

Inducing Energy and CO₂ Savings in Private Households by introducing CO₂-budgets – Findings from a Living Lab Experiment

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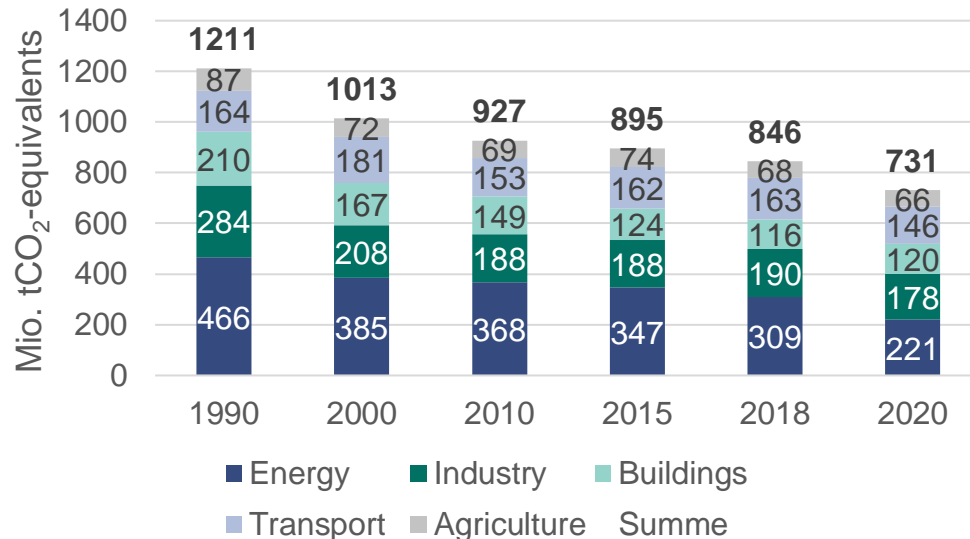
Agenda

- Motivation
- Methods
- Results
- Conclusion & Future Research



Motivation

Green house gas emissions in Germany

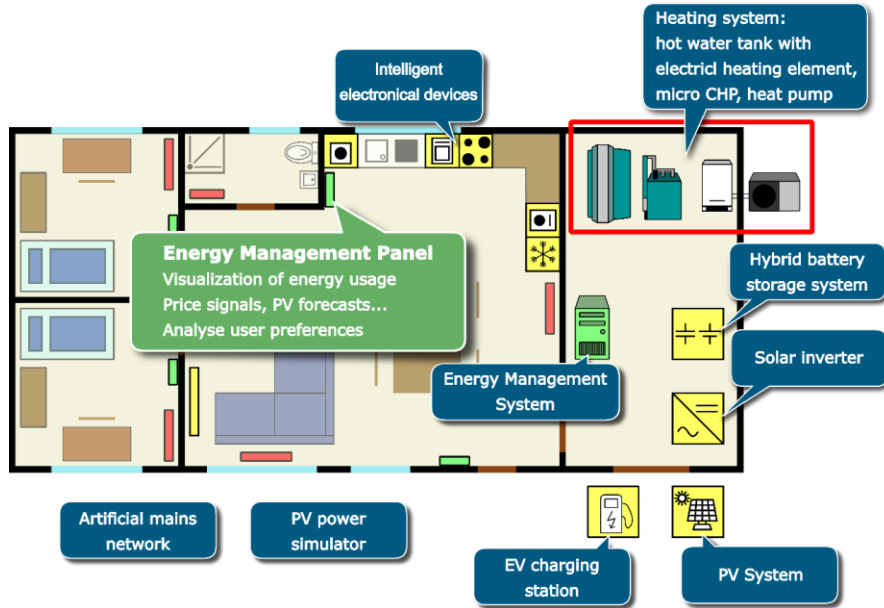


[BMUV 2021]

- Emission trading scheme: EU ETS (since 2005)
 - Big emitters (energy sector, industry)
- Carbon costs passed on to consumers (indirect incentive)
- Further reduction of emissions needed
- Some individuals already off-set their emissions voluntarily
- Direct allocation of allowances to end-users: direct, visible and 'hands-on' incentive

[Woerdman, Bolderdijk 2017]

The Energy Smart Home Lab - ESHL



Smart Home Features

Energy Technology Features



Research Questions

Motivation



Residential sector

Theoretical perspective

Guzman & Clapp 2017

Fuso Nerini, Fawcett et al. 2021

Woerdman & Bolderdijk 2017

Residential sector

Field studies

Howell 2012

Hendry, Webb et al. 2015

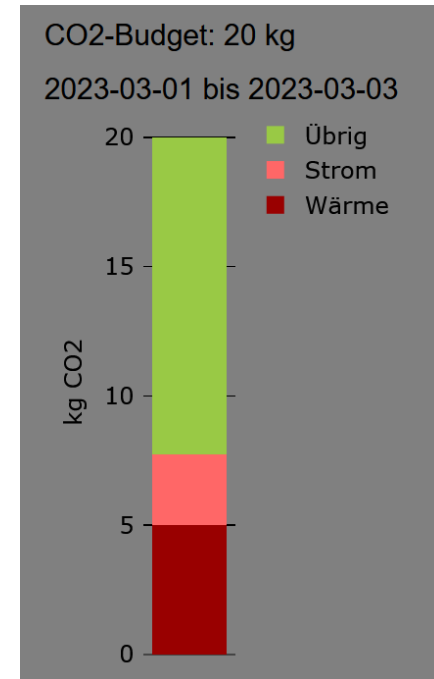
Research Questions

- Are the tenants willing and able to work with the given CO₂-Budget?
- Which trade-off results from adapting the electricity and heat consumption behavior accordingly?
- Is a gradually decreasing cap of the CO₂-Budget effective?
- Does real-time feedback support the acceptance of this measure?

Methods

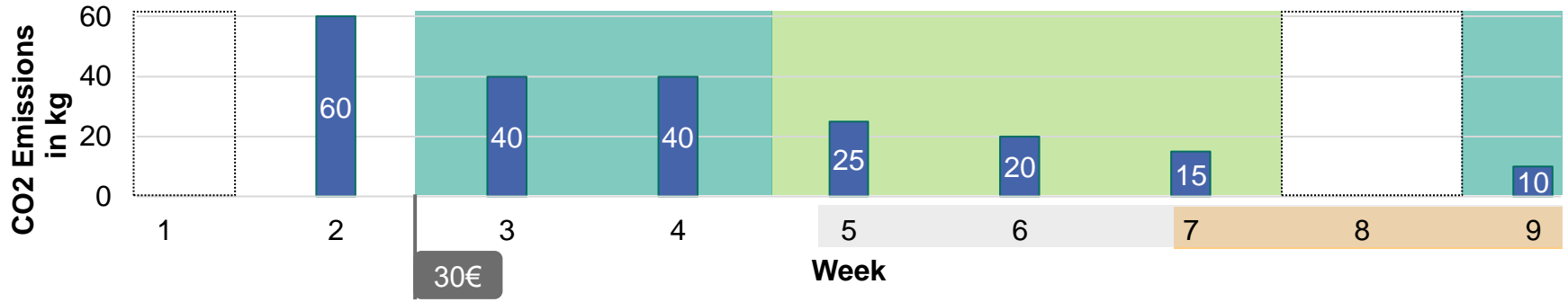
Experiment Design






- Experiment Duration: 9 weeks in the second quarter of 2023
- Weekly changing CO₂-budgets
- Comprising heating and electricity demand
- If exceeding the budget: automatically buying new allowances
- Weekly prompts on the dashboard within the smart home
 - Informing occupants about the new budget
 - Real-time feedback about their CO₂-emissions
- Weekly interviews



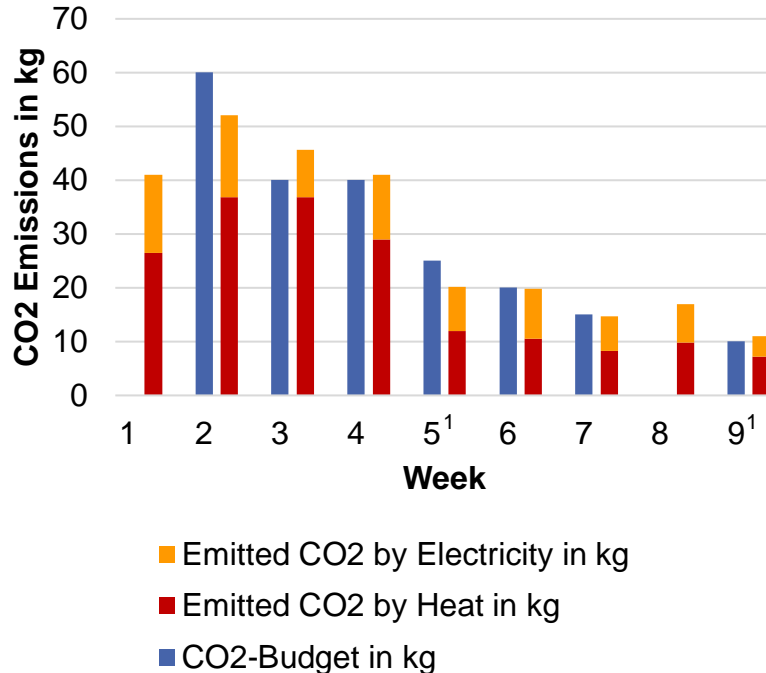
Dashboard screen and feedback on CO₂-budget performance

Allocated CO₂-budgets



-  Reference intervals wo. CO₂-budget
-  0,65€/kg_CO₂ charge if exceeding the budget
-  Purchase additional 5kg CO₂-budget for 3,25€
-  Heat: now only heatpump considered within emission factor from here-on
-  Photovoltaik feed-in is from now-on accounted for

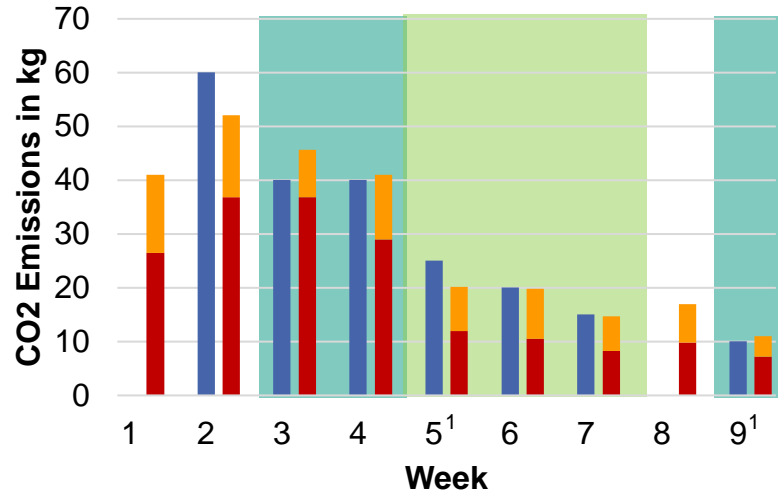
CO₂-budget and actual CO₂-emissions by electricity and heat consumption



- Overall reduction in emissions in correlation with budget reduction (factor five)
- Week five and nine: only one occupant
- Week five: no significant change compare to the week before
- Week nine: significant reduction in comparison to all the other weeks, two full days not occupied, still breaching the budget

¹Only one person at home during the week

Results – Penalty schemes



■ Emitted CO2 by Electricity in kg

■ Emitted CO2 by Heat in kg

■ CO2-Budget in kg

■ 0,65€/kg_CO₂ charge if exceeding the budget

■ Purchase additional 5kg CO₂-budget for 3,25€

¹Only one person at home during the week

- Penalty one → soft approach
 - Tenants' always breached the budget
- Penalty two → buying 5kg extra
 - Tenants' always within budget

■ Residents' perspective

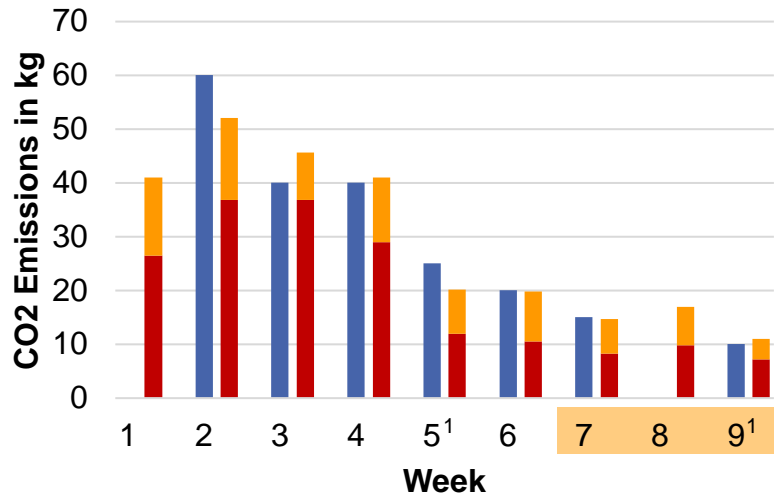
■ Week seven:

■ Last day/evening:

- could soup, no light (candles), no tea, staying longer outside using campus facilities for charging the laptop, not showers

Resident A: „We could see that we would make it barely, therefore we were motivated to not exceed the budget.“

Weeks with and without Photovoltaik generation



Resident A: „PV was making it easier – using the sun hours for the washing machine, the dishwasher.“

Resident B: „I am coming home from work only around 6pm, so the sun window was too short to be useful for me.“

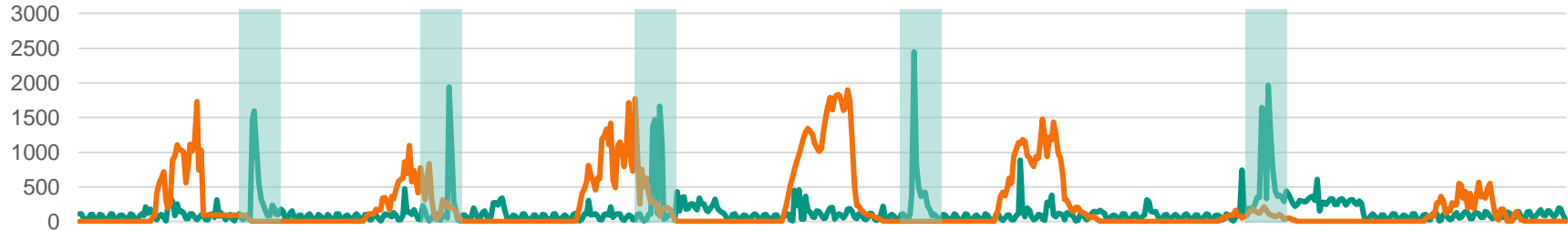
- Emitted CO2 by Electricity in kg
- Emitted CO2 by Heat in kg
- CO2-Budget in kg
- Photovoltaik feed-in is from now-on accounted for

¹Only one person at home during the week

Exemplary weeks without and with PV generation

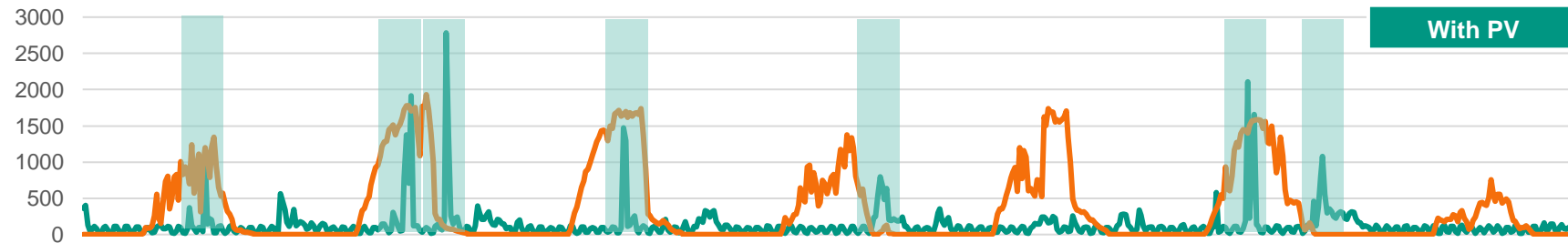
Week 4

Without PV



Week 7

With PV



— Total load (15min) — PV generation

Conclusion

Summary

- Effective reduction of emissions
- Being charged for the next consecutive 5kg of CO₂-emissions had a successful effect
- PV enabled demand shift
- Bias: voluntary participation, short period

Outlook

- Expand the sample size and duration
- Add personal transport emissions into the budget
- Expanding the trading options

Thank you!



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