TECHNISCHE UNIVERSITÄT WIEN Vienna | Austria

Energy Economics Group

Local Sustainable Communities: Consumer involvement for sustainable development in energy transition

Matthias Maldet
Carlo Corinaldesi
Georg Lettner
Christoph Loschan
Daniel Schwabeneder

Content

- Introduction and motivation
- Investigation setup
- Methodology
- Results
- Conclusions and outlook

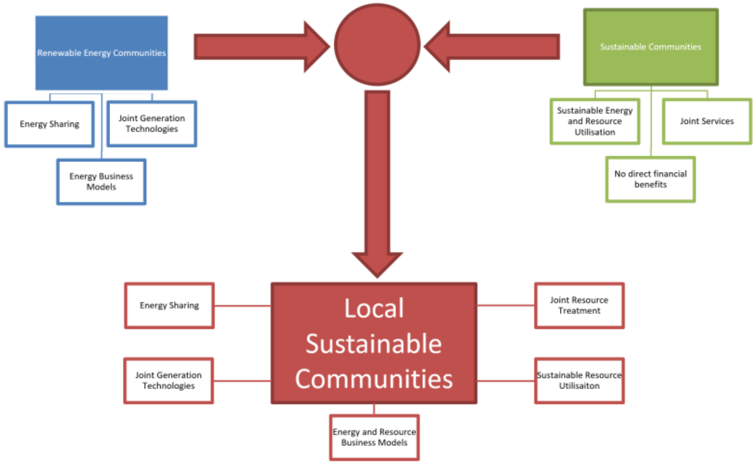
Introduction and Motivation

- Sustainability in energy system operation: Transition from energy efficiency to energy- and resource efficiency
- United Nation Sustainable development goals as motivation[1]
- EU Taxonomy Regulation also with consideration of sectors beyond electricity[2]
- Local Sustainable Communities as a concept to reach these goals
- Involve consumers in energy and resource utilisation operations

1: https://sdgs.un.org/goals
2: https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/eu-taxonomy-sustainable-activities_en

LSC – Local sustainable community

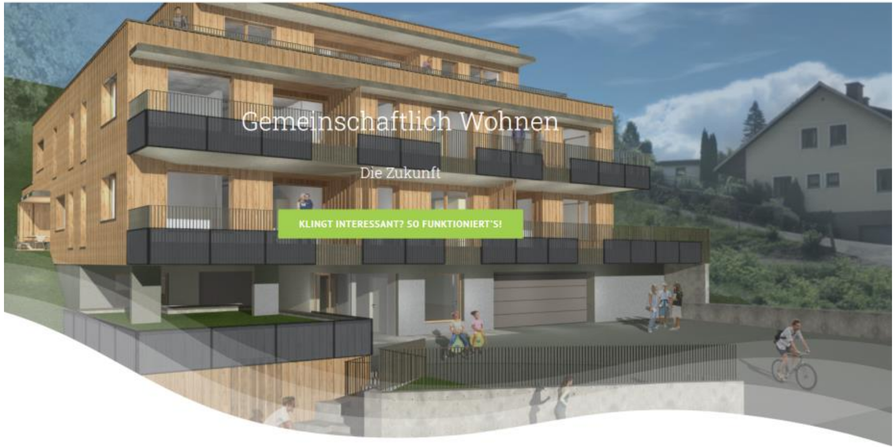
- Sustainable Community
  - Definition by Institute of Sustainable Communities[1]
  - Manage human, natural and financial capital to meet the current needs
  - Own initiative without financial incentives
- Local Energy Community
  - Joint use and trading of energy
  - Financial incentives like reduced grid tariffs
- Local Sustainable Community
  - Combination of both
  - Sustainable Communities with financial incentives



1: https://sustain.org/about/what-is-a-sustainable-community/

Investigation setup – State of the art

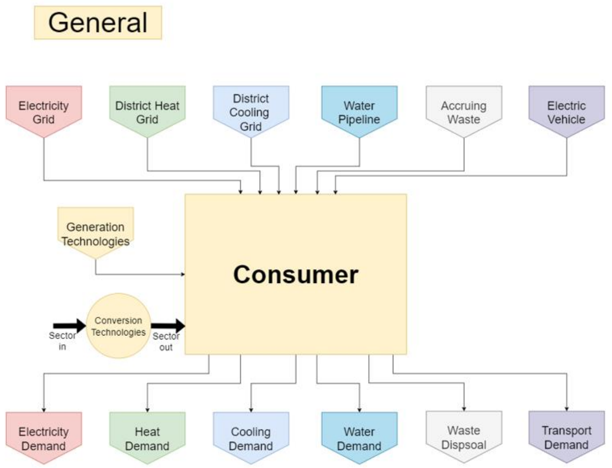
- Local sustainable community GeWoZu[1]
  - „Gemeinschaftlich Wohnen Die Zukunft“ in Waidhofen/Ybbs (Lower Austria)
  - 12 households and 33 people
  - Joint technologies
- Extension for analyses
  - Consumer technologies
  - Energy sharing
  - Joint resource treatment
  - LSC business models



1 https://gewozu.at/

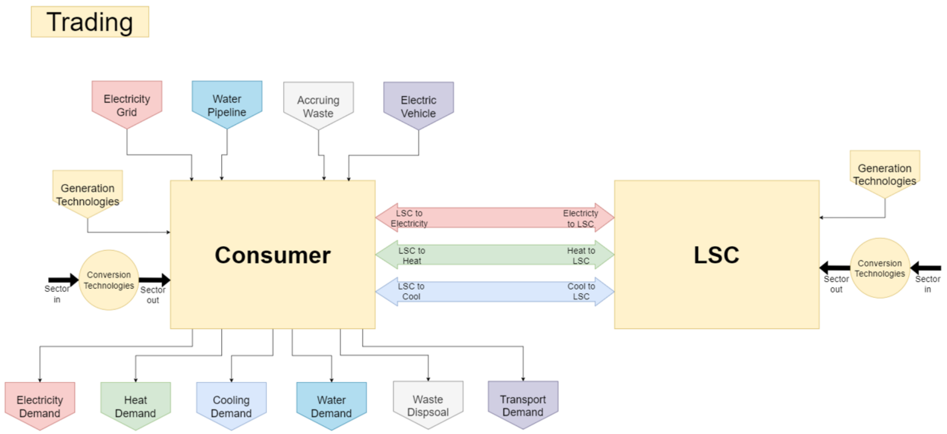
Methods - Model Setup

- Minimum cost optimisation for LSC and its consumers: $\min z = \min c^{total}$
- Costs: Purchase costs, O&M costs, disposal costs
  - $C_{i,j} = \sum_t^T (\sum_{k \in Sources} x_{t,i,j,k} \cdot \Pi_k^{purchase} + \sum_{l \in Technologies} x_{t,i,j,l} \cdot C_l^{O\&M} + x_{t,i,j} \cdot C_j^{disposal})$
- Consumers in LSC with predefined demands
- Constraints
  - Balance rule for each sector
    - $X_{t,i,j}^{Demand} = x_{t,i,j}^{in} \; \forall \; i \in Consumers, \; j \in Sectors$
    - $x_{t,i,j}^{in} = \sum_{k \in Sources} x_{t,i,j,k} + \sum_{l \in Technologies} x_{t,i,j,l}$
  - Technology limitations
    - $\frac{x_{l,t}}{\Delta t} \leq \frac{X_l^{max}}{\Delta t} \; \forall \; l \in Technologies, t \leq T$
  - Conversion relationships
    - $x_{l,t}^{out} = F_{l,t}^{conversion} \cdot x_{l,t}^{in} \; \forall i \in Technologies$



Introduction of trading

- Operations manager for LSC
  - Main responsibilities of LSC operation
  - Joint generation technologies and resource treatment organisation
- Trading between LSC participants over LSC operator
  - Selling of energy or resource to LSC operator
  - Consumer purchase of energy or resource from LSC operator



Introduction of trading

- Additional option to cover balance rule → LSC purchase
- Option for consumers to provide energy to LSC + LSC can provide generation and conversion technologies
- Balance rules and costs change
- Change in consumer balance rule
  - $X_{t,i,j}^{Demand} = \sum_{k \in Sources} x_{t,i,j,k} + \sum_{l \in Technologies} x_{t,i,j,l} + x_{t,i,j}^{LSC2energy} - x_{t,i,j}^{energy2LSC}$
- LSC with own balance rule
  - $\sum_{k \in Sources} x_{t,i,j,k} + \sum_{l \in Technologies} x_{t,i,j,l} + \sum_{i \in Consumers} x_{t,i,j}^{energy2LSC} = \sum_{i \in Consumers} x_{t,i,j}^{LSC2energy}$
- Consumer costs
  - $C_{i,j}^{new} = C_{i,j}^{old} + C_{i,j}^{LSCpurchase} - Rev_{i,j}^{LSCsale}$
- LSC costs
  - $C_{LSC,j} = \sum_t^T (\sum_{k \in Sources} x_{t,i,j,k} \cdot \Pi_k^{purchase} + \sum_{l \in Technologies} x_{t,i,j,l} \cdot \mathrm{C}_l^{O\&M} + x_{t,i,j} \cdot C_j^{disposal} + C_{i,j}^{consumerpurchase} - Rev_{i,j}^{consumersale}$

Energy recovery options

- Service costs paid by LSC
- Recovered energy and resources assigned to LSC
- Treatment at sewage treatment plant: Waterrecovery
  - Recovered water: $v_{t,LSC}^{water,recovered} = K^{waterrecovery} \cdot v_{t,LSC}^{sewage}$
- Sludge incineration:
  - $q_{t,LSC}^{sludge,i} = \eta^{sludge,i} \cdot v_t^{sludgeincineration}, i \in \{elec, heat\}$
- Waste combustion
  - $q_{t,LSC}^{waste,i} = \eta^{waste,i} \cdot v_t^{wastecombustion}, i \in \{elec, heat\}$
- Costs dependent on O&M costs of technologies and on processes resource amount

Water demand coverage

- $d_{t,i}^{water} = v_{t,i}^{Pipe2consumer} + v_{t,i}^{LSC2consumer} + v_{t,i}^{Pool2consumer} + v_{t,i}^{pipe,excess}$
- Limited Pipeline Purchase $v_{t,i}^{Pipe2consumer}$ at normal costs
- LSC purchase from recoverd sewage $v_{t,i}^{LSC2consumer}$ at reduced costs
- Non-limited excess purchase $v_{t,i}^{pipe,excess}$ at higher costs
- Waterpool with indirect water consumption right trading
  - Water reduction flexibility: $d_{t,i}^{water} \geq D_{t,i}^{water} - V_{t,i}^{WFF}$, $V_{t,i}^{WFF} \in [0, 0{,}5 \cdot D_{t,i}^{water}]$
  - Water reduction potential stochastically[1] determined or pre-defined
  - Reduced waterdemand as input to LSC waterpool → revenues
  - Pool purchase with reduced costs

1: http://www.oecd.org/env/consumption-innovation/43181277.pdf

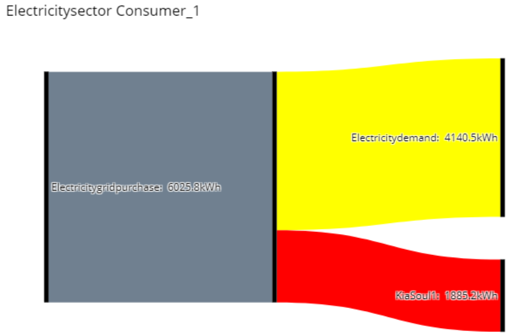
Waste recycling price

- Implementation of a recycling and reduction market
- Consumers can reduce waste and generate revenues
- Definition of recycling intention for each consumer in the LSC
- Willingness for recycling stochastically[1] or pre-defined
- Implementation of a waste market
  - Definition of a recycling price to generate revenues by recycling
  - $Rev^{recycling} = \sum_{t \in T} m_{t,i}^{recycling} \cdot C^{reycling}$
  - Competition waste recycling – energy recovery savings → promotion of recycling by price setting

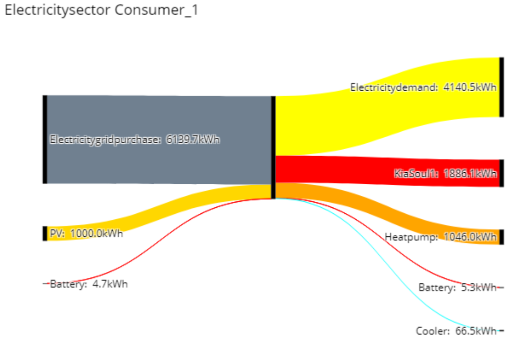
1: https://de.statista.com/statistik/daten/studie/1304250/umfrage/umfrage-zur-persoenlichen-einstellung-zum-recycling-in-oesterreich/

Results Single Consumer Consideration

- No technologies
  - 23070€ total costs, emissions of 26,4t CO_2
  - All energy obtained from grids, all water from pipeline
  - No value in waste → just disposal
- Technology Introduction
  - Certain consumers in the LSC with technologies
  - Total cost reduction to 20899€
  - Cost decrease for consumers with technology
  - Emission reduction to 23,2t CO_2
  - Only for consumers with own technologies



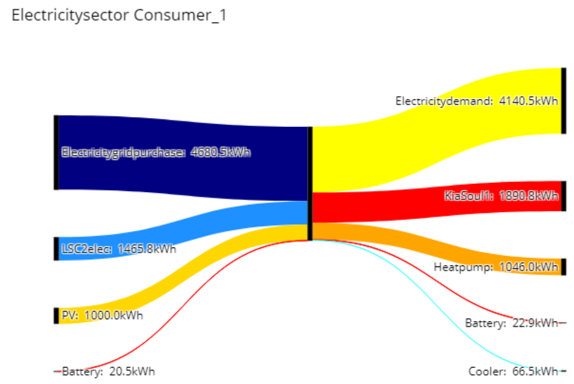
No Technologies

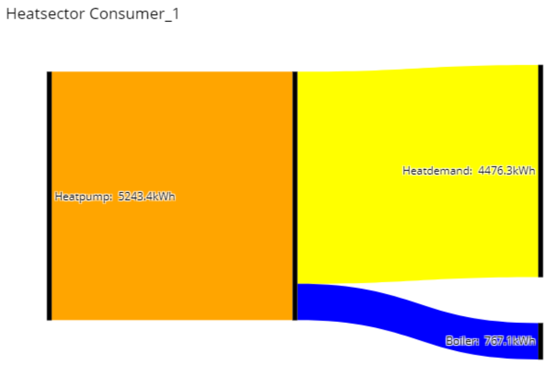


Technologies

Results Trading

- Total cost reduction to 17493€, total emission reduction to 15,7t
- Consumers without own heating and cooling technologies can purchase all heating and cooling from the LSC → Savings as no own conversion technologies are required
- No heat trading → rather heat provision via LSC heatpump (same for cooling)
- Joint generation technologies lead to a more efficient technology operation

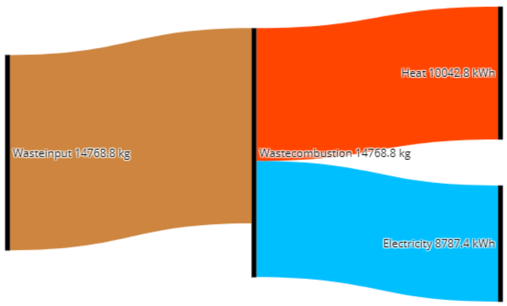




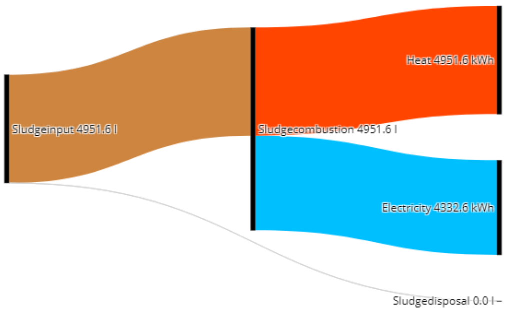
Results LSC Business Model

- Introduction of energy recovery
- Total costs decrease by 9200€ to 8301€
  - Waste with value in energy
  - Water recovery purchase with lower prices
- Emissions decrease by 5,2t to 10,5t CO_2
- Electricity: Waste combustion 21%, sludge combustion 10,4%
- Heat: Waste combustion 22,7%, sludge combustion 11,2%
- Waste recycling not carried out

Waste Treatment

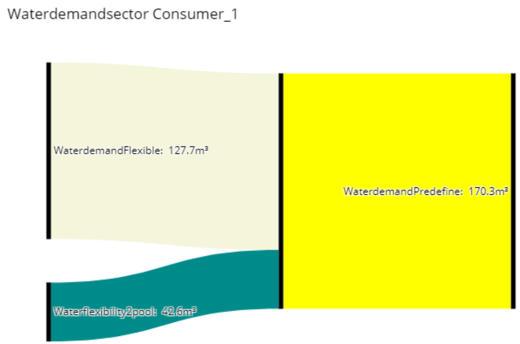


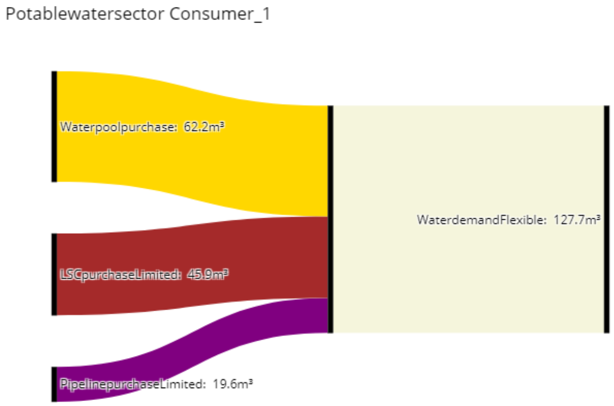
Sludge Treatment



Results LSC Business Model

- Water demand coverage model as efficient option for water reduction
- Total demand decreases by 350m³ (about 25%) in LSC
- Only 27% (288m³) covered by pipeline purchase
- 34% by waterpool purchase, 39% by recovered water purchase
- LSC watermodel for more efficient water use and lower total costs (-945€)
- But: requires agreement in reduction





Conclusions

- LSCs lead to a more efficient energy use and resource utilisation
- The alternative use of resources has a positive impact on the LSC
- Alternative uses (reduction and treatment) are in competition
- Policy actions are required to promote certain alternative uses if desirable
- These policy actions can be market price settings, CO2 prices, reduction targets or energy efficiency measures
- Water reduction agreements have a positive impact on water balance and water costs

Outlook

- LSC operation has a high potential in upscaling by adding further service providers and generation technology providers
- Interaction between multiple LSCs can be a future extension of LSC implementation
- However, an extension beyond borders can be misleading
- Borders of LSC scopes need to be defined

Acknowledgement

- This work was performed under the “Hybrid Local Sustainable Communities” project, and was supported with funds from the Climate and Energy Fund and implemented in the framework of the RTI-initiative “Flagship region Energy” within the Green Energy Lab.

Matthias Maldet

Technical University of Vienna

Institute of Energy Systems and Electrical Drives

Energy Economics Group - EEG

Gußhausstraße 25-29 / E370-3

1040 Vienna, Austria

(T) +43 1 58801 370 365

(E) maldet@eeg.tuwien.ac.at

(W) www.eeg.tuwien.ac.at