.
WP5	**D5.1**	**22**	Physical, structural and chemical properties of HTC treated and dried hydrochars
WP5	**D5.2**	**23**	Physical, structural and chemical properties of magnetic hydrochars
WP6	**D6.1**	**25**	The use of post-HTC reject liquid reject and hydrochar in the anaerobic digestion
WP6	**D6.2**	**26**	Hydrothermally treated digestate as a fuel for pyrolysis, gasification and combustion
WP6	**D6.3**	**27**	Optimized production of the magnetic hydrochars.
WP7	**D7.1**	**28**	Detailed mass, energy and exergy balance of the installation for water recovery from hydrothermally treated digestate
WP7	**D7.2**	**29**	Techno-economic, environmental and sustainability assessment of the installation for water recovery from hydrothermally treated digestate
WP8	**D8.1**	**34**	Technical design of the containerised installation for water recovery from hydrothermally treated digestate: retrofitting possibilities and economic feasibility (internal report – not for publication due to possible IP restrictions)
WP8	**D8.2**	**35**	Retrofitting possibilities and economic feasibility of the installation for water recovery from hydrothermally treated digestate (executive summary of D8.1, without information that cannot be disclosed - publishable)
WP9	**D9.1**	**33**	Dissemination activities report

An Erasmus + Internship at UT for a PhD student from WUST is proposed as a Mobility Scheme, thus fostering deeper relationships and fostering co-operation between the two academic institutions. Mobility Scheme in a form of a couple of 2 week visits of WUST researchers and PhD students to KTH, within BRISK2 network, is planned.

3.2. Appropriateness of the management structure and procedures, including quality management

RECOWATDIG partners were selected on the basis of their high skill, their experience to cooperate at international level. The consortium of partners is strongly motivated in achieving the project targets. The Consortium is constituted by 6 partners and a suitable organisational structure and a decision making mechanism is implemented to match the scale of the project (Figure 4). The roles and responsibilities of the Coordinator and the consortium bodies will be defined in the Grant Agreement and the Consortium Agreement. The management structure of RECOWATDIG is designed to be simple, flexible and efficient in achieving its aims: to process knowledge and information fast and to ensure implementation of objectives. The Project Coordination Office consists of Project Coordinator (PC) and Technical Manager (TM) and Partner Leaders. The Project Coordination Office will have the overall technical responsibility of the project. Progress monitoring will be implemented using deliverables and project meetings[29] as

[29] PM – marking of Project Meetings on the Gantt chart. 1st PM is a kickoff meeting. The last meeting is a closing meeting.

monitoring tools. Management of knowledge, intellectual property and other innovative activities arising in the project will be supported by a set of procedures.

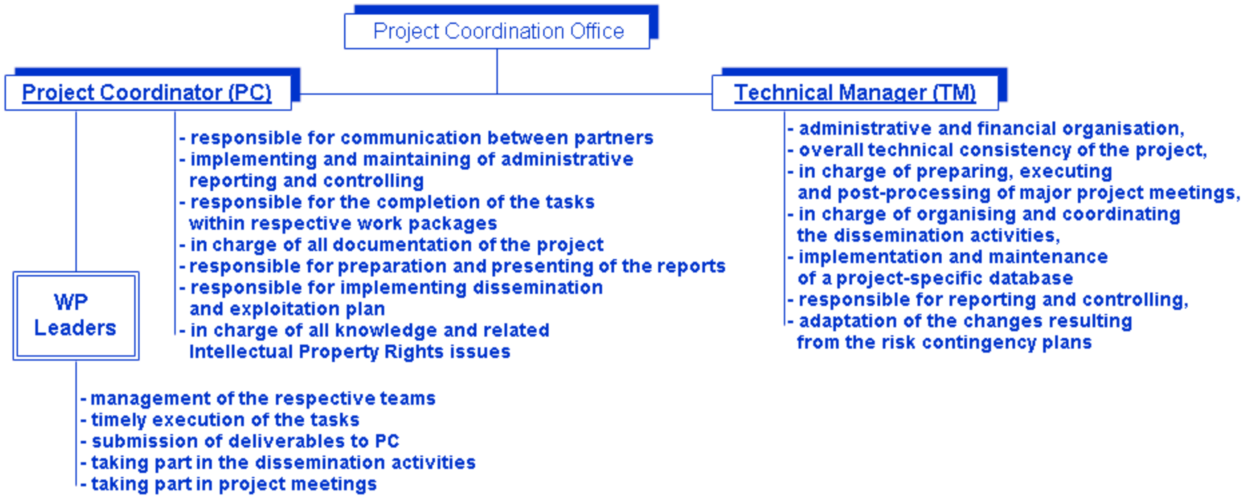

Figure 4: Simple, flexible and efficient management structure of the project

3.3. Risk management

To minimize technical and non-technical risks, a project risk management process will be implemented. It shall identify and analyse possible risks and contain a contingency planning. WUST will be in charge of this continuous management task. Risk management will be performed throughout the project by the Project Coordinator with help of Technical Manager and Partner Leaders. Progress Monitoring will be performed by communication with WP Leaders and regular reporting during project meetings. In case of risks, contingency plan will be developed in close collaboration between PC and WP leaders. After accepting the contingency plan will be implemented and an appropriate update will be introduced into the Gantt chart by TM. The mitigation of technical and scientific risks is based on proven methodologies, the involvement of participants with relevant expertise, and the setting of well-defined goals and deliverables on a realistic timescale.

3.4. Potential and commitment of the consortium to realise the project

Consortium's commitment for successful realisation of the project is based on moral, academic and commercial grounds. Moral commitment is determined by recently observed and experienced consequences of draught in the countries of origin of the involved partners. This year drought in Poland caused estimated losses of approximately 120 million EUR, with significant impact on livelihood of the inhabitants of 112 000 of small scale farms over an estimated area of 2 million of hectares [30]. These farms are often the only source of income for whole families. In parts of the Netherlands, like Limburg and West Brabant, watering of the crops was banned because of too-low water levels [31]. Forest fires in Sweden claimed lives of at least one firefighter [32]. Moreover, over 80 wildfires, some of them within the arctic circle, caused losses estimated to 60 million EUR [33]. Aid pledged to the farmers in Sweden, hit by extreme drought, amounts to approx. 120 million EUR [34]. The foundation of the academic commitment is a promising publication potential for the proposed, highly innovative research. Commercial opportunity possible due to the development of the designed installation is an important driver for the involved technology developer (HoSt), whereas the usefulness of the proposed installation and its potential is an important factor for the key user involved in the project (ZGO).

[30] "Susza w Polsce: Straty Przekroczyły Już Pół Miliarda Złotych – EURACTIV.Pl," accessed August 1, 2018, https://www.euractiv.pl/section/rolnictwowpr/news/susza-w-polsce-straty-przekroczyly-juz-pol-miliarda-zlotych/.

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Month/ Description	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Work Package 1	WP1																																			
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Deliverable		D1.1										D1.2		D2.1		D2.2	D3.1		D2.3	D2.4	D4.1	D5.1	D5.2	D1.3	D6.1	D6.2	D6.3	D7.1	D7.2				D9.1	D8.1	D8.2	D1.4
Milestone		M1.1				M3.1	M4.1	M9.1		M2.1		M1.2		M2.2	M3.2	M2.3	M3.3	M2.4	M4.2		M4.3	M5.1	M2.5	M1.3	M6.1	M6.2	M6.3	M7.1	M7.2				M8.1	M8.2	M9.2	M1.4
Progress Monitoring Risk Management	PM1												PM2						PM3						PM4						PM5					PM6
Mobility schemes				Erasmus+ Internship at UT for a PhD student from WUST																BRISK2 scheme WUST to KTH																

4. DESCRIPTION OF THE PARTICIPATING RESEARCHERS

Partner Number, according to Part A	Research Team Members (for personnel include name, position and affiliation)	General Description
Wrocław University of Science and Technology (WUST) **Project Co-ordinator: Halina Pawlak-Kruczek** **PI: Agnieszka Urbanowska**	**Małgorzata Kabsch-Korbutowicz, Professor, Investigator**	**Małgorzata Kabsch-Korbutowicz** is the **head of Chair in Water and Wastewater Treatment, Faculty of Environmental Engineering of WUST**. Her 190 publications include 89 journal articles, 4 books, 32 monograph chapters, 30 conference publications and was cited 546 times. Took part in many research projects both as a leader and investigator. ☑Major publications: **A.Urbanowska, M.Kabsch-Korbutowicz** „The properties of NOM particles removed from water in ultrafiltration, ion exchange and integrated processes.“ *Desalin Water Treat* 2016, vol. 57, no. 29, pp. 13453-13461; **M.Kabsch-Korbutowicz, J.Wiśniewski, S.Kliber, A.Urbanowska** „Application of UF, NF and ED in natural organic matter removal from ion-exchange spent regenerant brine.“ *Desalination* 2011, vol. 280, no. 1-3, pp. 428-431
	Mateusz Wnukowski, Investigator	Expertise in GC-MS analysis. ☑Major publications: **P.Jamróz, W.Kordylewski, M.Wnukowski** “Microwave plasma application in decomposition and steam reforming of model tar compounds.” *Fuel Processing Technology* 2018, vol. 169, pp. 1-14.
	Michał Czerep, Investigator	Expertise in drying. ☑Major publications: **W.J.Tic, J.Guziałowska-Tic, H.Pawlak-Kruczek, E.Woźnikowski, A.Zadorożny, Ł.Niedźwiecki, M.Wnukowski, K.K.Krochmalny, M.Czerep, M.J. Ostrycharczyk, M.J.Baranowski, J.M.Zgóra, M.Kowal** “Novel concept of an installation for sustainable thermal utilization of sewage sludge.” *Energies* 2018, vol. 11, no. 4, s. 1-17.
	Łukasz Niedźwiecki, PhD Student	☑Major publications: **M.Wnukowski, P.Owczarek, Ł. Niedźwiecki** “Wet torrefaction of miscanthus – characterization of hydrochars in view of handling, storage and combustion properties.” *Journal of Ecological Engineering* 2015, vol. 16, no. 1, pp. 161-167.
Zakład Gospodarowania Odpadami Gać sp.z o.o. (ZGO) **PI: Przemysław Seruga**	**Katarzyna Kuriata, head of accounting**	MSc at WSB University in Wroclaw. Specialist on economic feasibility analysis of investments.
HoSt **PI: Marcel te Braak**	**Tjeerd Smit, Project Developer**	**Business development manager of HoSt,** MSc degree in Industrial Engineering and Management, 15 years’ experience in the field of project development and bioenergy financing.
KTH-Royal Institute of Technology (KTH) **PI: Weihong Yang**	**Pär Jönsson, Prof. Vice Dean of School of Industrial Technology and Mangment, KTH**	Published 265 peer-reviewed journal papers and 180 conference papers. Have been the main or co-supervisor for 60 students receiving a PhD and 48 students receiving a Licentiate degree. He has **participated in more than 8 EU projects, and coordinating and participating over 20 Energimyndigheten and VINNOVA.** Has also obtained more than 10 projects contracted directly by industries. Teacher of the year in the KTH materials design Bsc and MSc program three times. He **received the Adrian Normanton Medal and the The Stokowiec Medal** by the Institute of Materials, Minerals and Mining. Member of Royal Swedish Academy of Engineering Sciences.

Partner Number (Organisation Name)		General Description
University of Twente (UT)	**Eddy Bramer, Investigator**	Supervising more than 50 Post graduate students (Postdoc, PhD, PDEng and MSc). ☑ Major publications: **Z.A.El-Rub, E.A.Bramer, G.Brem** ”Experimental comparison of biomass chars with other catalysts for tar reduction” *Fuel* 87 (10-11), 2243-2252
	Artur Pozarlik, Investigator	Supervising more than 30 Post gradates students. Expertise in experimental and numerical research. ☑ Major publications: **R.Yukananto, A.Pozarlik, E.Bramer, G.Brem** “Numerical modelling of char formation during glucose gasification in supercritical water” Journal of Supercritical Fluids 140, 258-269
University of Science and Technology (AGH) PI: Aneta Magdziarz	**Agata Mlonka – Mędrala, PhD, Investigator**	Works in the Faculty of Energy and Fuels of AGH. Her research topics are renewable fuels thermal processing technologies, fuel characterization by advanced instrumental techniques, ash and deposit formation including heat transfer processes, mineral phase transformations and high-temperature corrosion. She participated in many international research projects and scholarships e.g. Analysis of biomass gasification and pyrolysis process in small scale application (BRISK project, Sweden), Phosphine oxide functionalized ionic liquids (Belfast - United Kingdom). ☑ Major publications: **R.Kaczmarczyk, A.Mlonka-Mędrala, S.Gurgul** “A thermodynamic analysis of chloride corrosion in biomass analysis of chloride corrosion in biomass-fired boilers for Fe-O-Cl-S” *E3S Web of Conferences*, 2017, 14, 02040; **W.Gądek, A.Mlonka-Mędrala et al.** „Gasification and pyrolysis of different biomasses in lab scale system: A comparative study” *E3S Web of Conferences*, 2016, 10, 00024

5. CAPACITY OF THE CONSORTIUM ORGANISATIONS

Partner Number (Organisation Name)		General Description
Wrocław University of Science and Technology (WUST)	**Role and main responsibilities in the project**	**Project coordinator, Leader of WP1, WP2, WP4 and WP9. Involved in all WP's.**
	Key research facilities, infrastructure, equipment	**Membrane research rigs for microfiltration, ultrafiltration, nanofiltration; GC-MS; CHNS analyser; TG/DTG-MS; ASA; DSC; autoclave for HTC; Toroidal dryer (research rig); Tape dryer (research rig); Drop Tube furnace.**
	Relevant publications / research/innovation products	• Patent PL 217515 "Installation and way of drying of lignite" **H.Pawlak-Kruczek, W.Mazurek, J.Lichota** • **A.Urbanowska, M.Kabsch-Korbutowicz** „The properties of NOM particles removed from water in ultrafiltration, ion exchange and integrated processes." *Desalin Water Treat* 2016, vol. 57, no. 29, pp. 13453-13461
Zakład Gospodarowania Odpadami Gać sp.z o.o. (ZGO)	**Role and main responsibilities in the project**	**<u>Key user.</u> Leader of Task 8.2 in WP8. Participating in WP1, WP2, WP4, WP5, WP6, WP7 and WP9.**
	Key research facilities, infrastructure, equipment	**Anaerobic digestion installation** within the confines of the waste processing facility.
	Relevant publications / research/innovation products	ZGO is a key user company, that has already managed to build a state-of-the-art waste processing facility, including anaerobic digester.
HoSt	**Role and main responsibilities in the project**	**<u>Technology developer.</u> Leader of WP8. Participating in WP1, WP7 and WP9.**
	Key research facilities, infrastructure, equipment	**Laboratory facilities in Enschede, with biomass to gas analysis equipment, such as batch-testing, continuous small scale digesting, separator equipment and dm/om ovens. Three operating plants in ownership with digestors, separation equipment, water purification, UF and RO-facilities.**
	Relevant publications / research/innovation products	Several Dutch reports as part of grants of RVO, such as 'Hernieuwbare energie in Topsector Energie / Renewable Energy within Topsector Energie', 'retreaving minerals for digestion', 'Demonstating Demon-proces'
KTH-Royal Institute of Technology (KTH)	**Role and main responsibilities in the project**	**Leader for WP6. Participating in WP1, WP2, WP7, WP8 and WP9.**
	Key research facilities, infrastructure, equipment	**Oil bath heater, pyrolysis bench test reactor, SEM, XRD, GC/MS, ASPEN software.**
	Relevant publications / research/innovation products	• "A novel process to produce Magnetic biochar derived from lignin" industrial contract 2018-2019 • **Jun Li, Xiaolei Zhang, H.Pawlak-Kruczek, Weihong Yang, P.Kruczek, W.Błasiak** "Process simulation of co-firing torrefied biomass in a 220 MWe coal-fired power plant." *Energy Conversion and Management* 2014, vol. 84, s. 503-511.

Partner Number (Organisation Name)		General Description
University of Twente (UT)	**Role and main responsibilities in the project**	**Leader of WP3. Participating in WP1, WP2, WP4, WP5, WP6, WP7, WP8, WP9.**
	Key research facilities, infrastructure, equipment	**Supercritical Autoclave Batch Reactor, continuous gas analysing systems, IR, FID, FTIR GC and GS-MS, element analyser, Bomb calorimeter, TGA, BET surface area and porosimetry.**
	Relevant publications / research/innovation products	• **Z.Abu El-Rub, E.A.Bramer, G.Brem** „Review of catalysts for tar elimination in biomass gasification processes“ *Industrial & engineering chemistry research* 2004, 43 (22), 6911-6919 • **T.S.Nguyen, M.Zabeti, L.Lefferts, G.Brem, K.Seshan** **„**Conversion of lignocellulosic biomass to green fuel oil over sodium based catalysts“ *Bioresource technology*, 2013, 142, 353-360 • **J.A.M.Withag, J.R.Smeets, E.A.Bramer, G.Brem** „System model for gasification of biomass model compounds in supercritical water–a thermodynamic analysis“ *The Journal of Supercritical Fluids*, 2012 , 61, 157-166
AGH University of Science and Technology (AGH)	**Role and main responsibilities in the project**	**Leader of WP5. Participating in WP1, WP6, WP7, WP9.**
	Key research facilities, infrastructure, equipment	**CHNS analyser (LECO), Scanning Transmission Electron Microscope FEI Nova NanoSEM 450 with STEM mode, Quantachrome Poremaster, Mettler Toledo STA (TG-DSC) Analyser with GS-MS, PANalytical Empyrean X-ray Diffractometer (XRD), Spectrometer WD-XRF ZSX Primus II Rigaku (XRF)**
	Relevant publications and/or research/innovation products	• **A.Magdziarz et al**. “Mineral phase transformation of biomass ashes - Experimental and thermochemical calculations.” *Renewable Energy* 2018, 128, 446–459. • **M.Wilk, A.Magdziarz** “Hydrothermal carbonization, torrefaction and slow pyrolysis of Miscanthus Giganteus.” *Energy* 2017, 140, 1292–1304 • **M.Wilk, A.Magdziarz et al.** “Combustion and kinetic parameters estimation of torrefied pine, acacia and Miscanthus giganteus using experimental and modelling techniques.” *Bioresource Technology* 2017, 243, 304–314. • **A.Magdziarz et al.** “Chemical composition, character and reactivity of renewable fuel ashes.” *Fuel* 2016, 176, 135–145. • **W.Gądek, A.Mlonka-Mędrala et al.** „Gasification and pyrolysis of different biomasses in lab scale system: A comparative study” *E3S Web of Conferences*, 2016, 10, 00024