Sustainable and efficient resource utilization of waste and water in energy transition

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Overview

In order to achieve energy transition goals, sector coupling is frequently described as a solution for decarbonisation across different energy sectors in the energy system. Investigations like in [1] found that energy transition scenarios considering sector coupling lead to the highest emission reductions. To achieve the maximum emission reduction, a holistic view on sector couplig with the consideration of as many energy sectors as possible is mandatory [2]. In addition to energy input, conversion of energy between different sectors requires resource utilization, whereas the latter is often not considered in corresponding methodologies. Publications like [3] and [4] examine waste and water management concepts, without investigating the entire energy system. The contribution of this article is to combine the holistic investigations on sector coupling beyond energy with sustainable resource utilization, also considering greywater as possibility to increase water sustainability. In that context, the impact of waste and water energy recovery and the resource utilization of sector coupling conversion technologies is investigated in theoretical use cases of cities in Austria, Spain and Israel. The goal is to evaluate the amount of used resources in conversion technologies and how to process the available and emerging resources optimally.

Methodology

For the investigation of the use cases, the energy system in each country is modelled and the operation of the energy systems is optimized. For this purpose, a linear optimisation problem (LP) is set up and implemented in the Open Energy Modelling Framework OEMOF [5]. In the model, the optimal energy, volume and mass flows between the energy sectors are evaluated by minimum costs (dispatch model). The costs comprise by operational costs of conversion technologies and costs for externally purchased energy.
Each energy sector is modelled as a bus, implementing a balance rule for input and output flows as a model constraint. Furthermore, the conversion technology operation is limited by the maximum processable amount per timeunit. Conversion equations between input and output of a conversion technology are implemented as further constraints. In addition to traditional sector coupling models, the resource utilizations of certain conversion technologies, like potable water use for electrolysis, are implemented as supplemental model constraints. Water scarcity is considered in form of scarcity factors and maximum limits in additional constraints.

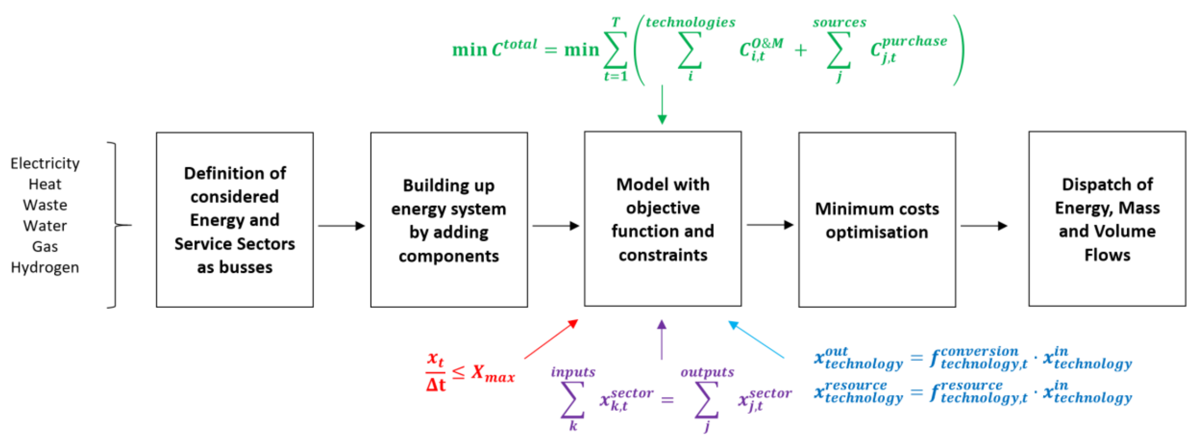

Figure 1 Model Workflow

Results

Waste and water treatment energy recovery has a high impact on the energy system in the different use cases. Waste combustion can contribute to about 20% of the electricity generation and 7% of the heat generation in the considered cities, which is presented in Figure 2. For sludge combustion, the contributions of 10% to electricity and 4% to heat are slightly lower. Furthermore, efficiently implemented sludge anaerobic digestion can provide all the required

process gas in Austria and Spain. In Israel, the energy system is more dependent on natural gas, whereas in the considered city, 80% of the gas demand for process gas and decentral gas conversion technologies can be covered by sludge anaerobic digestion. Additionally, the contribution of waste combustion to electricity and heat generation is higher due to less decentral generation alternatives. All of this requires efficiently timed treatment of waste and sewage sludge. Otherwise, the resource treatment can not be implemented in an efficient manner, and the energy recovery potential is wasted.
Resource utilization of water in electrolysis has a minor impact compared to the total water demand. In areas with water scarcity, like Spain and Israel, the potable water use for electrolysis is not negligible. However, with the consideration of greywater as an additional option to cover the water demand (presented in green in Figure 3), electrolysis can be implemented in dry areas despite water scarcity constraints.

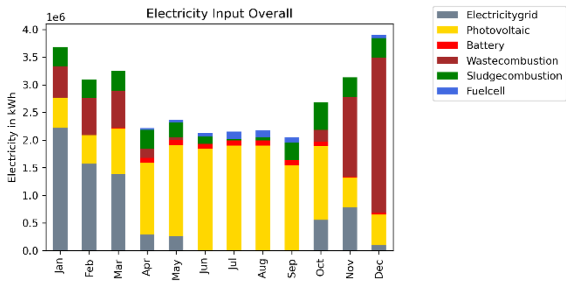

Figure 2 Electricity Coverage

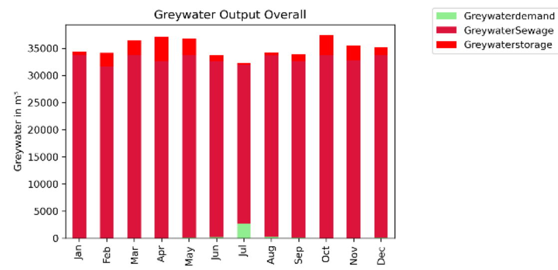

Figure 3 Greywater Contribution

Conclusions

Waste and water energy recovery can contribute significantly to the generated energy in cities. An efficient and consumption behaviour tailored resource treatment should be implemented in cities, to reduce the required amount of non-renewable energy generation. Water as a resource for hydrogen production has a comparably low contribution to the total water consumption. The low share of water for electrolysis can still have an impact in dry areas with a certain level of water scarcity. In an optimized energy system, greywater is utilized to cover the water demand in order to make hydrogen production by electrolysis possible from the water resource point of view. In conclusion, sustainable sector coupling implementation requires the consideration of waste and water energy recovery technologies. Furthermore, an efficient and sustainable use of resources and resource saving options like the use of greywater are mandatory.

Acknowledgement

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