HVACC 4.0
- Update Masdar City -

Expert meeting
SHC Task 53

Dresden, 10.4.2018

Dr. Thomas Noll, Kipfenberg
TNT (Thomas Noll Technologies)

HVACC:
- Heating
- Ventilation
- Air Conditioning &
- Chilling (=R of HVACR)

4.0:
- PVT 2.0
- Smart Grid 2.0
- District Grid 5.0
- Energy transition
- Sector Coupling

Global Care
€ A $ ¥ b(u)y T N T
Thomas Noll Technologies

HPT
ANNEX 50
ANNEX 49
ANNEX 47
ANNEX 45

SHC Task 44
Solar and Heat Pump Systems

Task 53

SHC Task 54
Price Reduction of Solar Thermal Systems

SHC Task 55
Integrating Large SHC Systems into DHC Networks

SHC Task 56
Building Integrated Solar Envelope Systems

SHC Task 58
Material & Components for Thermal Energy Storage

SHC Task 60
Application of PVT Collectors

Content I Backup slides
Missions & Visions

1. **Introduction: System optimization and Sector Coupling**
2. **Requirements on future proof HVACR systems**
3. **Summary: Business model I Next steps I References**

Source: LinkedIn

Thomas Noll, PhD

Entrepreneur & Founder of €A$¥ - TNT - HVACC 4.0 -

easy-tnt • Technische Universität Kaiserslautern

Kipfenberg, Bayern, Deutschland • 500+

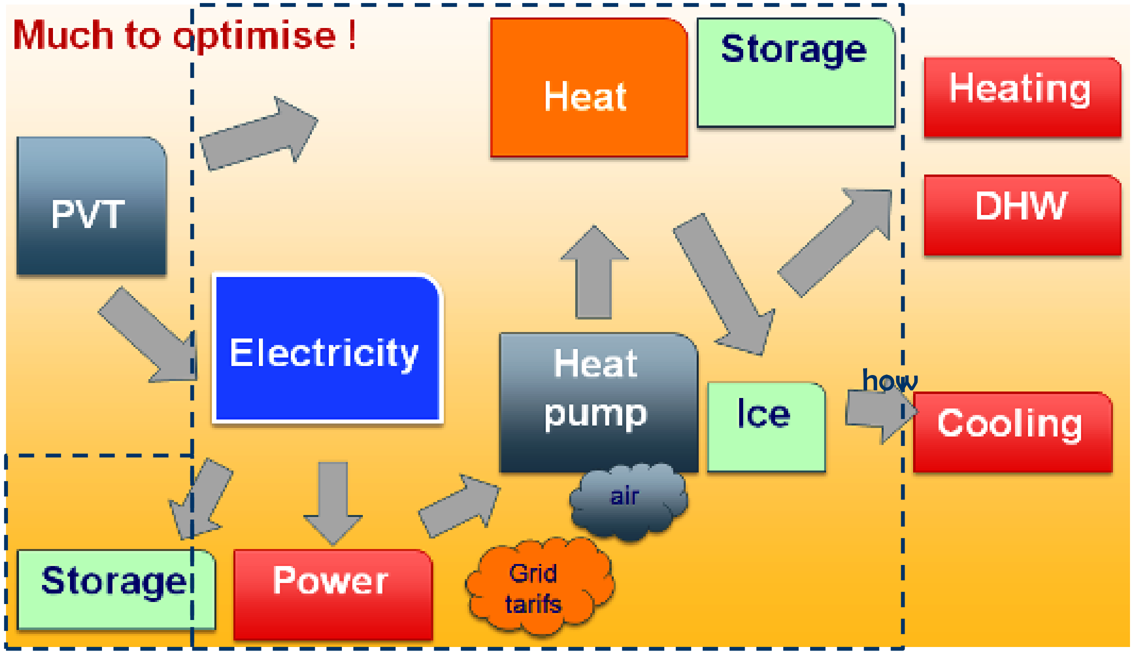
Thinking in systems and consequent application of Triz-Methodology offer opportunities to overcome paradigms, which is a prerequisite for boosting COP and EER of today's heat pumps & chillers towards double-digit values. A "Green Field Approach" opens the door for reduction of carbon footprint from today 300 mg CO2 to about 70 mg CO2 per kWh. The solution is HVACC 4.0, patent pending.

Missions & Visions:
- Highly efficient water-based refrigerant cycle for simultaneous heating & cooling (no VRF).
- Refrigerants with GWP<10 w/o conflict with F-gas regulation.
- Interface to District Grid 5.0 and Smart Grid 2.0 for demand side control.
- Affordable by avoiding expensive boreholes, seasonal storages and PCM.
- Suitable for the building stock to replace oil and gas heaters.
- Invitation of first movers for collaboration in a research project.

Efficiency fist is not negotiable!

Introduction #1
Motivation: There is much more to optimize…

System hardware



Source: Epp/Hadorn

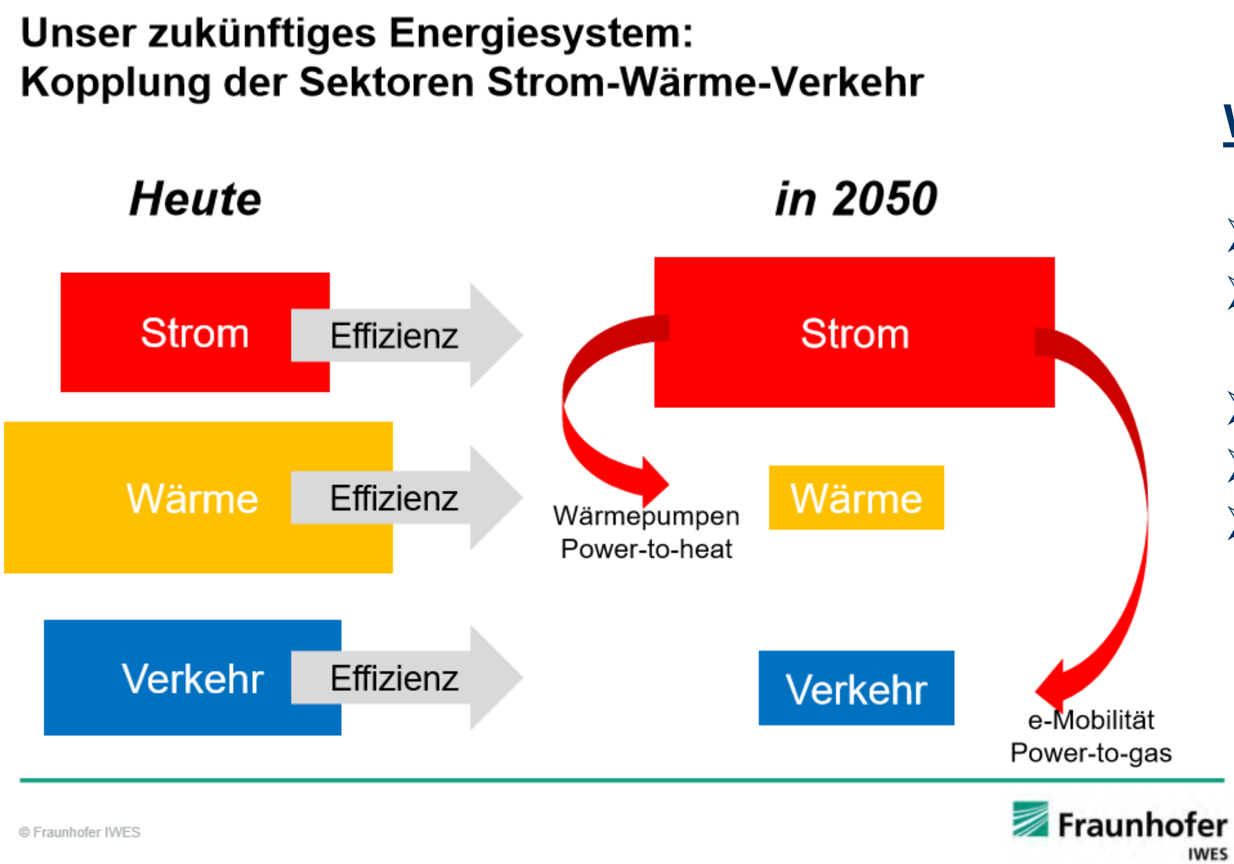
… but not mentioned:

- Active PVT cooling
- Solar cooling over night @ EER up to 60
- PVT with Tracker
- Refrigeration 4.0
- 5G District Grids
- Daily storage for H/C as Virtual power plant

“The key issue is how to design optimized and reliable PVT systems,” explained Jean-Christoph Hadorn, member of the IEA SHC Executive Committee (ExCo) and manager of Swiss firm Base Consultants.

Introduction #2
Megatrend Sector Coupling

Wärmetagung 2017
21.09.2017 - Köln



Winners of the game:

- Heat pumps
- District Grids

- **PVT collectors**
- **Thermal storages**
- **Smart Grid 2.0**

Source: [Sc17]

Problem: The renovation-dilemma:

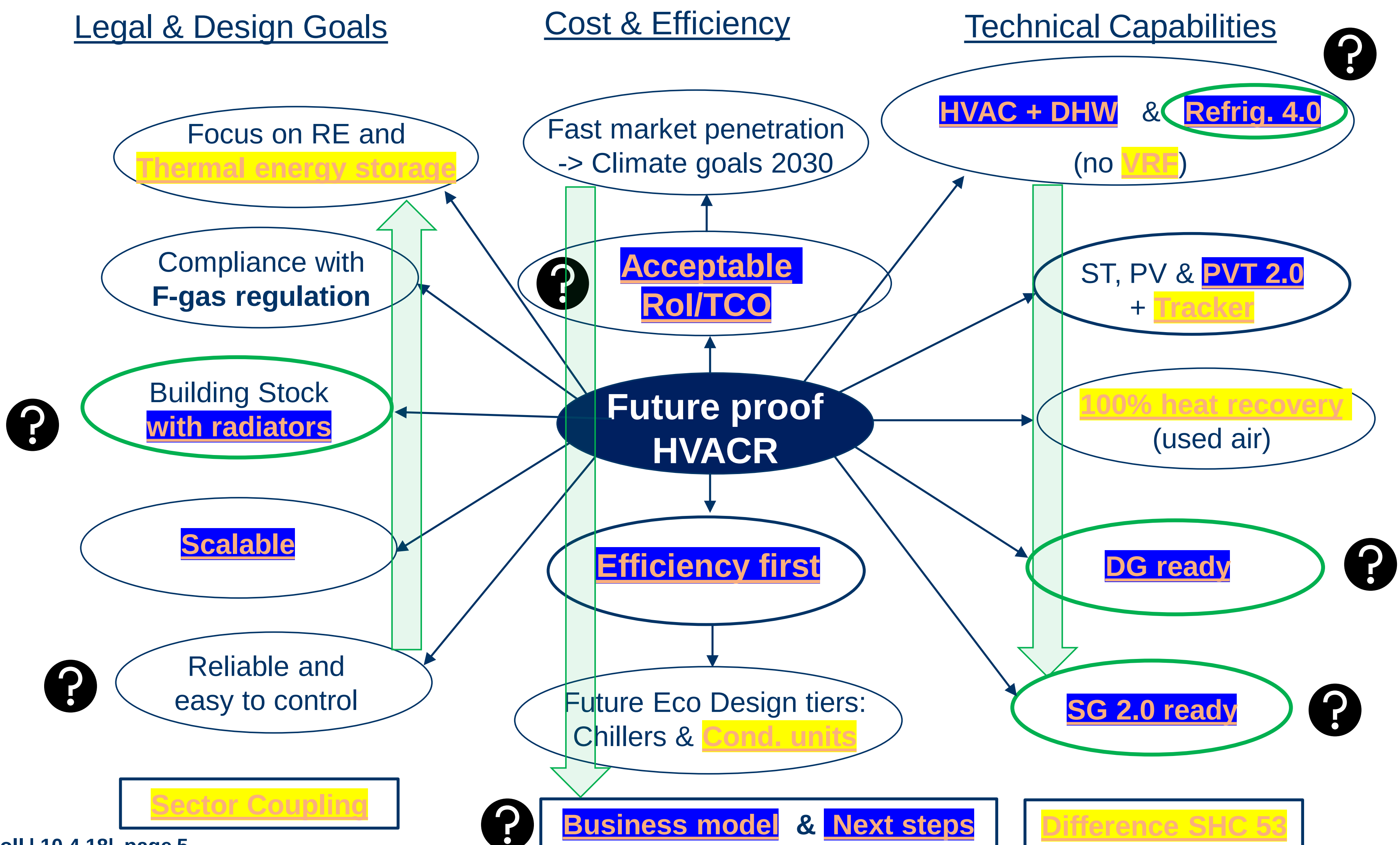
„Die aktuellen Vollsanierungsäquivalente liegen im Durchschnitt über die vergangenen Jahre regelmäßig im Bereich von 0,8 bis ca. 1,0 %“

Source: TGA-Fachplaner

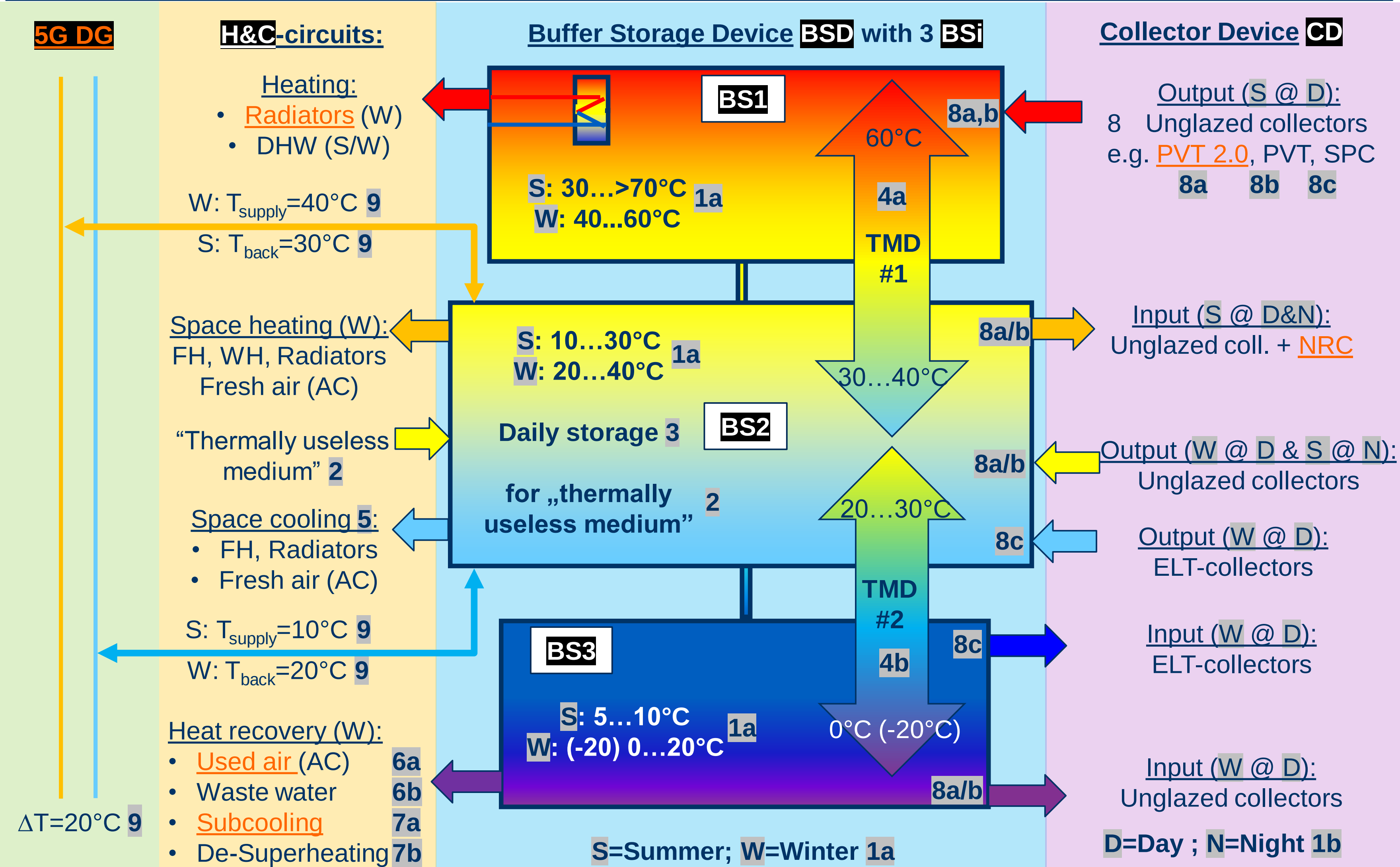
Requirements on future proof HVACR systems

Future Proof = Efficiency 1st + RE + Int. storage + low GWP. + DSC = HVACC 4.0

New



HVACC 4.0: Summary Masdar City #1
Thermal management and Refrigeration Cycle



Source: T. Noll, Abstract Eurosun

HVACC 4.0: Summary Masdar City #2
2-step refrigerant cycle: Disruptive Supercooling (SC)

Cycle:	T in °C
4',1': Evap#1 (no overheating needed):	10
1'2': Comp#1 (15°C Superheating)	55
2'2'': De-Superheating (via DSH-Device)	41
2''3': Cond#1 (SC 30°C via SCD)	10
2''2''': Comp#2 (15°C Superheating)	85
2'''3'': Cond#2 (SC 60°C via SCD)	10

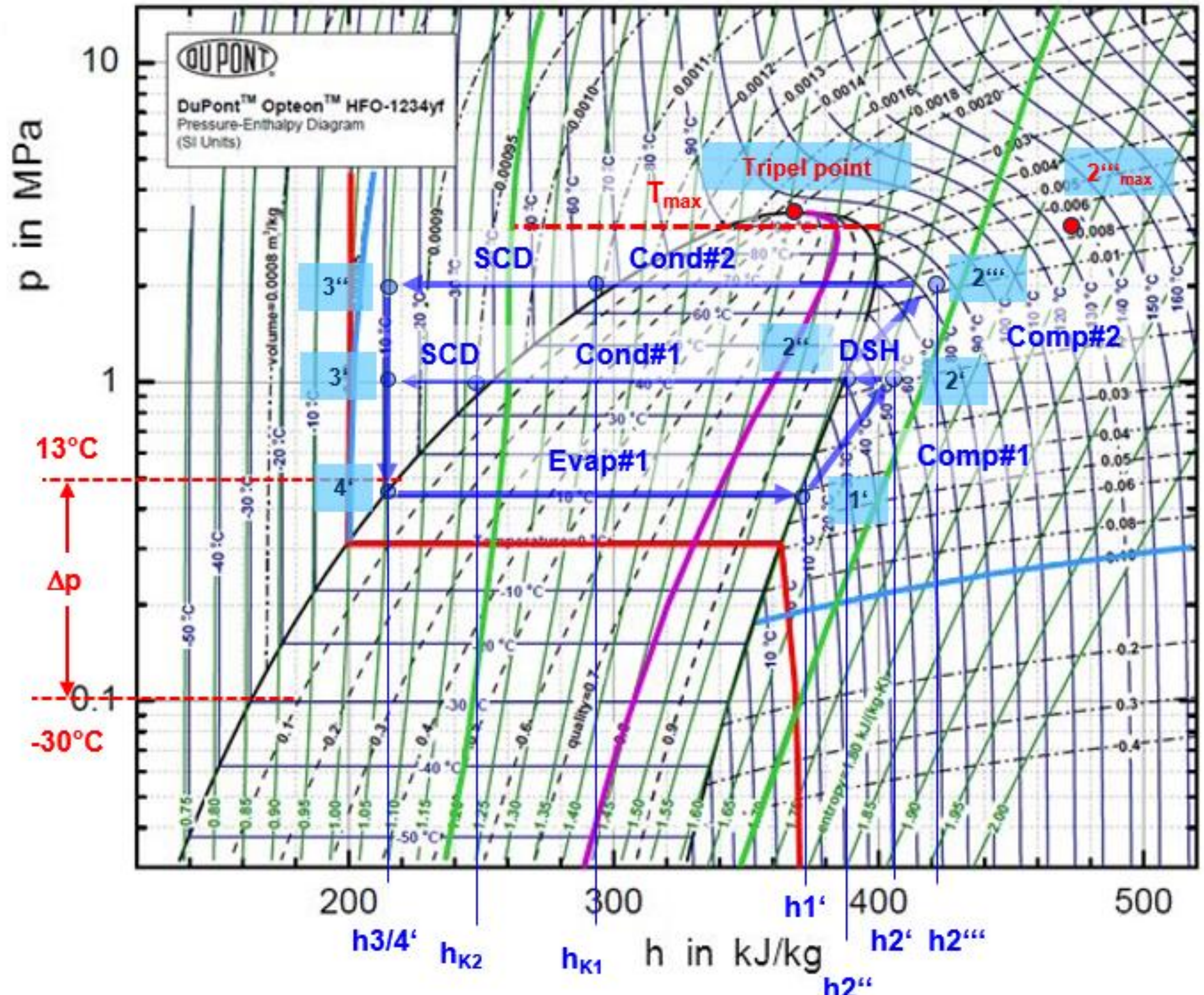
Formulas:

$$COP = \frac{Q_h}{P_V} = \frac{h2' - h3'}{h2' - h1'} = \eta_{WP} * \frac{T_W}{T_W - T_k}$$

$$EER = \frac{Q_c}{P_V} = \frac{h1' - h4'}{h2' - h1'} = \eta_{KM} * \frac{T_W}{T_W - T_k}$$

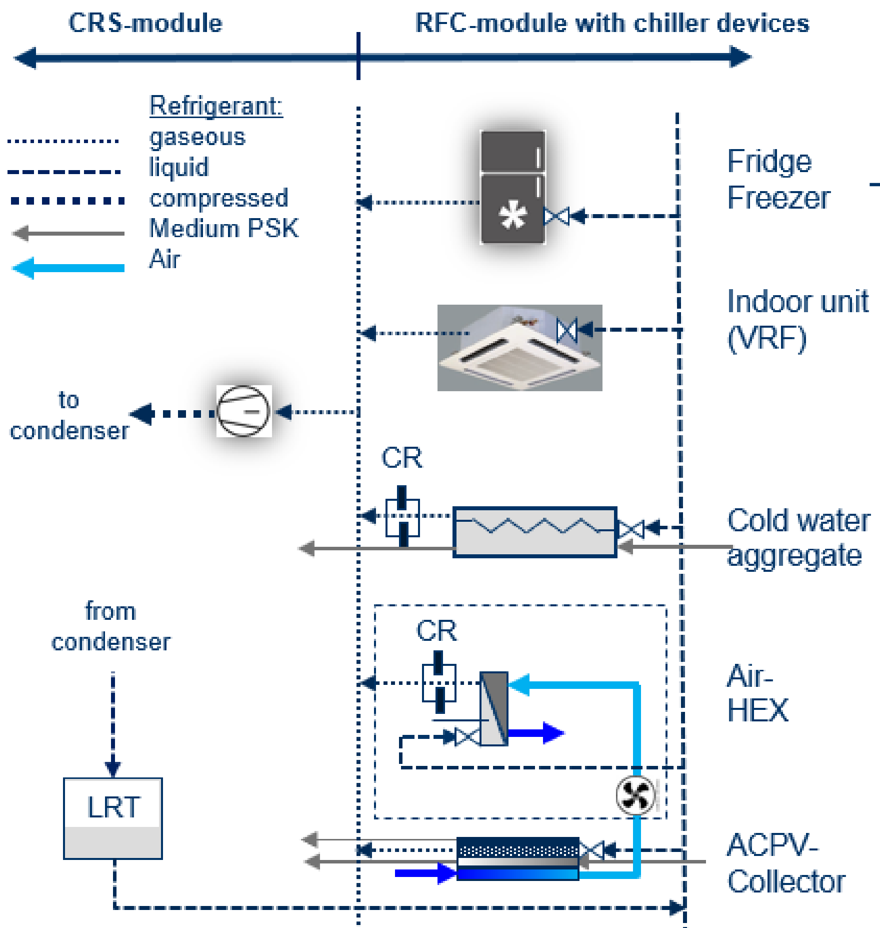
Efficiency improvement potential:

	COP/EER für R1234yf (Fig. 3a)				
	Enthalpie [kJ/kg]		Tw/Tk	°C	
(A)	h1'	371	Tk (PS3)	10	
	h2'	406	Tw(PS2)	40	
	h2''	387	Tw(PS1)	70	
	h2'''	424	Freiwerdende Enthalpien [kJ/kg]		
	h3', h3'', h4'	214	2'->2'': EHS/HGK -> PS1		19
	h_{K1}	293	SCS Kond. 1 (hK1-h3'')		79
	h_{K2}	248	SCS Kond. 2 (hK2-h3')		34
(B)	T-Hub	Definition Enthalpie		Definition Tw/Tk	
	°C	EER	COP	EER	COP
	10↔70	2,96	3,96	2,96	3,96
	10↔40	4,49	5,49	4,49	5,49
(C)	η für T-Hub	η ber.	COP/EER	SdT	Potenzial
	ηWP 10…70	69%	134%	45%	54%
	ηWP 10…40	53%		45%	17%
	ηKM 10…70	52%	122%	33%	59%
	ηKM 10…40	43%		33%	32%



Source: [No17]

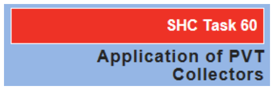
HVACC 4.0: Building blocks
Chiller devices and Refrigeration 4.0



→ **Refrigeration 4.0**

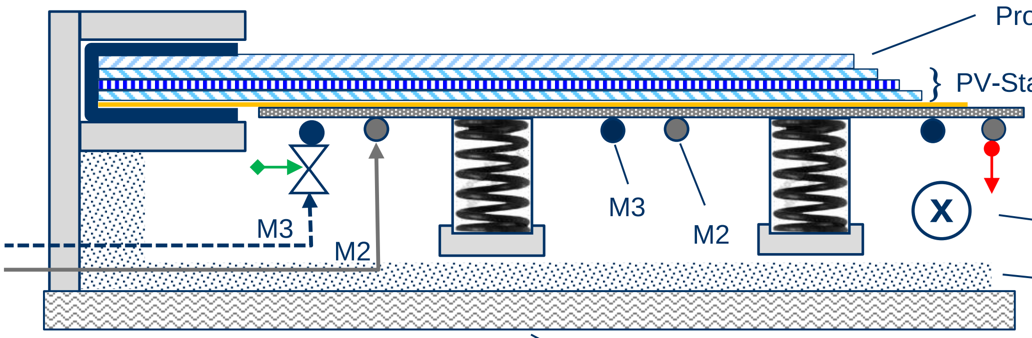
HVACC = HVAC + Chilling in general

HVACR = HVAC + Refrigeration



Source: T. Noll: „A disruptive heat pump and chiller process using R1234yf"
1st IIR International Conference on the Application of HFO Refrigerants, Birmingham, 2.9.-5.9.2018

HVACC 4.0: Building blocks
PVT 2.0 collector with 8 hybrid functionalities

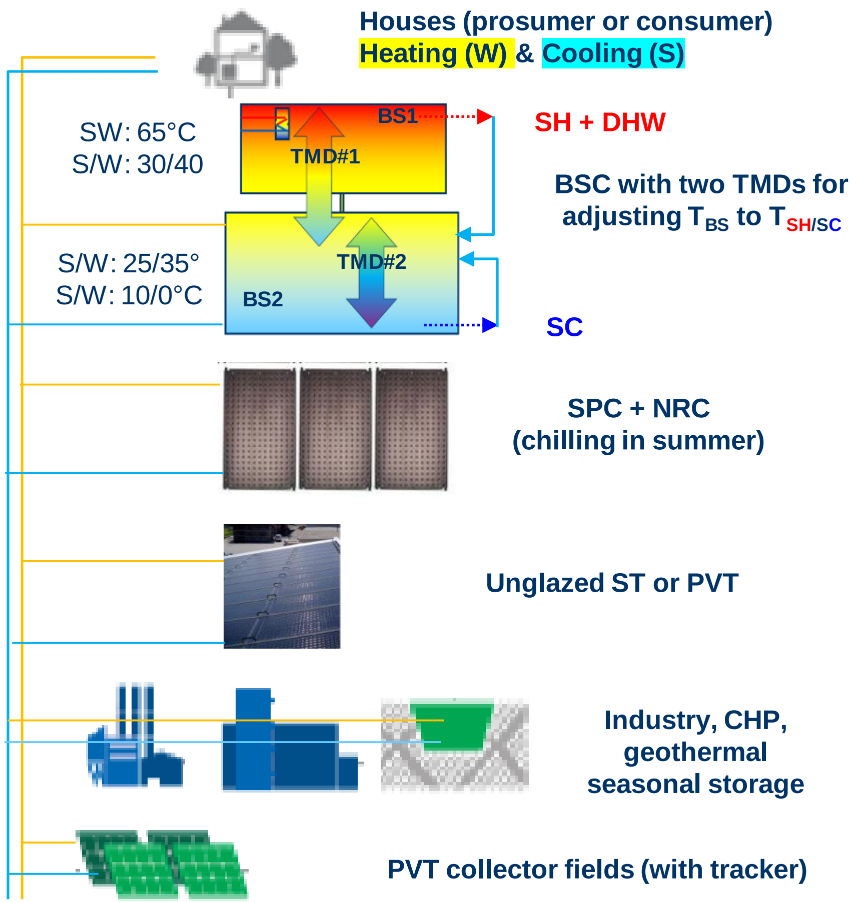


Source: DualSun (private picture)

#	Task	BS	8 hybrid operation modes (ext. to SotA PVT)	Day/Night	Season
1	H	3	Evap. of excess refr. (M3) (in cold regions)	D+N	Wi
2	C	2/3	RE cooling utilizing air cooling + NRC effect	N	Su
3	H	2	Boosting COP by rising $T_{cold} > T_{Brine}$	D	Wi
4	H	1	DHW-production (T>50°C)	D	Su+Wi
5	PV	2/3	Maximize PV output by active cooling (M2)	D	Su
6	H	./.	Preheat outside air for AC	D	W
7	C	2/3	Active cooling by evaporation of refrigerant	N	Su
8	PV	1/2	Max. PV output by evaporation of refrigerant	D	Su

Source: T. Noll: „Actively Cooled PVT collectors for HVACR applications"
1st Expert meeting SHC task 60, Freiburg, 16.5.-18.5.2018

HVACC 4.0: Requirements District Grid 5.0 ready



S: T_{DGin}=10°C -> SC; $\Delta T_{DG}=\Delta T_{BS2}$=15°C

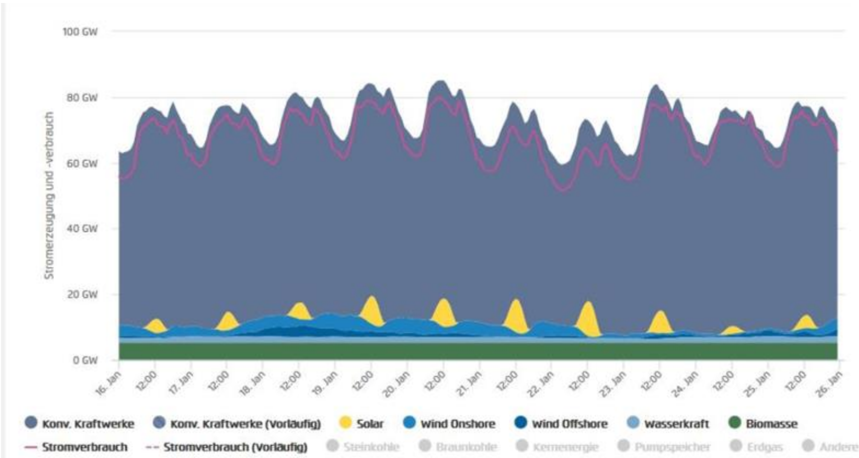
W: T_{DGin}=35°C -> SH; $\Delta T_{DG}=\Delta T_{BS2}$=35°C

Features:

- BS2 as transfer station to DG
- Seasonally different temperatures
- Heating & Cooling
- Much lower T_{in} compared to 4G DG

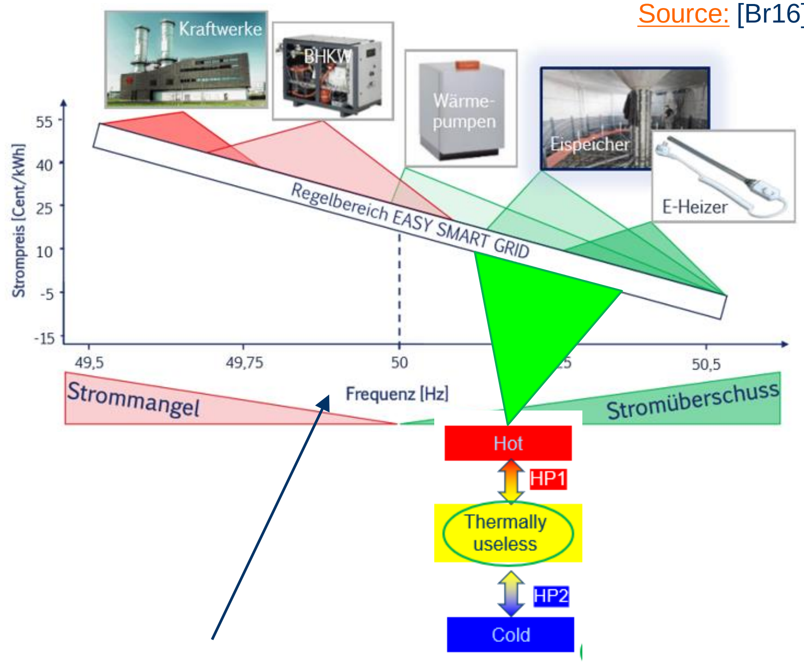
  -> Less insulation effort

HVACC 4.0: Requirements
Smart Grid 2.0 ready



Source: Agora

Source: [Br16]



- **Mismatch between demand and supply measured via frequency**
- **Balance indicator regulates price for providers, consumers and prosumers**
- **Real time Demand Side Response (DMS)**
- **Unmatched performance to cost ratio**
- **Thermal storage = virtual power plant @ 50…340 lower cost than electric storage**

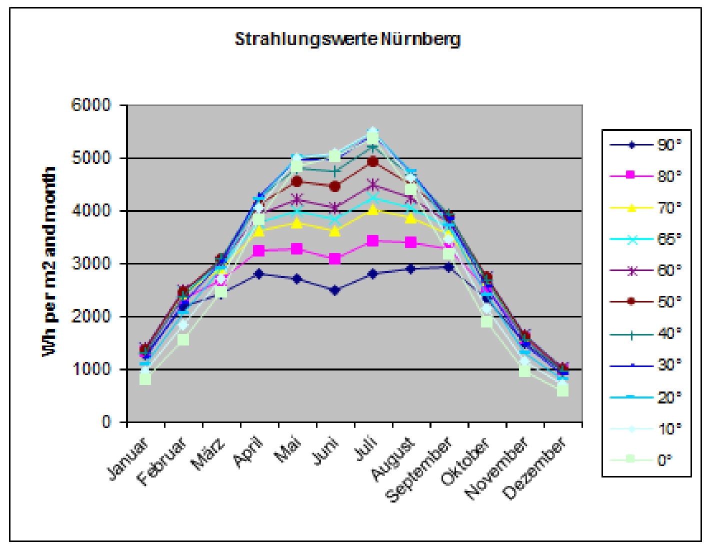
HVACC 4.0: Requirements Scalability (to Skyscrapers)

Source: TGA-Fachplaner

Source: A. Morgan

Advantages facade mount:

- No snow, no stagnation
- Higher efficiency
- Insulation basically "free of cost"
- More PV and ST power in winter when needed



Source: T. Noll

Near Zero Energy Buildings (nZEB) seem possible if two facades are equipped with PVT and windmill on roof.

HVACC 4.0: Requirements
Suitability for building stock (radiator heaters)

15% gas saving with ClimateBooster by lowering the supply temperature by 15°C

Source: [Be17]

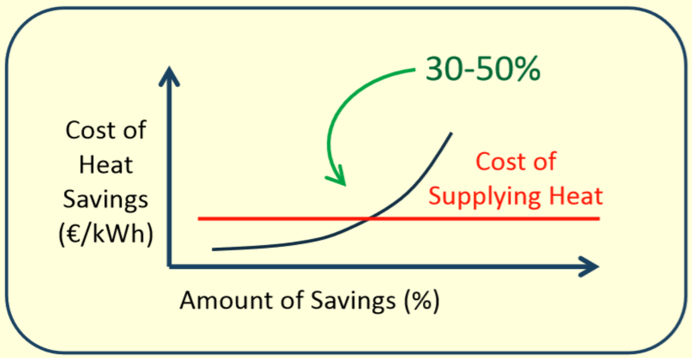
Comparison SotA Heat Pumps (HP) and Chillers (Ch) with HVACC 4.0										
Case	Technology	Operation	Type	Source	T_{warm}	T_{cold}	ΔT	η	COP/ EER	Δη
					°C	°C	°C	%		%
1a	SotA	HP	WW	Brine	65	5	60	45%	2,5	
1b	HVACC 4.0	HP + CB	WW	BS2	65	20	45	69%	5,2	105%
1c	HVACC 4.0	HP + CB	WW	BS2	50	20	30	69%	7,5	43%
1d	HVACC 4.0	HP + CB	WW	BS2	50	25	25	69%	9,0	72%

- **Saving potential in case of heat pump is between 43…72%**
- **Is a renovation solution for the building stock at 2-digit COP w/o insulation feasible?**
- **RoI<5 years for climate booster confirmed by Henk**

HVACC 4.0: Requirements
Some comments on „Efficiency First“

How Much Heat Should We Save?

➥ We should implement heat savings until the price of sustainable supply is less than the marginal price of additional savings



Source: [Co14]

EUROPEAN HEAT PUMP SUMMIT

It is "all" about COP...
(....and first cost, maintenance...)

Source: [Re17]

EUREKA 2017 Heating, Cooling & Ventilation: Sustainable technologies for a better life

Efficiency First + Renewables + Storage

Source: [SM17]

HVACC 4.0: Requirements “Acceptable RoI”

Liked ($$$, efficiency) & Not Liked ($$$, efficiency)

Wärmequelle	Gütegrad η
Umgebungsluft	0.35
Erdwärme (Erdwärmesonden)	0.45
Wasser (Grund-, Fluss-, Seewasser)	0.50

HVACC 4.0 Business Model:
20 Mio oil & gas heaters to be replaced in Germany

1. Houses with oil fired boilers: Use od old oil tank as BS2

- **Oil tank 8.000l sufficient for AC + active PVT cooling in summer**

2. Houses with gas fired boilers: Container solution

Sources: Sunoptimo (ST) MobiHeat (oil fired) Viessmann (CHP)

3. Buildings with high demand of cold (like supermarkets,…)

- **Utilize HVAC + Refrigeration 2.0 at high EER**
- **Use flat roof of building for installation of PVT**

Source: Bauzeitung

HVACC 4.0
Next steps

Project application H2020 via SME instrument

- **Phase 1: Feasibility study of concept (storage, collectors,…) (not needed for ME and SE countries)**
- **Phase 2: Validation via demonstrators**
  Companies are welcome for collaboration

Thank you for your attention

R

HVACC 4.0
References

Be17 Henk de Beijer: “Possibilities of ClimateBooster & SolabCool”, Expert meeting SHC Task 53, Masdar City, 31.10.2017

BMUB16 Klimaschutzplan 2050: „Klimaschutzpolitische Grundsätze und Ziele der Bundesregierung, Referat KII1, 2016“

Br16 Robert Brockmann: „Die Eisspeichertechnologie“, 9.12.2016

Ca16 Carel 2016: Application note on Condensing units: Scenario in Europe

Co14 David Conolly, Heat Roadmap Europe, 28.8.2014

EC12 EC: Commission Staff Working Document “Proposal for a Commission Regulation implementing Directive 2009/125/EC …”

Lu14 Henrik Lund: Heat Roadmap Europe 2050, IEA CHP/DHC Working Group Joint Strategic Workshop, 27.5.2014

No17 Thomas Noll: “HVACC 4.0 - A Green Field Approach”, Expert meeting SHC Task 53, Abu Dhabi, 29.10.2017

Pe17 Svend Vinther Pedersen: “Annex 47: Heat Pumps in District Heating Systems”, EU Heat Pump Summit, Nürnberg, 24.10.2017

POK15 Pean et al.: “Nighttime radiative cooling potential of unglazed and PV/T solar collectors: parametric and experimental analyses”, 2015

Re17 Lars Reinholdt: “Higher Heat Pump COP through better temperature match”, EU Heat Pump Summit, Nürnberg, 24.10.2017

Sc17 Schmidt/Fhg: Innovative Wärmeversorgungskonzepte für Siedlungen und Quartiere, Wärmetagung Köln 21.9.77

SM17 Stefan Scheuer, Michèle Mondot: “The EUREKA vision; EUREKA 2017 – Heating, Cooling & Ventilation: Thematic Panel Session: A FOCUS ON BUILDINGS”, Berlin, 20.12.2017

Wa17 Thomas Walter: “White Paper: Cheaper Energy for Islands and Isolated Grids”, 2017

Wg17 Peter Wagener: IEA Annex 42: „Heat pumps in smart grids“, EU Heat Pump Summit, Nürnberg, 24.10.2017

Zo09 Martin Zogg, ETH Zürich: Zertifikatslehrgang ETH in angewandten Erdwissenschaften „Geothermie– die Energie des 21.JH“

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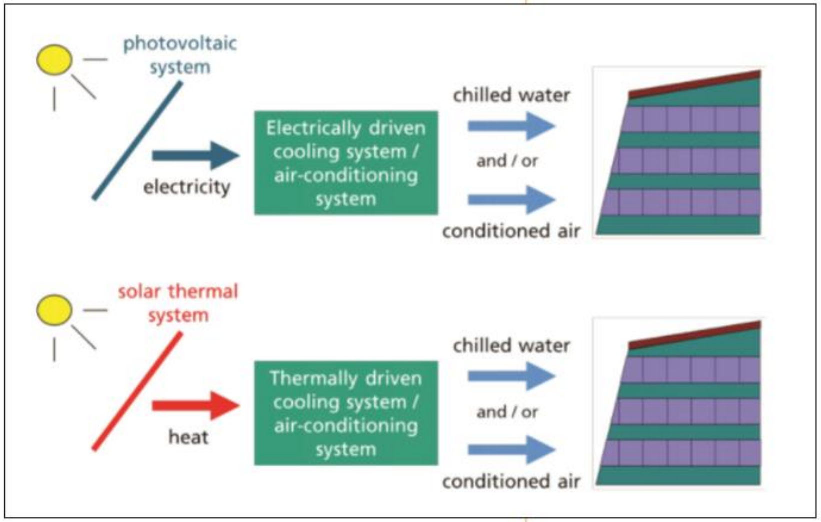
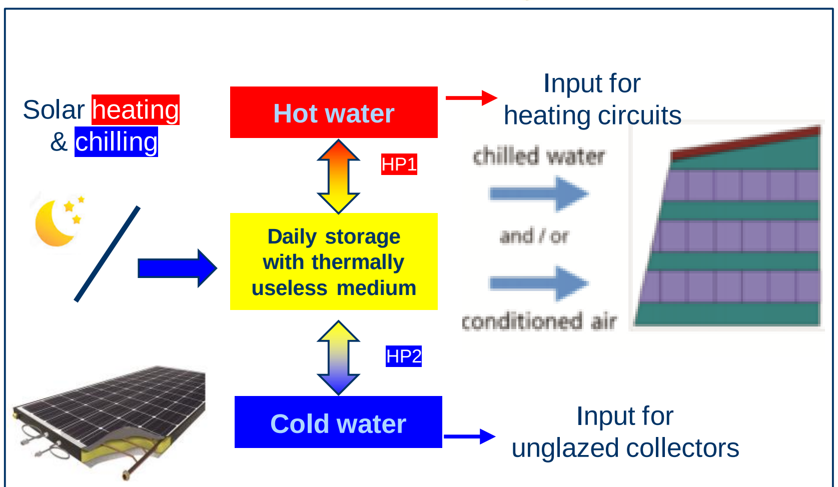
HVAVV 4.0
Backup slides

Backup
Difference to SHC task 53





Source: [No17]

Source: Spirig

Arno A. Evers
Retired, but not getting tired to create a new energy infrastructure; form...
I saw some photovoltaic installations
full of sand in th UAE recently, too

Questions:

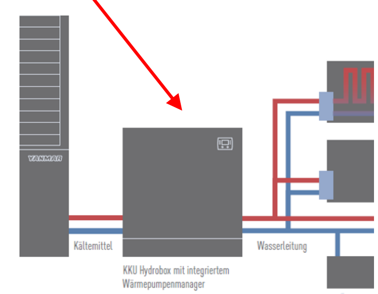
- **Is PV the right concept for ME countries?**
- **What's the RoI of PV-solar cooling compared to PVT solar cooling over night @ EER up to 60?**

Backup
VRF-Technology: Separating facts from fiction

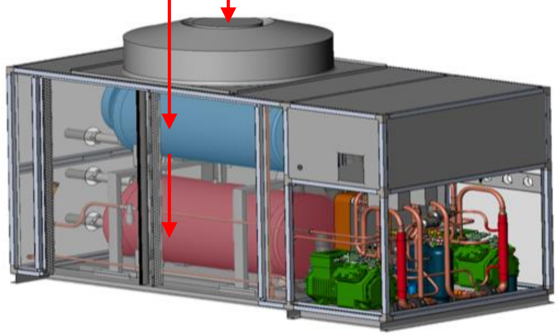
- **Strongly promoted as „The future HVAC-technology“.**
- **Simultaneous H&C @ HP only in case of Classic VRF - with usually >> 3kg R404A/R410A - and use of indoor units.**
- **No simultaneous H&C @ HP in case of water based systems, only “toggling source and sink” between “Hydrobox” and “outdoor device”.**
- **Simultaneous H&C @ consumers only in case of additional hot & cold BS serving circuits for space heaters & coolers.**
- **Mainly air based systems -> high T_w and low T_k.**
- **Not suitable for DHW.**
- **No storing of excess heat/chillness in BS, but in contrast to HVACC 4.0 release to environment.**

VRF System Market worth 22.79 Billion USD by 2023

Source: Bauherrenwissen



Source: Yanmar



Source: van der Hoff/TripleAqua

Backup
Storage cost

Heat Roadmap Europe 2050

Storage Costs

➥Electricity = €170/kWh

➥Thermal = €0.5-3/kWh

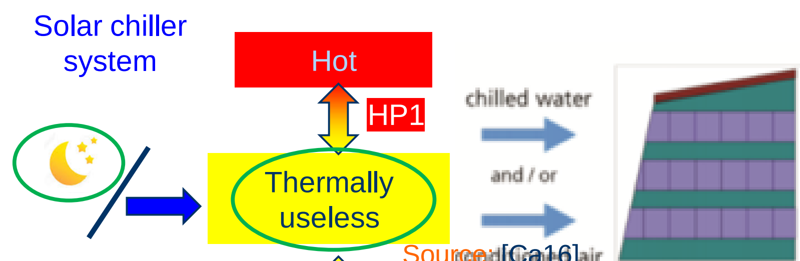
EUROHEAT & POWER · AALBORG UNIVERSITY DENMARK · ECOFYS · PlanEnergi

Source: [Co14]

Thermal storage is 50…340 times lower cost

Implications for HVACC 4.0:

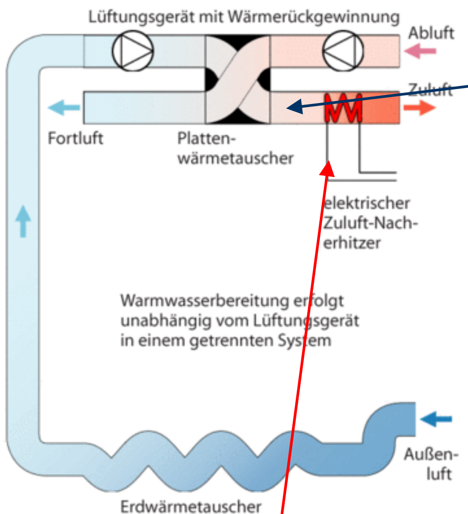
- **Replace big central storage by many „small“ storages like redesigned oil tanks**
- **Decentralized concept ahead of centralized (similar to electric grid)**

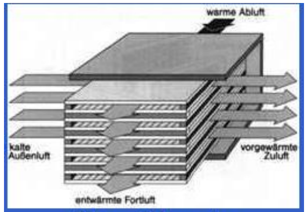


Source: [No17]

Backup
Heat Exchanger for Air Conditioning

Source: Energie-Sparen-im-Haushalt.de





Schema-Rekuperator

Source: bosy-online

Typical: η_{HE}=60…70% (CO2 Online)
Optimal: η_{HE}=91% (Inventer)

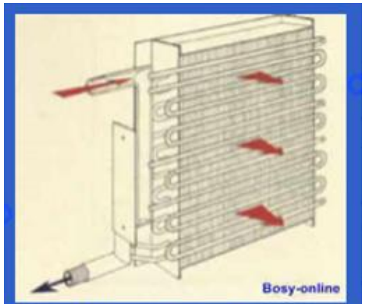
Lüftungsanlage: Kosten/Einbau

Eine energieeffiziente Lüftungsanlage kostet 40-60 €/m2 Wohnfläche. Bei einem Einfamilienhaus mit 120 m² macht das 4.800-7.200 €. Im Altbau muss man schon bereit sein, die Decken um ca. 15 cm abzuhängen. Nur dann ist ein nachträglicher Einbau möglich.
Zentrale Abluftanlagen ohne Wärmerückgewinnung kosten 25-45 €/m2 Wohnfläche (Angaben sind Richtwerte ohne Gewähr).

Hier könnte z.B. erwärmte Luft aus einem PVT 2.0-Kollektor einströmen

Implementation of air conditioning as VAF in HVACC 4.0 via VAF:

- **Summer: Use of cold water from BS_3 in HE mode “RKA1”**
  -> cooling of hot outside air
- **Winter: Use of cold water from BS_3 in HE mode “WRL”**
  -> Heat recovery from used warm inside air (>100% in case $T_{BS3}<T_{out}$)
- **Example SotA: $T_{in/out, prim}$=20/-10°C -> $T_{in/out, sec}$=5/5°C (best case)**
  -> additional electric heating necessary
- **Example HVACC 4.0: $T_{HE, prim}$=20/-20°C -> $T_{HE, sec}\cong$-18/+18°C + heating BS_3**
  -> energy stays in system.
- **Heating fresh outside air decoupled via 2nd HE “RKA2” served from BS_1**



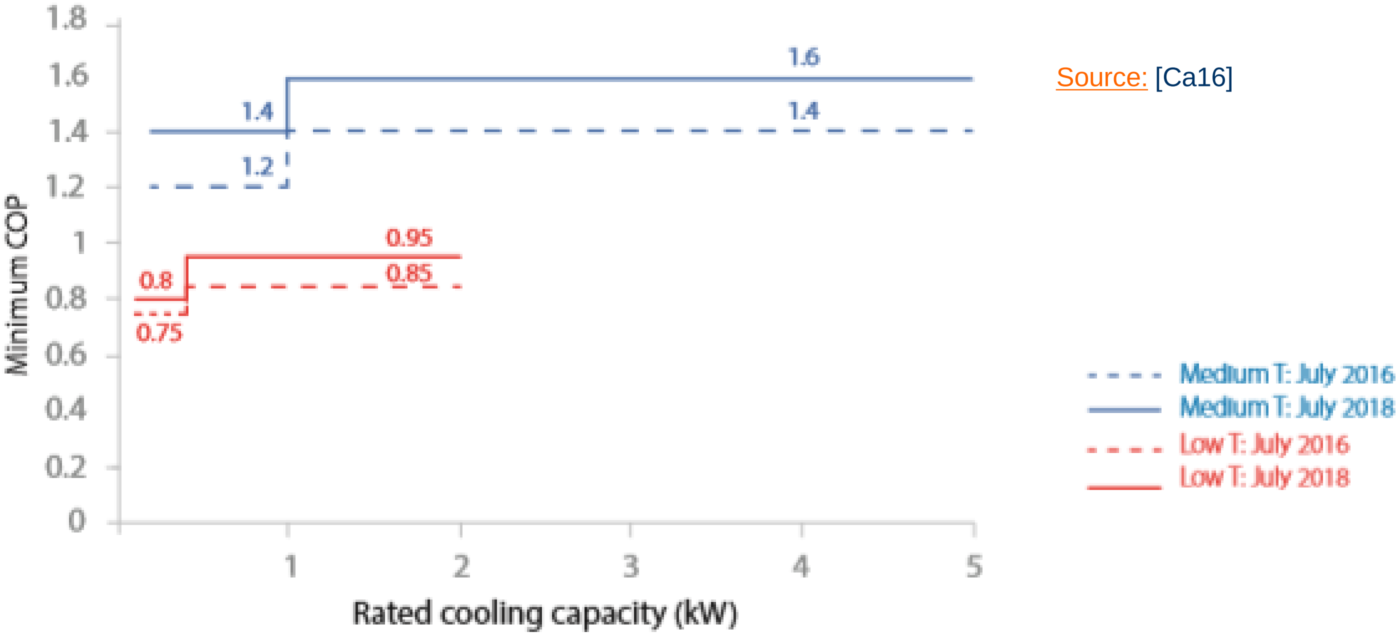
Wärmetauscher - Kreuzstrom - Luft/Wasser

Source: bosy-online

R

Backup
New efficiency limits for condensing units

Low capacities (0.2-5 kW): the minimum COP allowed for medium-temperature condensing units will increase from 1.2 to 1.4 (for capacities from 0.2 to 1 kW). This means a 14% increase. For higher capacities (up to 5 kW) the increase from the 2016 levels will be 13% (from 1.4 to 1.6).
If the condensing unit is designed to operate at low temperature, the increase will be 6% for low capacities (from 0.75 to 0.8) and 11% (from 0.85 to 0.95) for capacities in the range 0.4-2 kW.



Source: [Ca16]

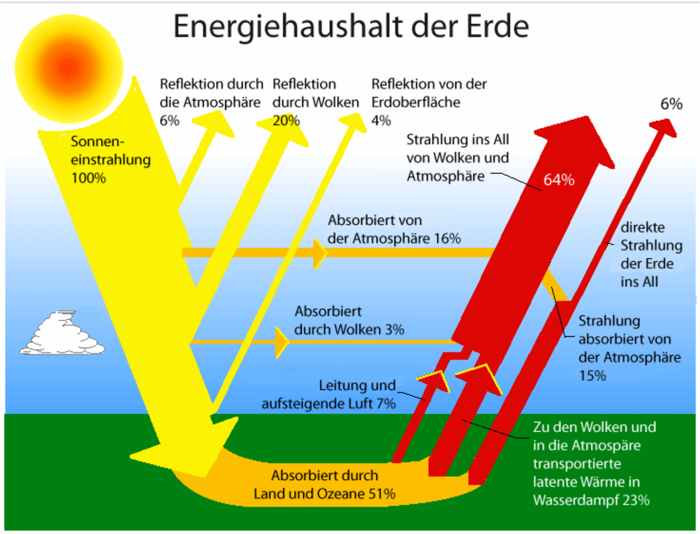
Potential HVAVC 4.0: very high due to strong subcooling with big potential for supermarkets

Backup
PVT-Tracker

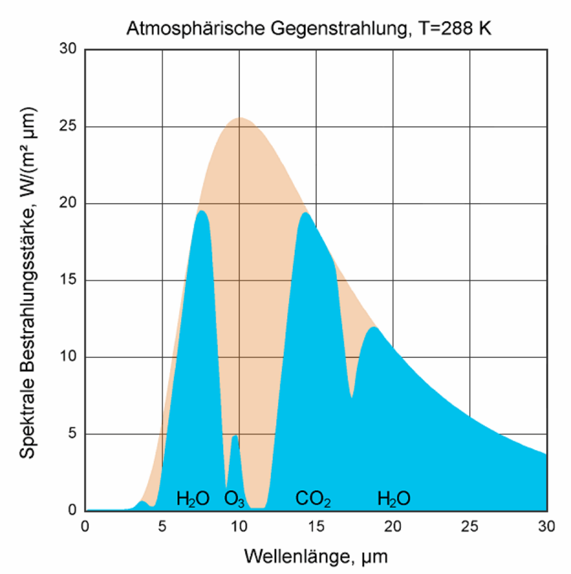
Premiere: res-PV++ Kombimodule auf Tracker installiert!

Source: res-energy

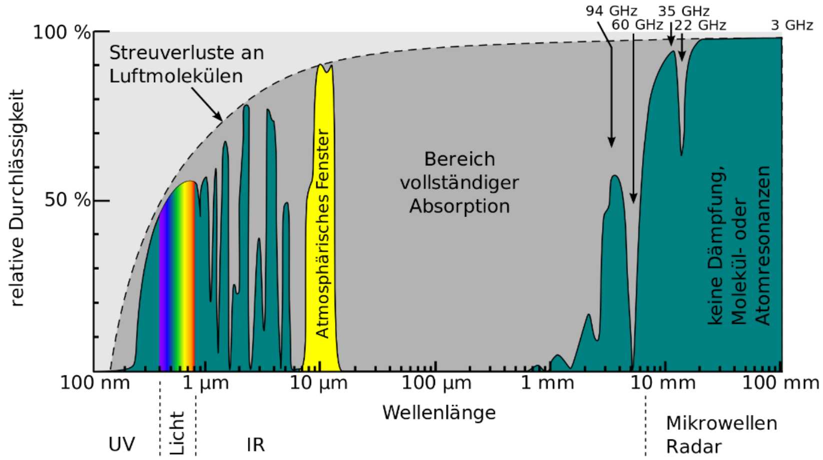
Backup
NRC-Effect (Nocturial Radiation Cooling)



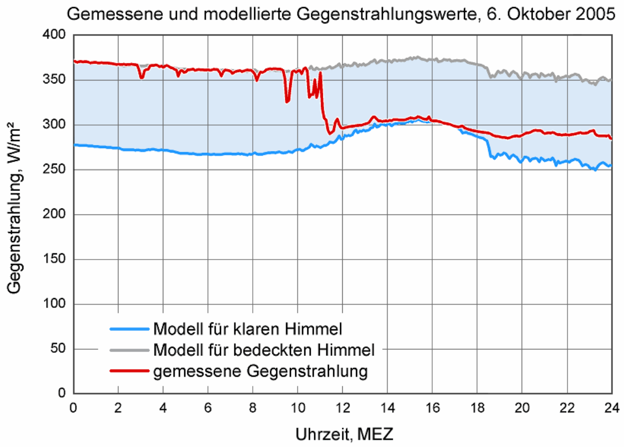
Source: Pfeffer



Source: Wikipedia

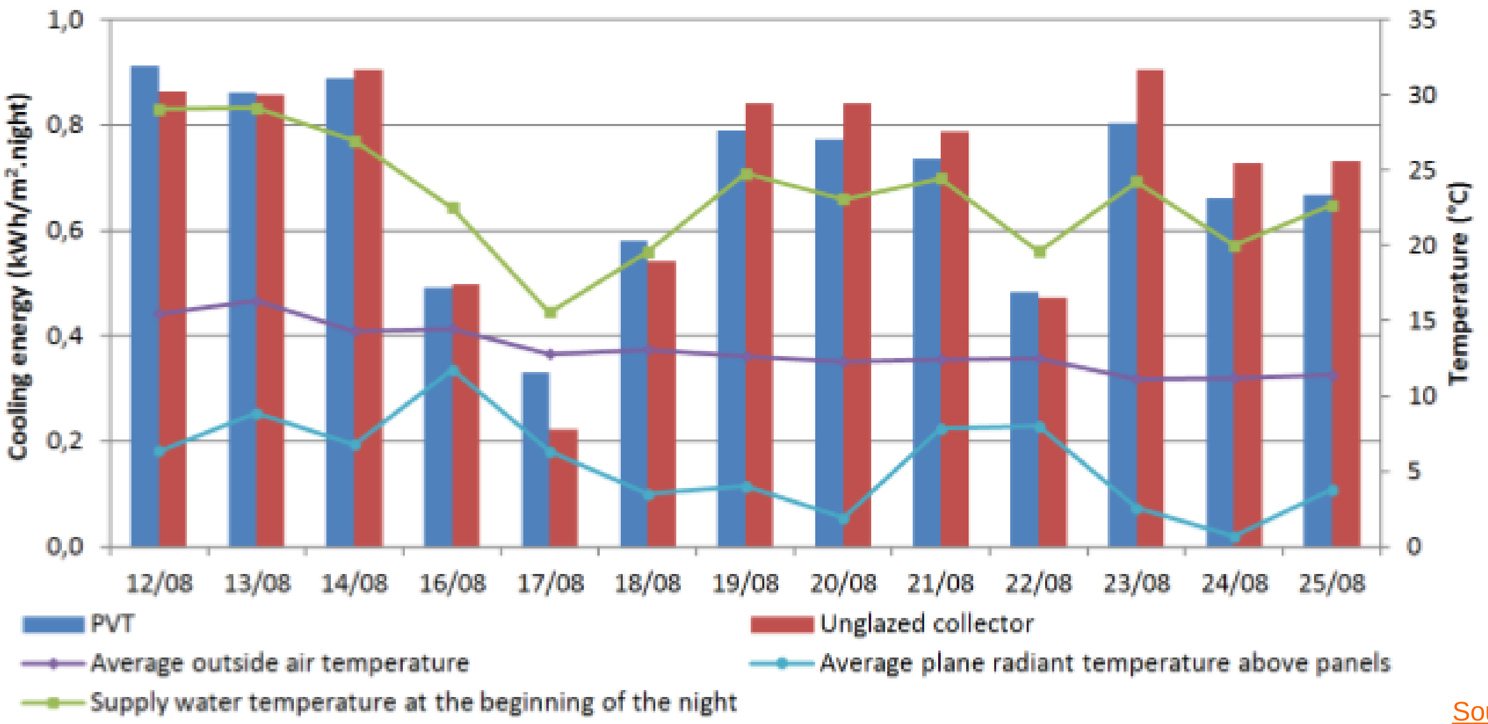


Source: Wikipedia



Source: Wikipedia

Backup
Solar cooling with unglazed collectors



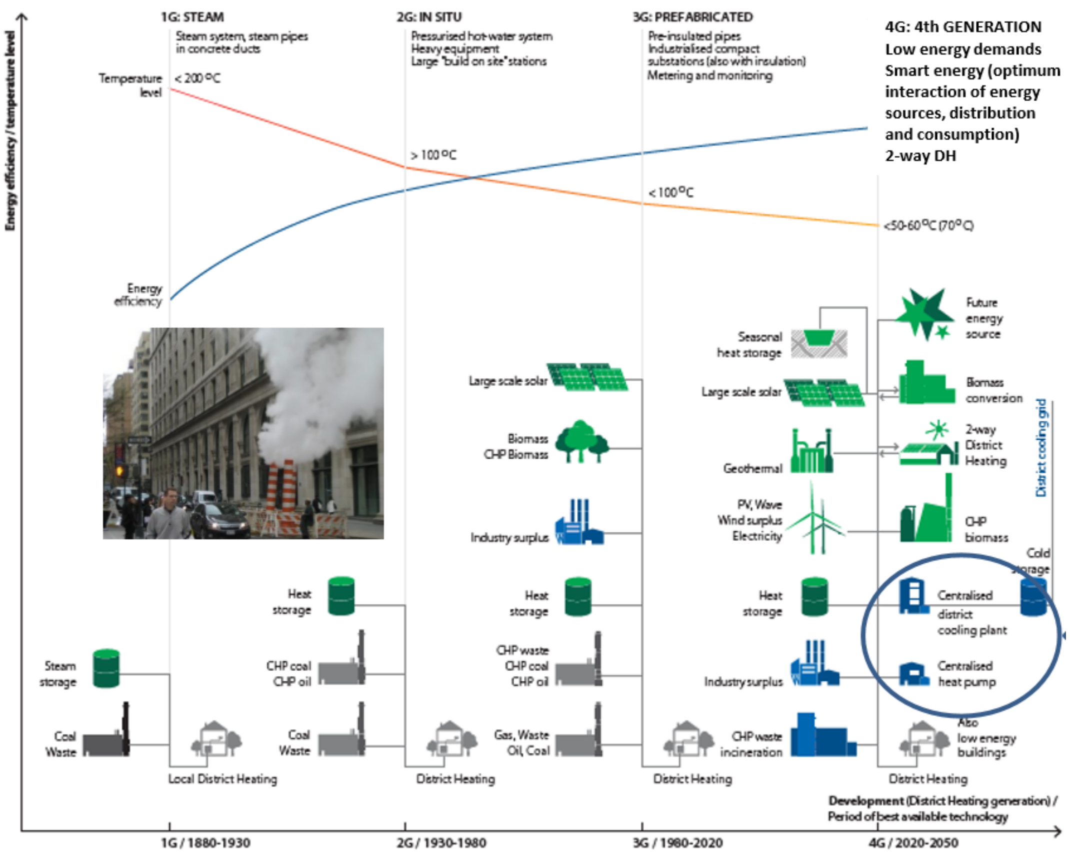
Source: [POK15]

Figure 4. Comparison of the cooling obtained by the PV/T and the unglazed collector per night, from 12/08/2014 to 25/08/2014 (the energy is an average of the outputs of the three adopted method; the supply water temperature at the beginning of the night is averaged from 19:00 until 20:00; the outside air and plane radiant temperatures are averaged from 20:30 till 7:00am).

In order to analyze the efficiency of the system, the coefficient of performance (COP) is used. The COP is the ratio of the cooling energy obtained by the energy used by the pump. The circulation pump had an average power of 8 W, which consumes 96 Wh during a night of 12 hours. The COP has been obtained based on the total cooling energy produced by PV/T and unglazed panels since one pump was used to supply both of them. COP range is from 19…59

R

Backup
4G DGs (District Grids)



Source: [Pe17]

4th Generation District Heating technological Systems are defined as a coherent technological and institutional system, which by use of district heating smart grids helps a suitable implementation of renewable energy systems by providing for heat supply of low-energy-buildings with low grid losses in a way in which the use of low temperature heat sources are integrated with the operation of electricity and gas smart grids. The concept involves the development of an institutional and organizational framework to facilitate suitable cost and motivation structures.

Source: [Lu14]