TECHNO-ECONOMIC AND ECOLOGICAL EVALUATION OF DIFFERENT DISTRICT HEATING NETWORK GENERATIONS FOR TWO GERMAN DISTRICTS

Marc-André Triebel

Daniel Siejak*
Dr. Annette Steingrube
Gerhard Stryi-Hipp

Fraunhofer Institute for Solar Energy Systems ISE

Smart Energy Systems Conference

Copenhagen / Online, 21.-22.09.2021

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* Schäffler Sinnogy

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AGENDA

- Introduction
- Methodology
- Study Results
- Conclusion

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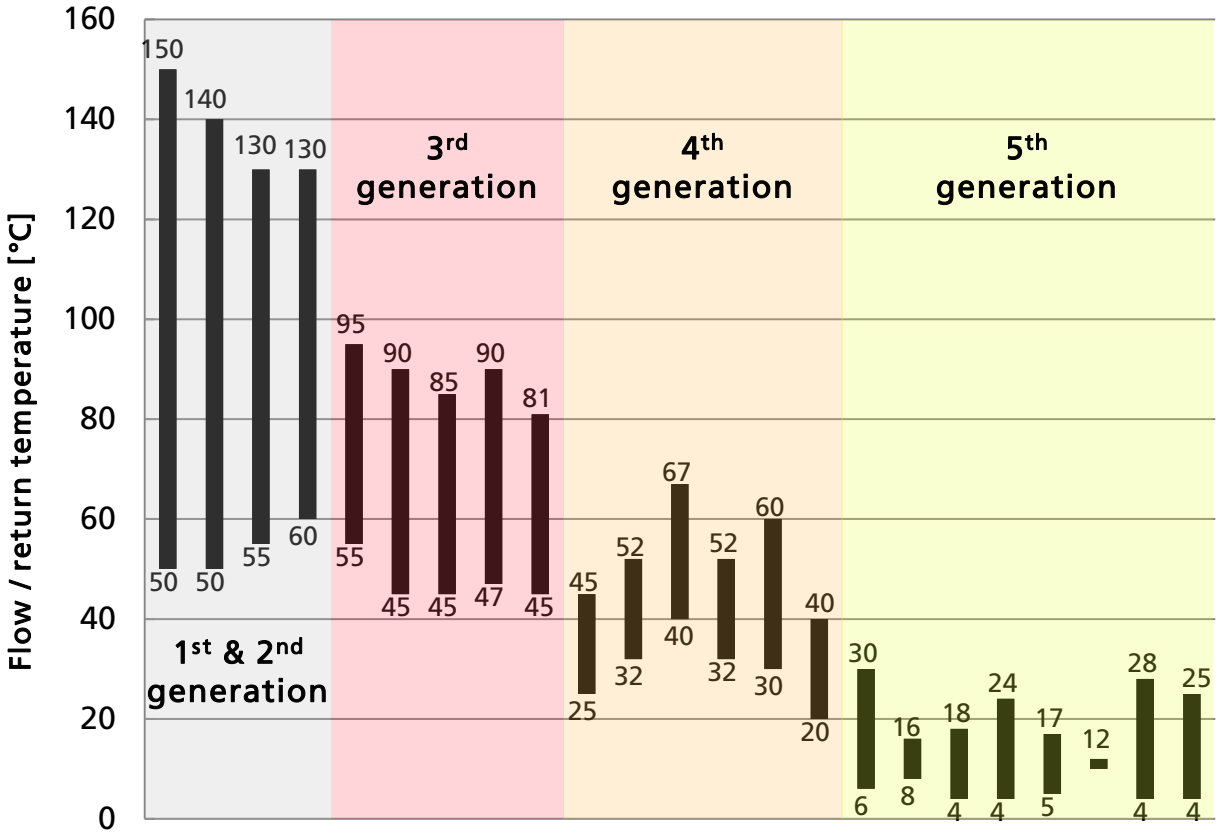
Introduction - Motivation & Need for Research

- Decarbonisation of heat supply via district heating networks (DHN) requires lower supply temperatures in order to:
  - Reduce heat losses
  - Integrate renewable energy sources
  - Integrate waste heat potentials

Research questions:

- What are the benefits of different DHN generations with regards to economic and ecological aspects for real case studies?
- Which boundary conditions promote the implementation of low temperature DHN?



Literature study results regarding flow / return temperatures for existing DHN clustered into different DHN generations

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Introduction – Case Studies

Techno-economic and ecological comparison of 3rd to 5th generation DHN for two German districts:

Case study 1: Pfaff-District (Kaiserslautern)

Pfaff-District, Source: Astoc Mess; 2018

Key data:

- 19 ha
- 41 Buildings (new & existing)
- Residential & commercial usage

Evaluated:

- 3rd – 5th generation DHN for whole district

Case study 2: Patrick-Henry-Village – PHV (Heidelberg)

Patrick-Henry-Village, Source: KCAP Achitects&Planners; 2019

Key data:

- 115 ha
- 212 Buildings (new & existing)
- Residential & commercial usage

Evaluated:

Two DHN:

- 3rd generation for existing buildings
- 3rd – 5th generation for new buildings

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Methodology

- Hydraulic sizing of the 3rd – 5th generation DHN for the Pfaff-District and Patrick-Henry-Village
- Modelling of the technical operation of the different DHN in Modelica Dymola for both districts

- Main characteristics:

	3rd generation (3G)	4th generation (4G)	5th generation (5G)
Heat source	Combined Heat and Power plant	Industrial waste heat	Environmental/waste heat
DHN flow temperature	70 – 90°C	40°C	12 – 20°C
ΔT flow/return	20 K	10 K	8 K
Heating system	Radiators	Underfloor heating	Underfloor heating
Space heating supply	District heating network	District heating network	DHN + Heat pumps
Domestic hot water supply	District heating network	DHN + Booster heat pumps	DHN + Booster heat pumps

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Methodology

- Ecological and economic impact assessment for different scenarios for the different DHN generations in both districts:

Ecological scenarios	Electricity	District heat	Waste heat
Base ecological scenario	0.537 t CO_2/MWh Constant (German electricity mix 2018)	0.195 t CO_2/MWh Constant	0.0 t CO_2/MWh Constant
80% RE scenario	Descending 80% renewable electricity in 2050		
100% RE scenario	Descending 100% renewable electricity in 2050		

Economic scenarios	Additional considerations	
Base economic scenario	Calculation of costs according to VDI 2067	
Carbon pricing scenario	Low price (10 – 60 €/t CO_2)	High price (50 – 250 €/t CO_2)
Subsidy scenario	Utilisation of German public subsidy programmes in 2019	
Cooling demand supply scenario	Additional benefits for 5th generation DHN by supplying cooling demand	
	Cooling demand	Comfort cooling demand (only for PHV)

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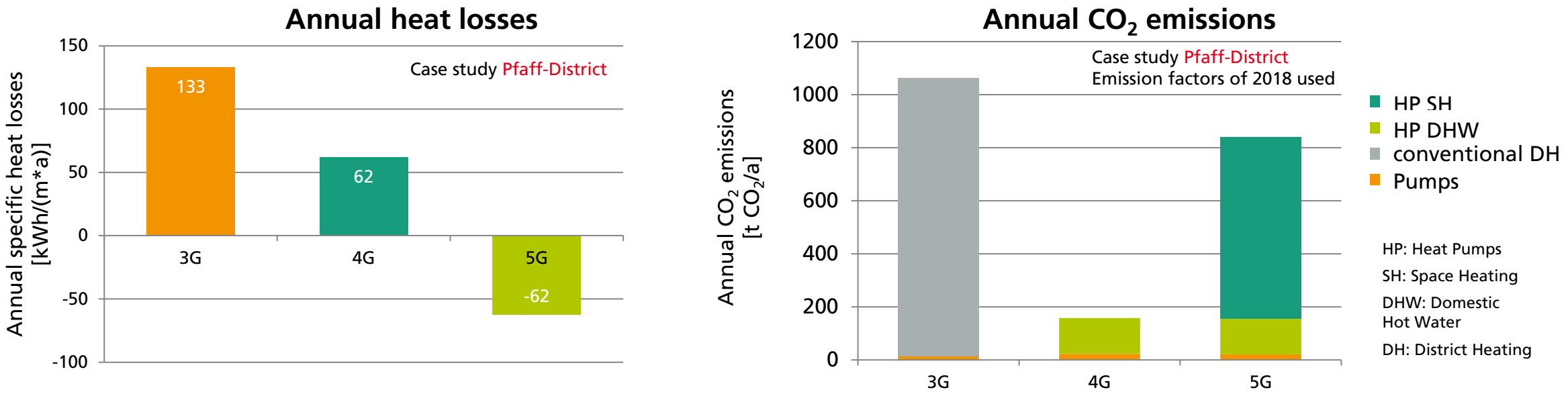
Study Results – Technical & Ecological Analysis

Simulation of the 3rd – 5th generations of DHN shows the following **technical and ecological results**:

- Reduction of supply temperatures reduce heat losses, 5th generation DHN shows heat gains
- 4th instead of 3rd generation DHN show high CO_2 reduction potentials (Pfaff-District -85%, PHV -54%)
- Higher electricity demand of 5th generation DHN leads to higher CO_2 emissions compared to 4th generation today
  ➔ 5th generation DHN benefit the most from decarbonisation of electricity supply



Annual specific heat losses per line length per DHN generation (left) and annual CO_2 emissions (in 2018) for DHN generations (right) for the Pfaff-District

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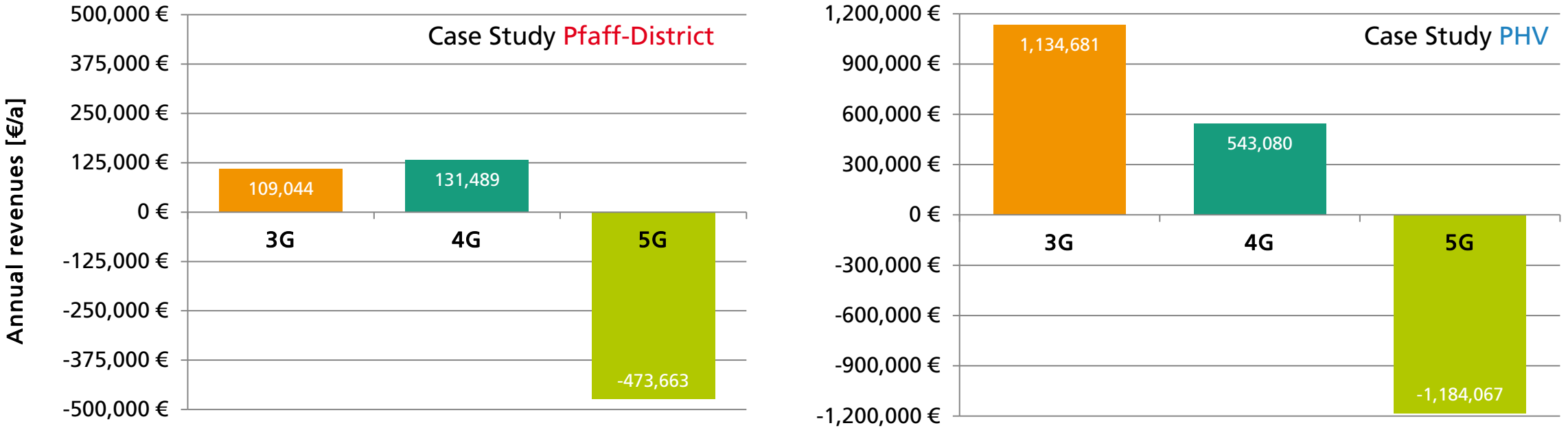
Study Results – Economic Analysis (1)

Economic comparison of the 3rd – 5th generation DHN for both districts in the **base economic scenario:**

- Pfaff-District: 4th generation DHN are the most cost-effective option in the base scenarios
- PHV: 3rd generation DHN avoids necessity to implement two separated DHN and hence has the highest revenues
- Operation of 5th generation DHN appears to be uneconomical

Annual revenues of the operator of the heat supply systems – comparison of different DHN generations



Mean annual revenues for the different DHN generations for Pfaff-District (left) and Patrick-Henry-Village (right)

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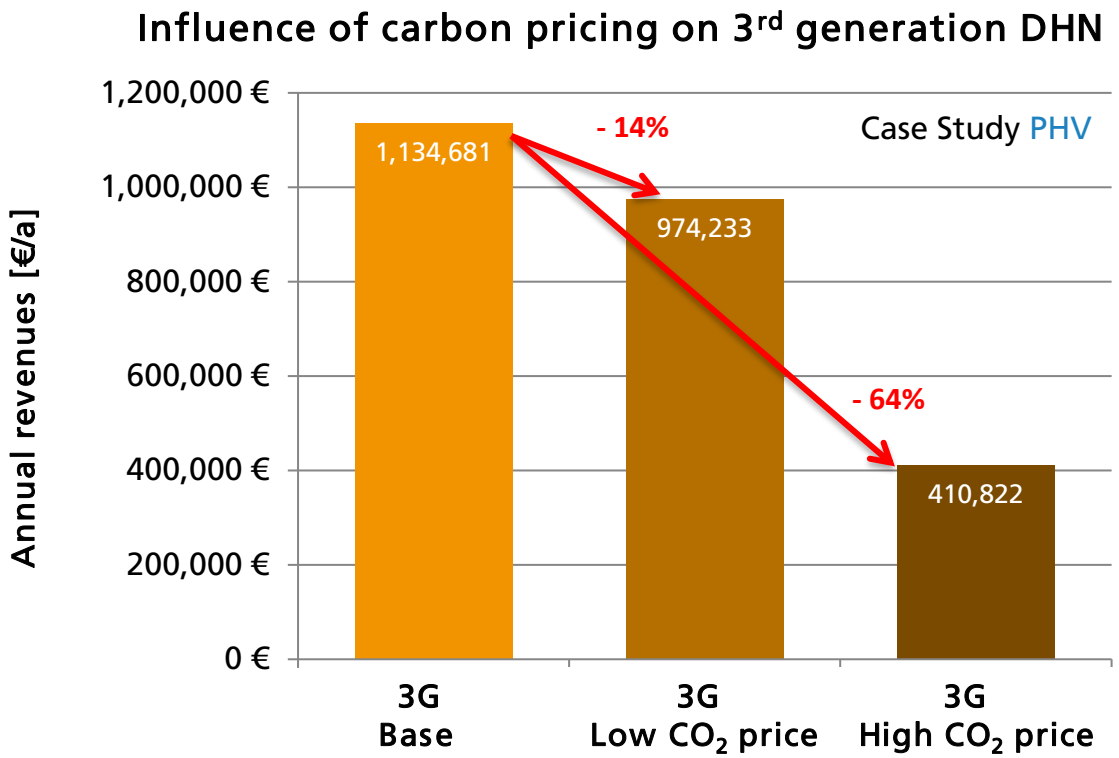
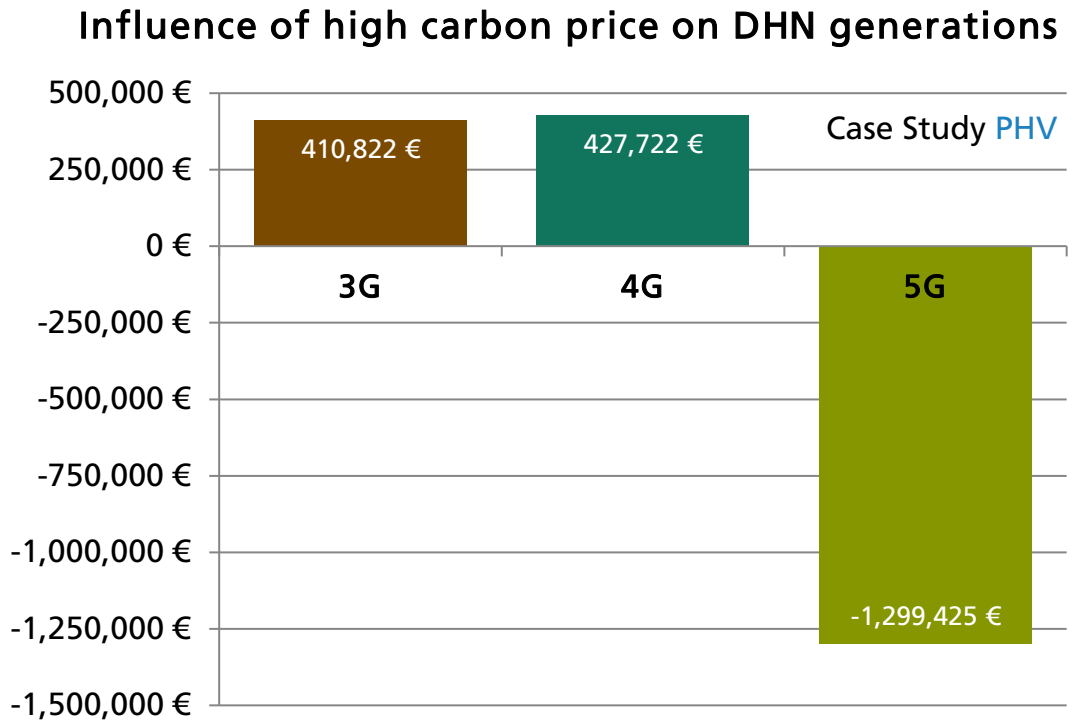
Study Results – Economic Analysis (2)

Comparison of **carbon pricing scenarios** for different DHN generations for CO_2-emission factors of 2018:

- 3rd generation is the most affected by carbon pricing
- Carbon pricing reduces the revenues for all generations, while 4th generation DHN are the least affected





Mean annual revenues for carbon pricing of the 3rd generation (left) and different generations with high carbon pricing (right) for Patrick-Henry-Village

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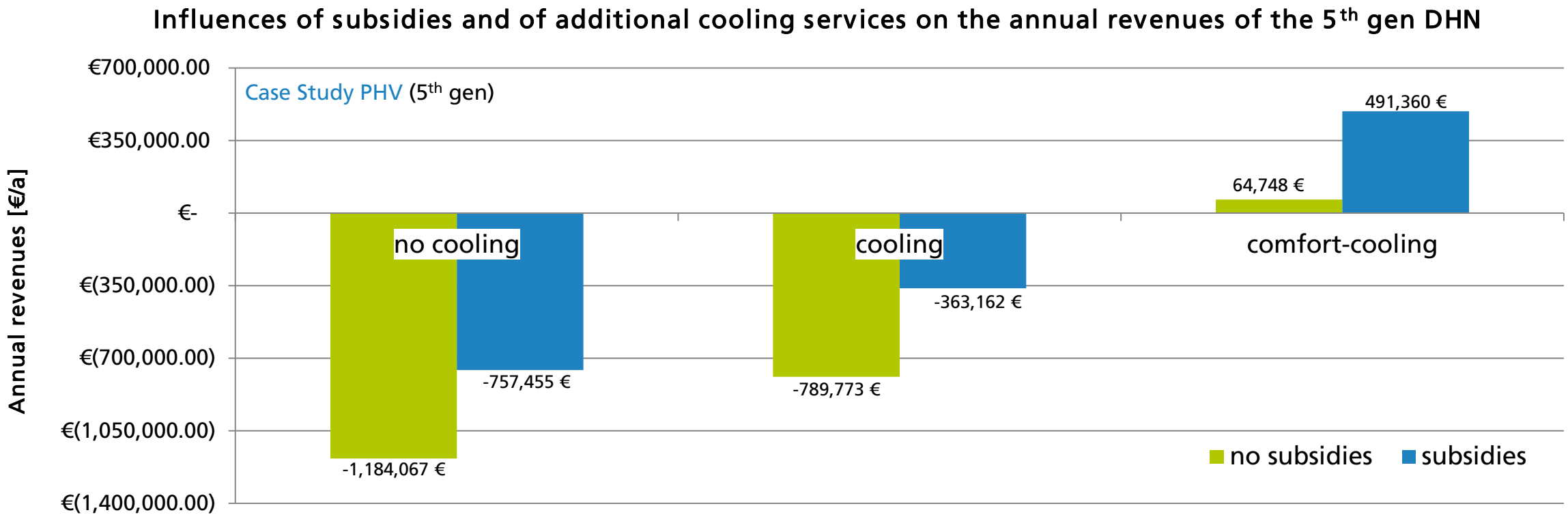
Study Results – Economic Analysis (3)

Impact of **subsidy and cooling demand supply scenarios** on the annual revenues of 5th generation DHN in PHV:

- Profitable operation of 5th generation DHN can already be achieved today through subsidies (German national programmes 2019) and/or supply of cooling demand



Mean annual revenues for Patrick-Henry-Village when considering subsidies and additional cooling demand supplied by the 5th generation DHN

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Conclusion

- Simulation study presents holistic evaluation of 3rd – 5th generation DHN for real districts
- The 4th generation DHN is the most economically and ecologically favorable option in the case studies (examined under current conditions) since industrial waste heat at sufficient temperature levels is available for both districts
- Remaining operational CO_2 emissions of 4th and 5th generation DHN are determined by the CO_2 emission factors of the used electricity mix
- Whether the implementation of the 5th generation DHN is advantageous decisively depends on the locally available heat sources, potential to supply cooling demand, subsidy framework conditions, and carbon pricing framework

Source: KCAP Achitects&Planners; 2019

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Thank You for Your Attention!

This study has been supported by:

- Weingarten Monitoring (FZK 03ET1264A)
- EnStadt:Pfaff (FZK 03SBE112D)

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Marc-André Triebel

www.ise.fraunhofer.de

marc-andre.triebel@ise.fraunhofer.de