3RD INTERNATIONAL CONFERENCE ON

SMART ENERGY SYSTEMS AND
4TH GENERATION DISTRICT HEATING

COPENHAGEN, 12–13 SEPTEMBER 201

# Wide scope categorization of DHC systems for the identification of emerging or disruptive technologies

Luc Girardin, Jessen Page, Duan Wu, François Maréchal

IPESE, EPFL-Lausanne - HES-SO Valais-Wallis
Mitsubishi Electric R&D Centre Europe

# CONTENT

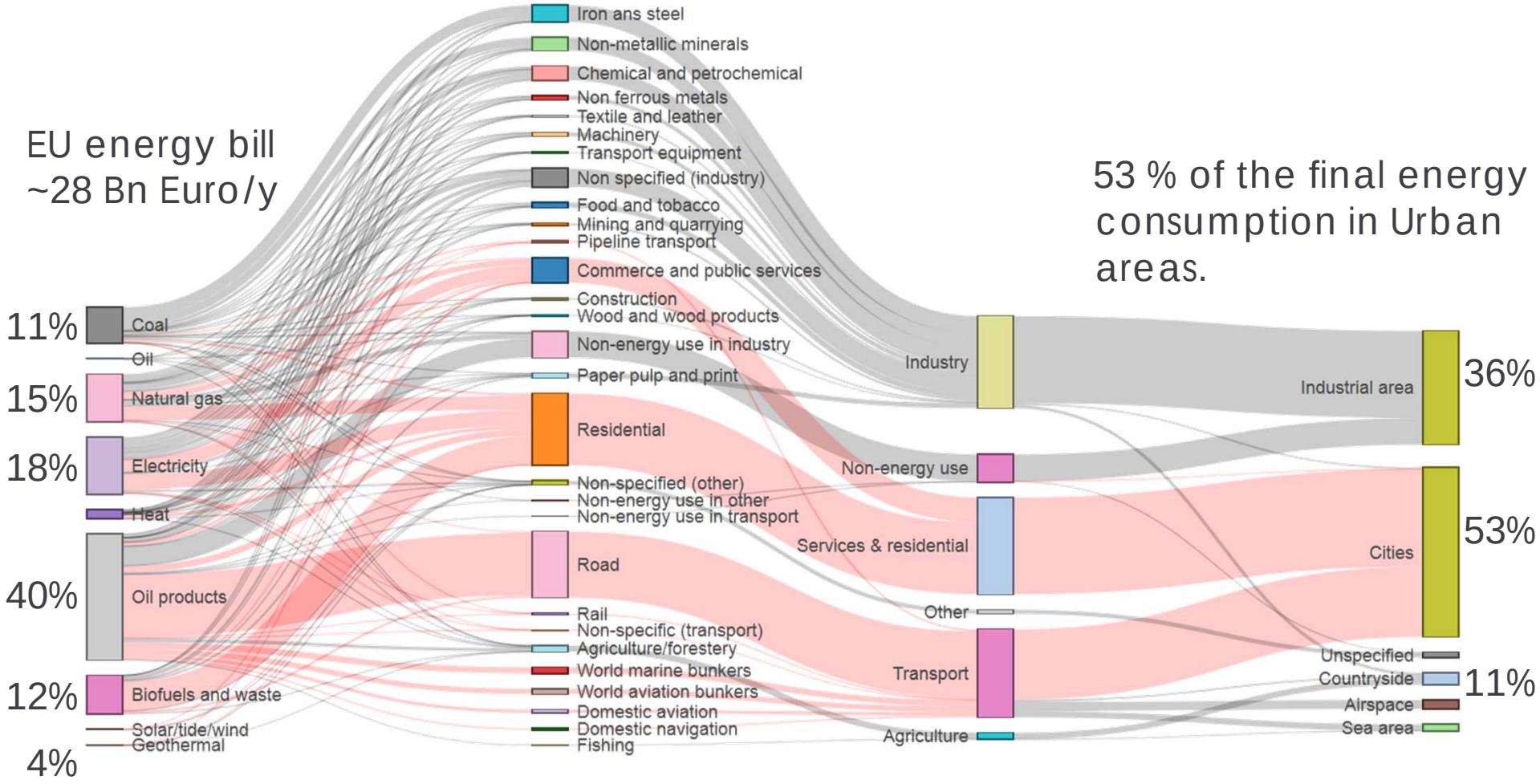
# INTRODUCTION
## Energy transition in cities

From IEA, Worl Final consumption (2014), http://www.iea.org/sankey/

European Commission, Directorate-General for Energy, An EU Strategy on Heating and Cooling', 2016.

EU energy bill
~28 Bn Euro/y

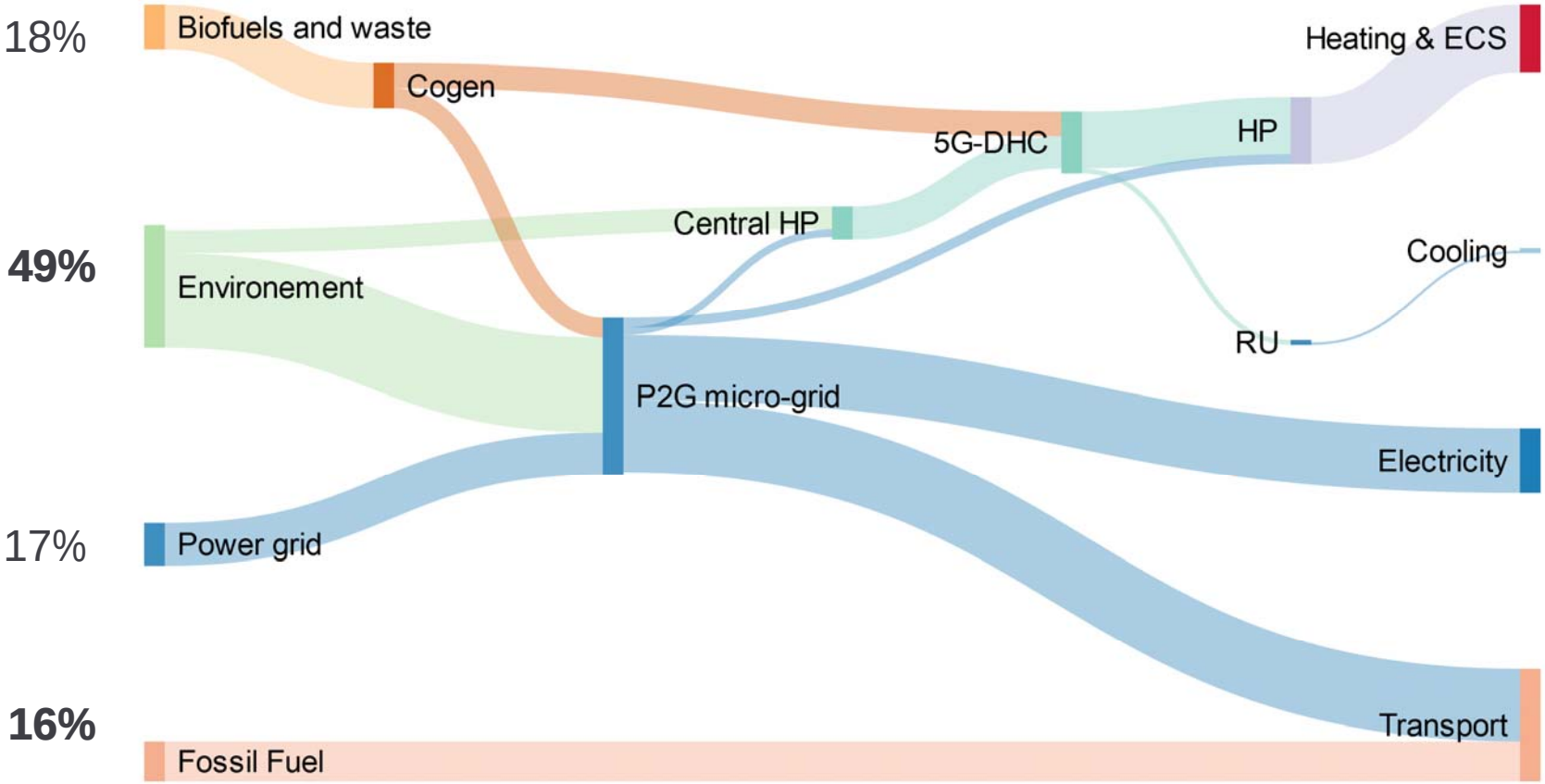
53 % of the final energy consumption in Urban areas.



# INTRODUCTION
# Future DHC systems

R. Suciu, et al., 'Energy integration of CO2 networks and Power to Gas for emerging energy autonomous cities in Europe', ECOS 2017.

## Advanced 4G-DH:
## distribute the environnement for H,C & Transport*

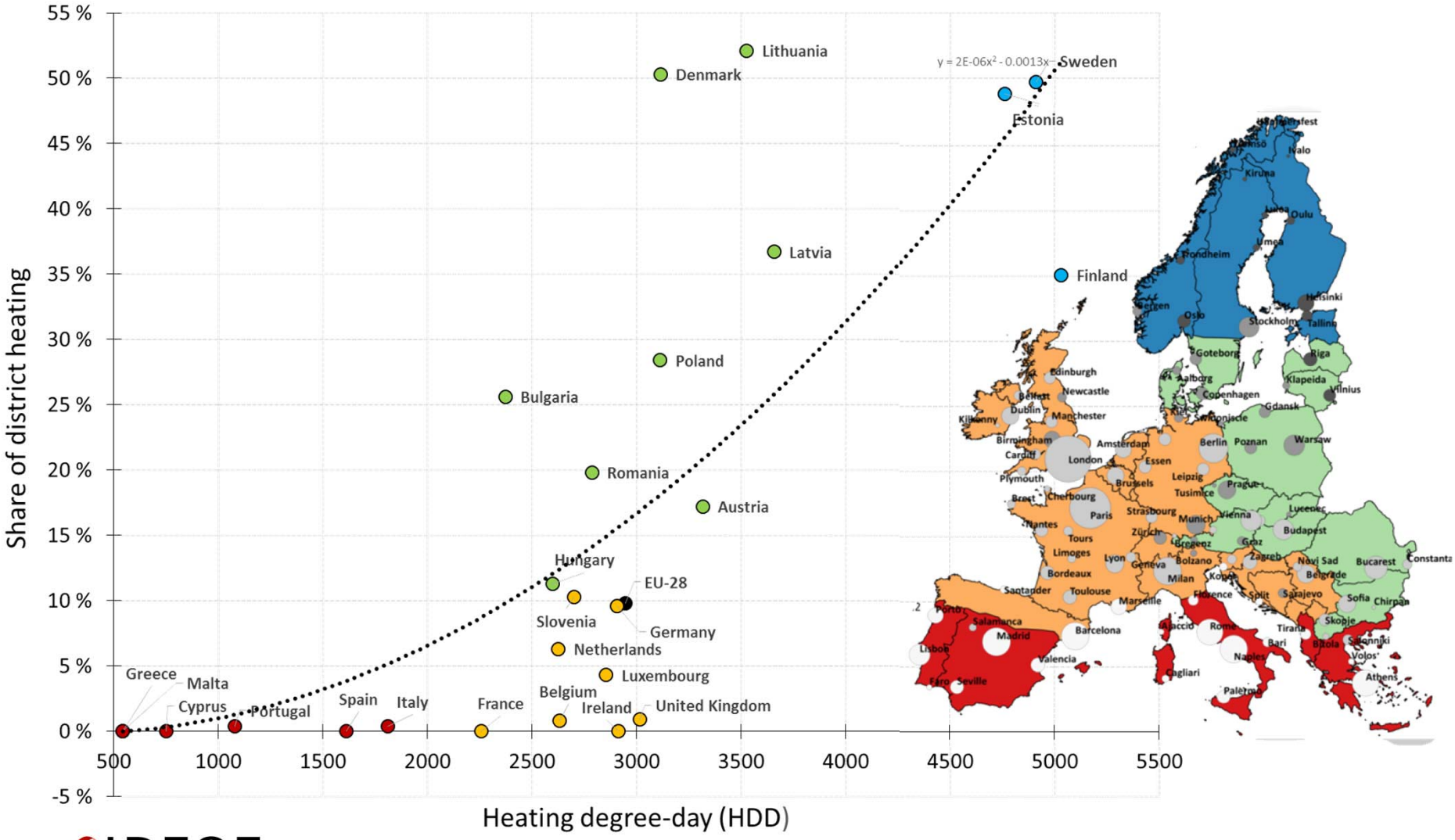



*Environment: Lake/River/Geothermal/Solar /Wind/Tide

# INTRODUCTION
## Trends in EU

T. Boermans, C. Petersdorff, and others, 'U-values for better energy performance of buildings', 2007

Pardo, N, et.al., "Heat and Cooling Demand and Market Perspective.", 2012.



# OBJECTIVE

- Categorize DHC systems in wide scope with organized fields
- Identify emerging or disruptive technologies with significant impact in each category
- Evaluate each identified technology by using pre-defined figures of merit (FOM)

# METHODOLOGY

## Open approach

- Considering a wide scope of technologies
- Avoiding preconceived ideas and limitation
- Literature review / Brain storming - mind mapping

Taking into consideration

- Past, present and future development of DHC systems in EU

# DHC CATEGORIZATION
## Analytical grid

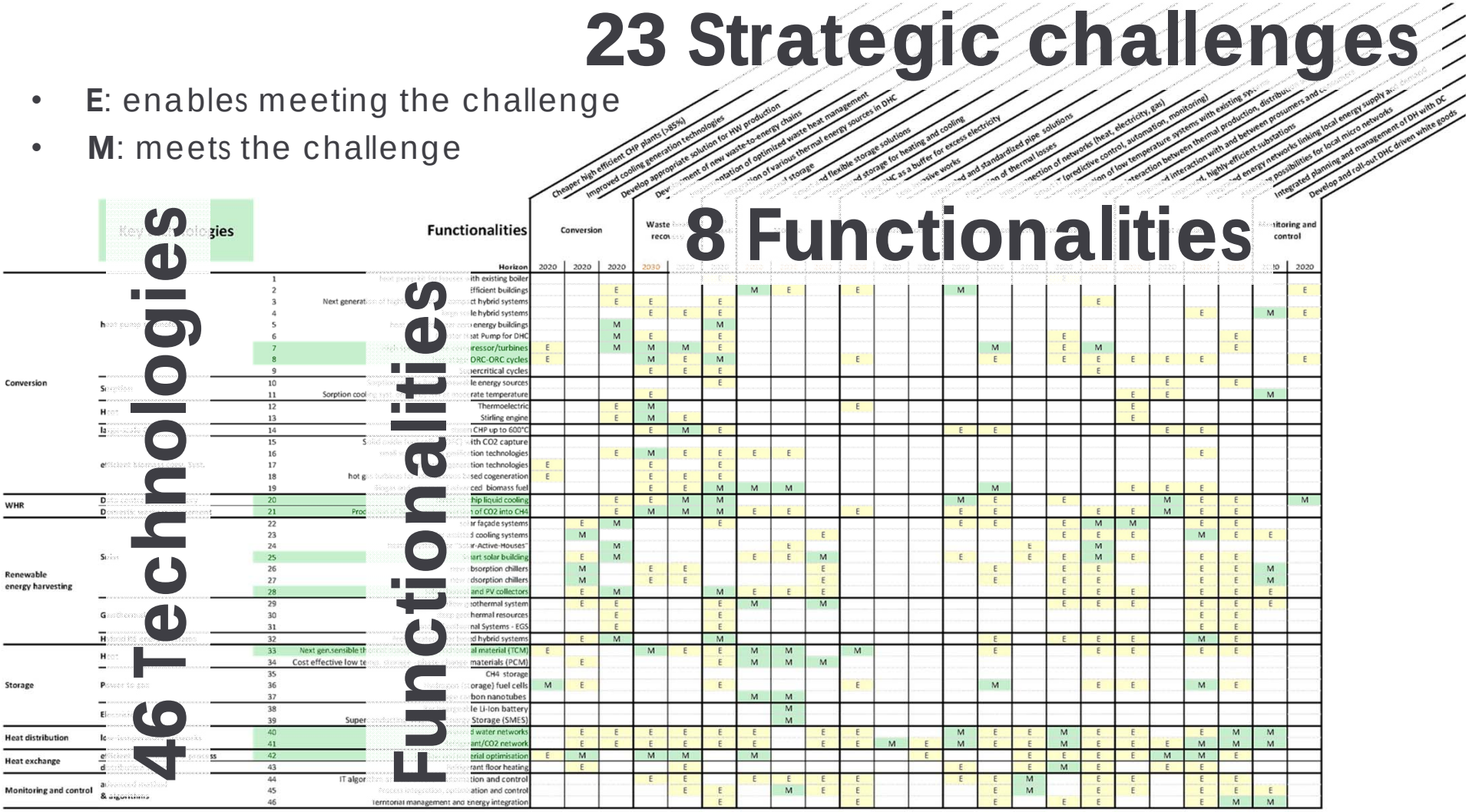
- **E**: enables meeting the challenge
- **M**: meets the challenge

**23 Strategic challenges**

**8 Functionalities**

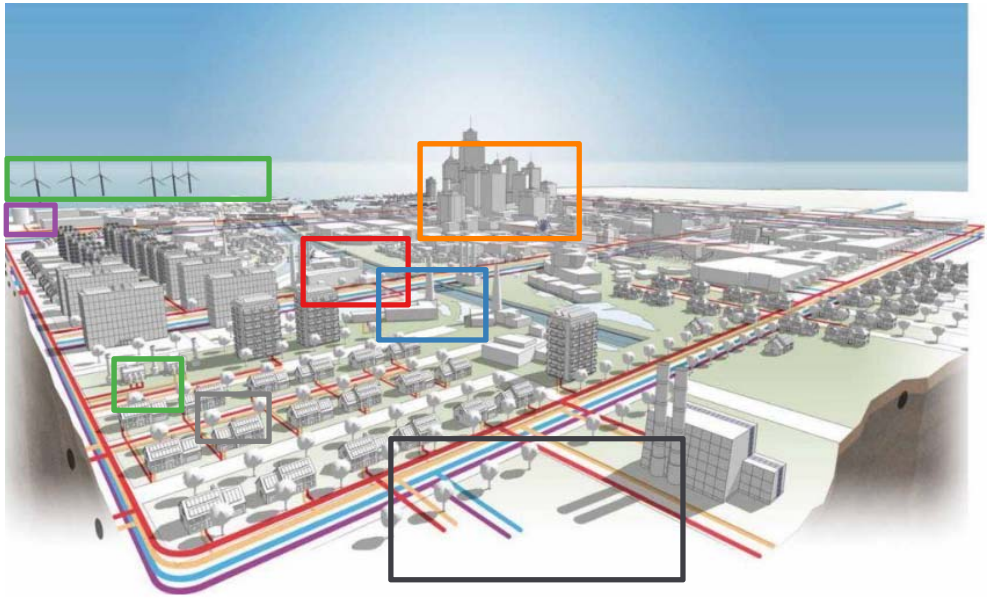
**46 Technologies**

**Functionalities**



# DHC CATEGORIZATION
# Functionalities

1. Energy conversion
2. Waste heat recovery
3. REn harvesting
4. Energy storage
5. Heat distribution
6. Supply/demand matching
7. Heat exchange
8. Monitoring and control



District Energy in Cities, ©UNEP, 2015.

# DHC CATEGORIZATION
# Technologies

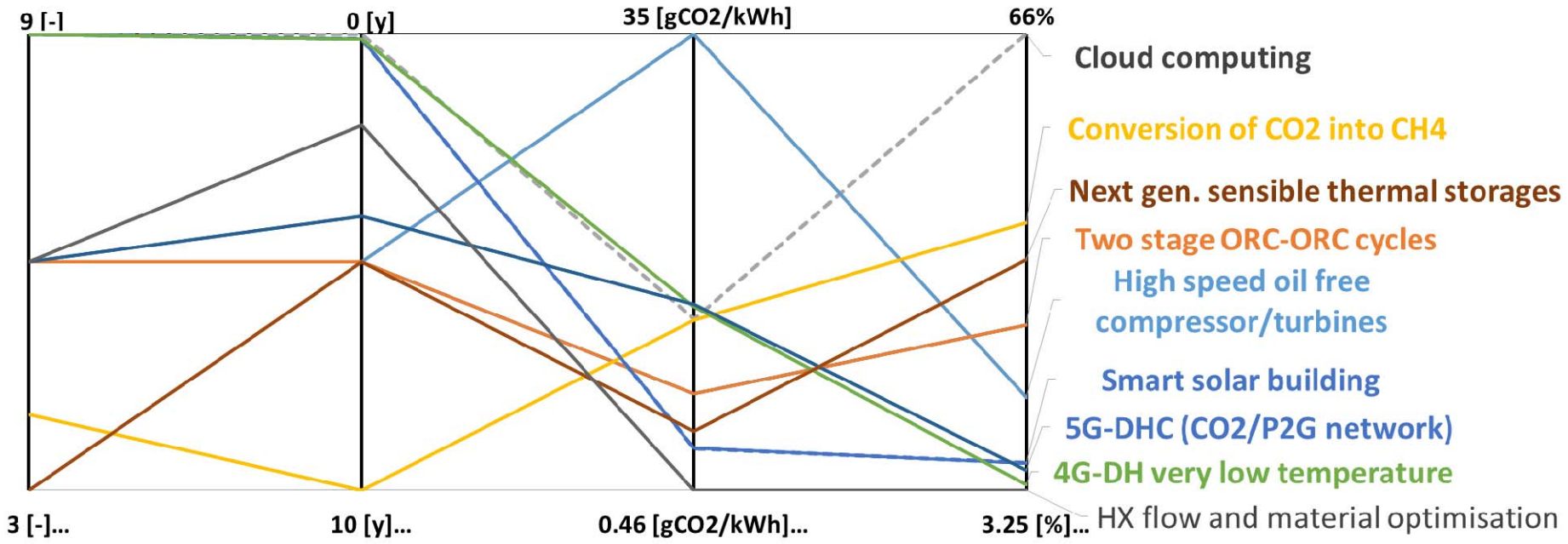
1. Heat pump kit for houses with existing boiler
2. Efficient buildings
3. Next generation of highly integrated, compact hybrid systems
4. Large scale hybrid systems
5. Heat pump for near-zero energy buildings
6. Booster Heat Pump for DHC
7. High speed oil free compressor/turbines
8. Two stage ORC-ORC cycles
9. Supercritical cycles
10. Sorption cooling form renewable energy sources
11. Sorption cooling syst. driven by HW at moderate temperature
12. Thermoelectric
13. Stirling engine
14. Steam CHP up to 600°C
15. Solid oxide fuel cells (SOFC) with CO2 capture
16. small scale biomass gasification technologies
17. Biomass cogeneration technologies
18. Hot gas turbines for solid biomass based cogeneration
19. Biogas and syngas and advanced biomass fuel
20. Direct-to-chip liquid cooling
21. Production of biogas and conversion of CO2 into CH4
22. Solar façade systems
23. Solar-assisted cooling systems
24. Heating systems for “Solar-Active-Houses”
25. Smart solar building
26. New absorption chillers
27. New adsorption chillers
28. Solar thermal and PV collectors
29. Design of shallow geothermal system
30. Deep geothermal resources
31. Enhanced Geothermal Systems - EGS
32. Prefabricated solar based hybrid systems
33. Next gen. sensible thermal storages – TCM materials
34. Cost effective low temp. storage – PCM materials
35. CH4 storage
36. Hydrogen (storage) fuel cells
37. H2 storage carbon nanotubes
38. Rechargeable Li-Ion battery
39. Superconducting Magnetic Energy Storage (SMES)
40. Tempered water networks
41. Refrigerant/CO2 network
42. HX flow and material optimisation
43. Refrigerant floor heating
44. IT algorithm and hardware -Automation and control
45. Process integration, optimisation and control
46. Territorial management and Energy integration

# DHC CATEGORIZATION
# Strategic challenges

Sanner, et al. Strategic Research and Innovation Agenda for Renewable Heating and Cooling: European Technology Platform on Renewable Heating and Cooling, 2013.
DHC+, District Heating Cooling, Strategic research agenda, 2012
EU Commission, "Review of Available Information, EU Strategy for Heating and Cooling", 2016.

1. Cheaper high efficient CHP plants (<85%)
2. Improved cooling generation technologies
3. Develop appropriate solution for DWP
4. Development of new waste-to-energy chains
5. Implementation of optimized waste heat management
6. Integration of various thermal energy sources in DHC
7. Seasonal storage
8. Smart and flexible storage solutions
9. Combined storage for heating and cooling
10. Using DHC as a buffer for excess electricity
11. Less invasive works
12. Integrated and standardized pipe solutions
13. Reduction of thermal losses
14. Interconnection of networks (heat electricity, gas)
15. Smart IT (MPC, automation, monitoring)
16. Integration of low temperature systems with existing systems
17. Better interaction between thermal production, distribution and demand
18. Improved interaction with and between prosumers and consumers
19. Improved, highly-efficient substations
20. Integrated energy networks linking local energy supply and demand
21. Assessing possibilities for local micro networks
22. Integrated planning and management of DH with DC
23. Develop and roll-out DH driven white goods

# TECHNOLOGY IDENTIFICATION FOM



# TECHNOLOGY IDENTIFICATION
## Emerging technologies

| Technology segment | Emerging aspects |
|---|---|
| **1. 4G-DH very low temperature network** | ● HP adaptation (design and sizes) to lower T°C difference<br>● Regulation |
| **2. Cloud computing** | ● Lightweight terminal to save electricity while<br>● recovering heat in the building by connecting server farms to DHC network |
| **3. Smart solar building** | ● Model predictive control<br>● Innovative solar collector / façade collector |
| **4. High speed oil free compressor/turbines** | ● Speed variation limiting on-off regulation<br>● Reduction of heat storage capacity<br>● Two-stage operation avoiding oil migration problems<br>● 3D printing manufacturing |
| **5. $CO_2$ DHC network** | ● Harvesting & distribution of the enviromnnment heat<br>● Use of the latent heat (compactness)<br>● P2G - integration with the transporation sector |
| **6. HX flow and material optimisation** | ● Phase change floor heating<br>● Two phase flow heat exchanger |
| **7. Two stage ORC-ORC cycles** | ● Reduced size of equipments<br>● Compact oil-free system<br>● Variety of fuels/heat sources (wood pellets, natural gas, solar heat, geothermal heat or waste heat) |
| **8. Next gen. sensible thermal storages** | ● Integration of new materials in buildings<br>● MPC strategies to lower energy consumption |
| **9. CO2 to methane conversion** | ● Energy carrier for heating, electricity generation, and transportation<br>● SOFC-GT Fuel cell using biomass in reverse mode |

# CONCLUSION

## Emerging/disruptive technologies

Disruptive Technology **?**

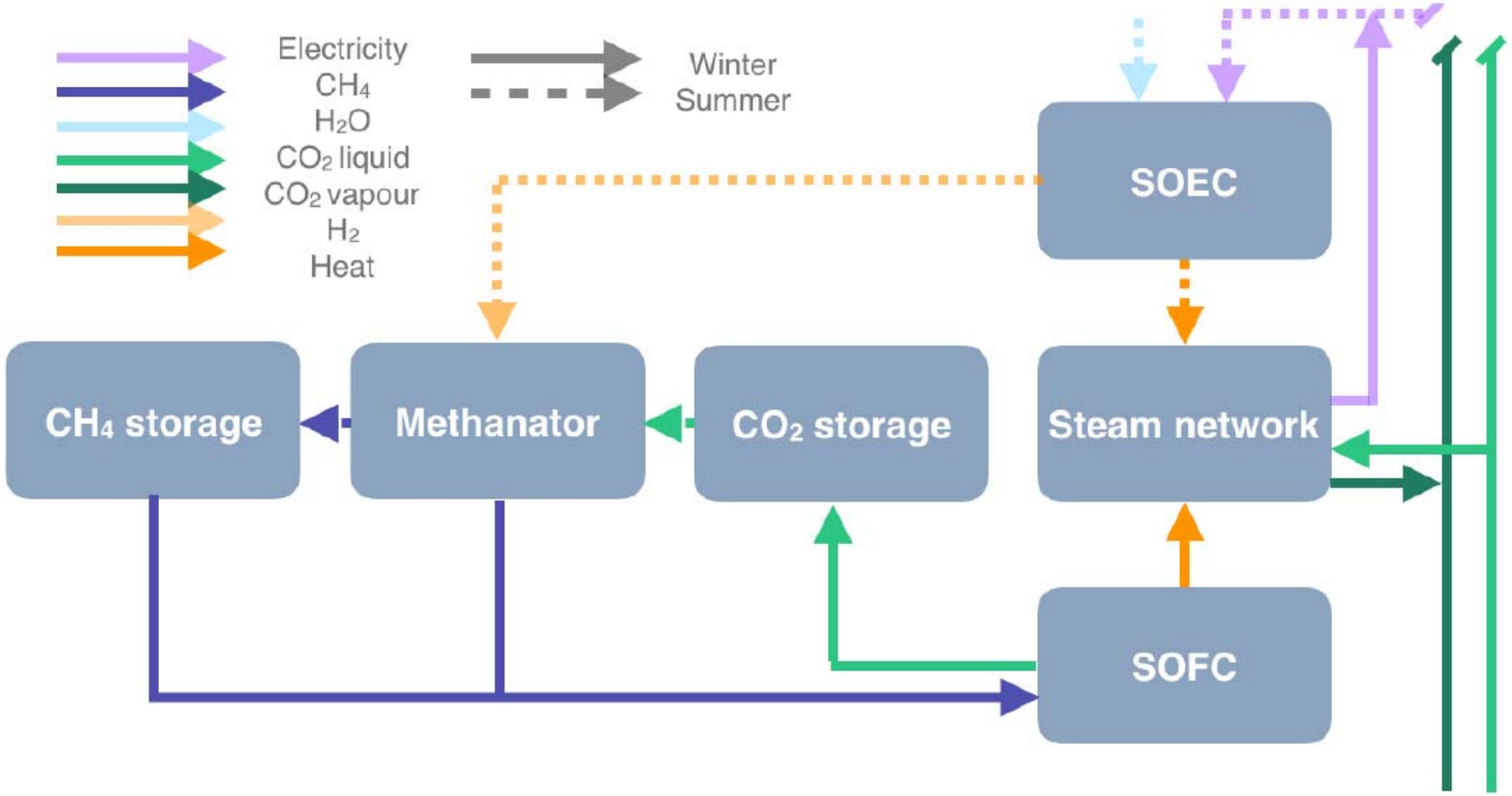
✓ Disruptive integration of emerging technologies

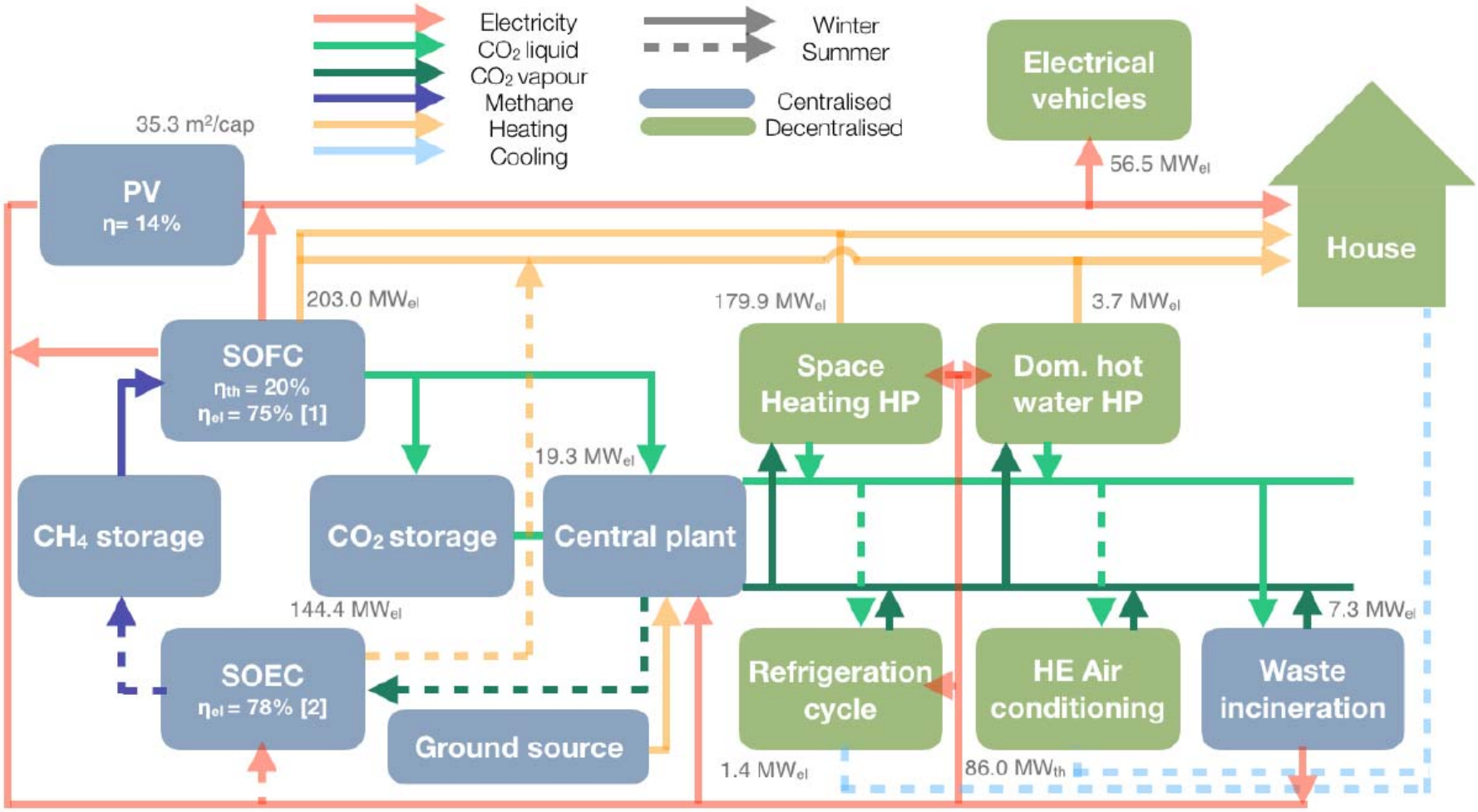
- Investment and maintenance cost only - energy for free

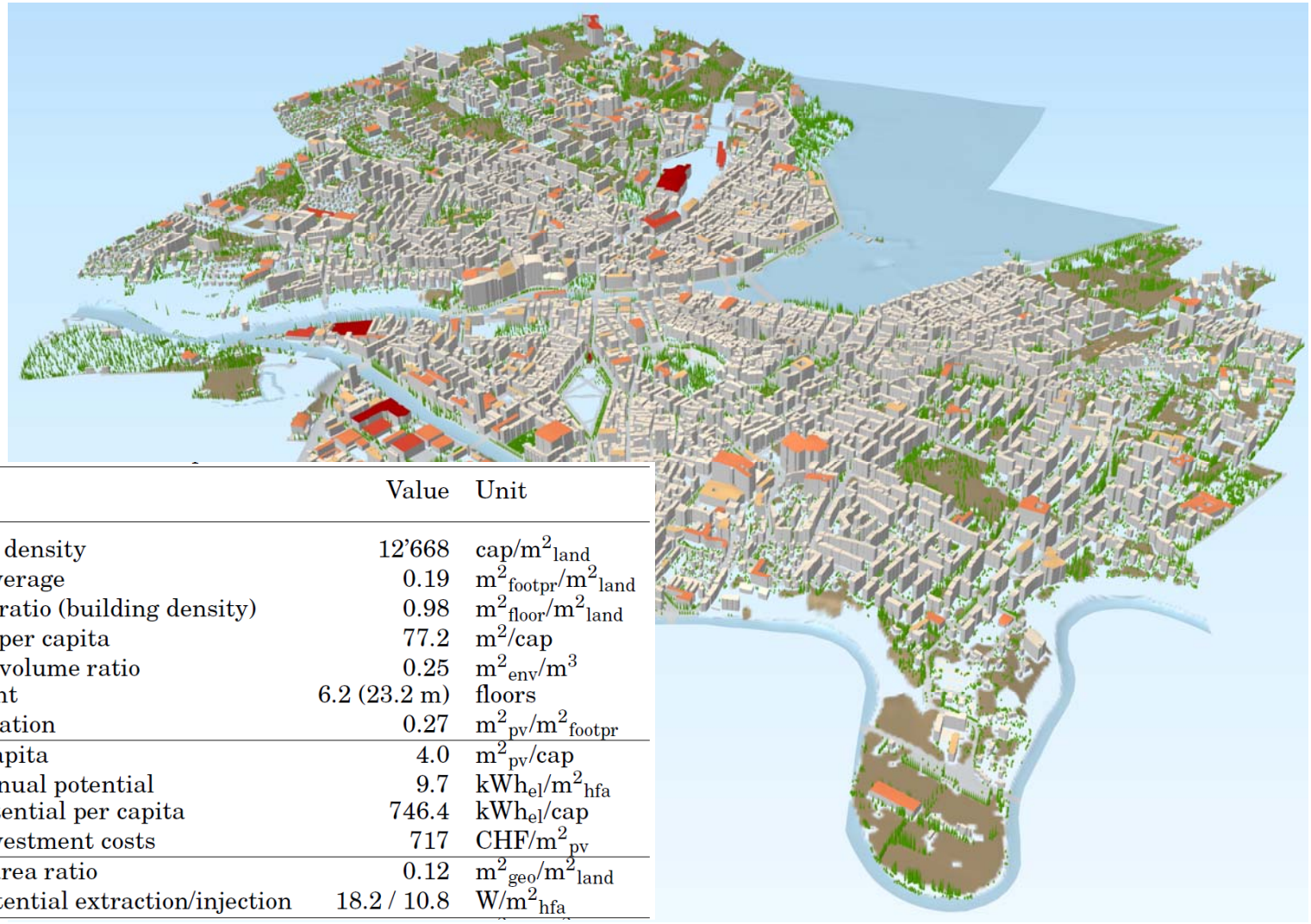
- Provide cooling at the highest possible temperature
- Match the temperature profiles
- Have small pressure drops
- Use machines (compressors, expanders, pumps) having high efficiency.
- Avoid thermal losses
- Recover waste heat

# QUESTION ?

luc.girardin@epfl.ch
francois.marechal@epfl.ch
Jessen.page@hevs.ch


Electricity
$CH_4$
$H_2O$
$CO_2$ liquid
$CO_2$ vapour
$H_2$
Heat
Winter
Summer
SOEC
$CH_4$ storage
Methanator
$CO_2$ storage
Steam network
SOFC


Electricity
CO2 liquid
CO2 vapour
Methane
Heating
Cooling
Winter
Summer
Centralised
Decentralised
35.3 m²/cap
PV
η= 14%
Electrical vehicles
56.5 MWel
House
203.0 MWel
179.9 MWel
3.7 MWel
SOFC
ηth = 20%
ηel = 75% [1]
Space Heating HP
Dom. hot water HP
19.3 MWel
CH4 storage
CO2 storage
Central plant
144.4 MWel
7.3 MWel
SOEC
ηel = 78% [2]
Ground source
Refrigeration cycle
HE Air conditioning
Waste incineration
1.4 MWel
86.0 MWth

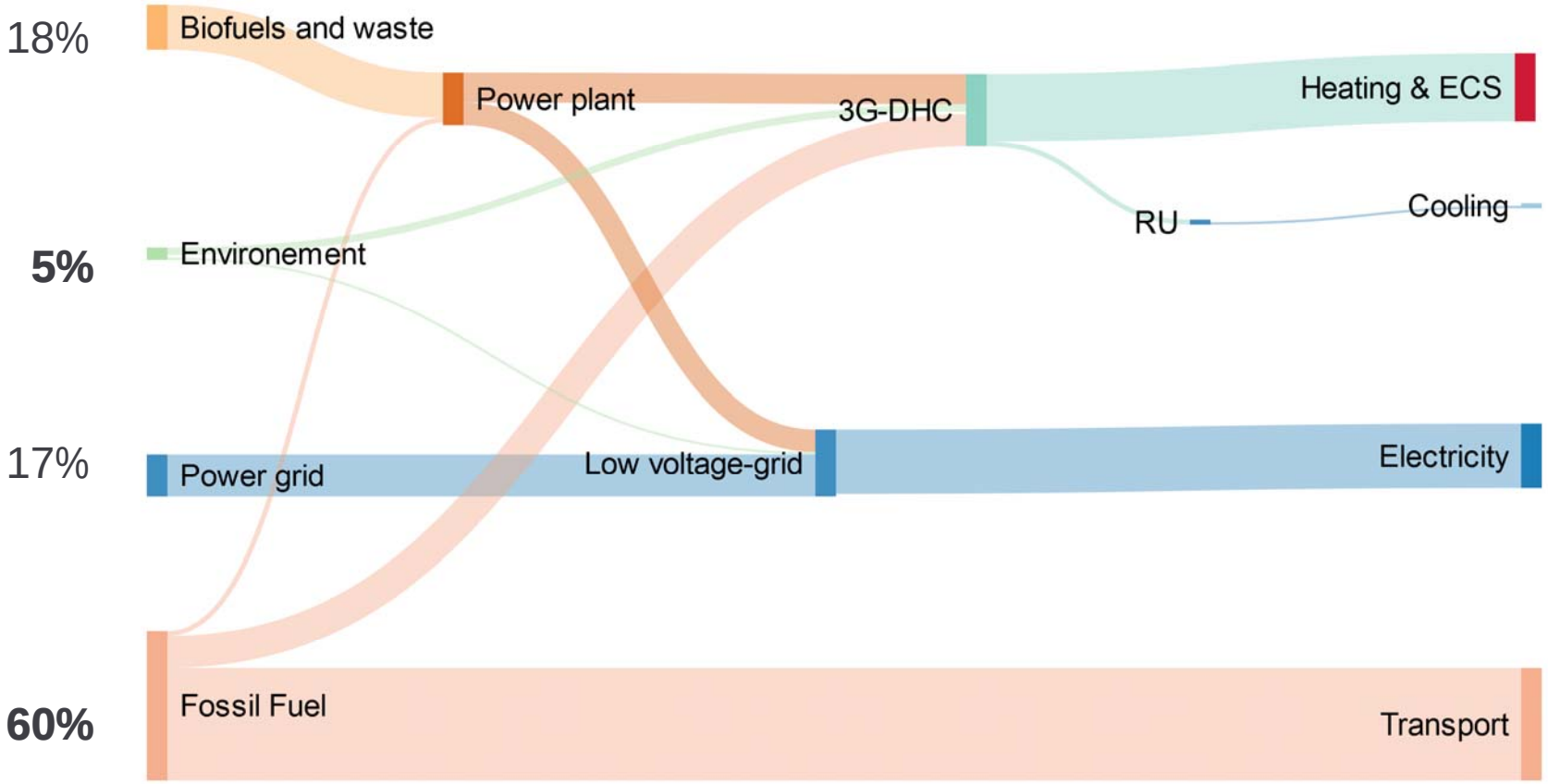


| Urban form | Parameter | Value | Unit |
|---|---|---|---|
| Buildings | Population density | 12'668 | cap/$m^2_{land}$ |
| | Surface coverage | 0.19 | $m^2_{footpr}/m^2_{land}$ |
| | Floor area ratio (building density) | 0.98 | $m^2_{floor}/m^2_{land}$ |
| | Floor area per capita | 77.2 | $m^2$/cap |
| | Surface-to-volume ratio | 0.25 | $m^2_{env}/m^3$ |
| | Mean height | 6.2 (23.2 m) | floors |
| | Footprint ration | 0.27 | $m^2_{pv}/m^2_{footpr}$ |
| Photovoltaic | Area per capita | 4.0 | $m^2_{pv}$/cap |
| | Specific annual potential | 9.7 | $kWh_{el}/m^2_{hfa}$ |
| | Annual potential per capita | 746.4 | $kWh_{el}$/cap |
| | Specific investment costs | 717 | CHF/$m^2_{pv}$ |
| Geothermal | Available area ratio | 0.12 | $m^2_{geo}/m^2_{land}$ |
| | Specific potential extraction/injection | 18.2 / 10.8 | W/$m^2_{hfa}$ |

# DHC SYSTEMS
# Past technologies

From IEA, World Final consumption (2014), http://www.iea.org/sankey/

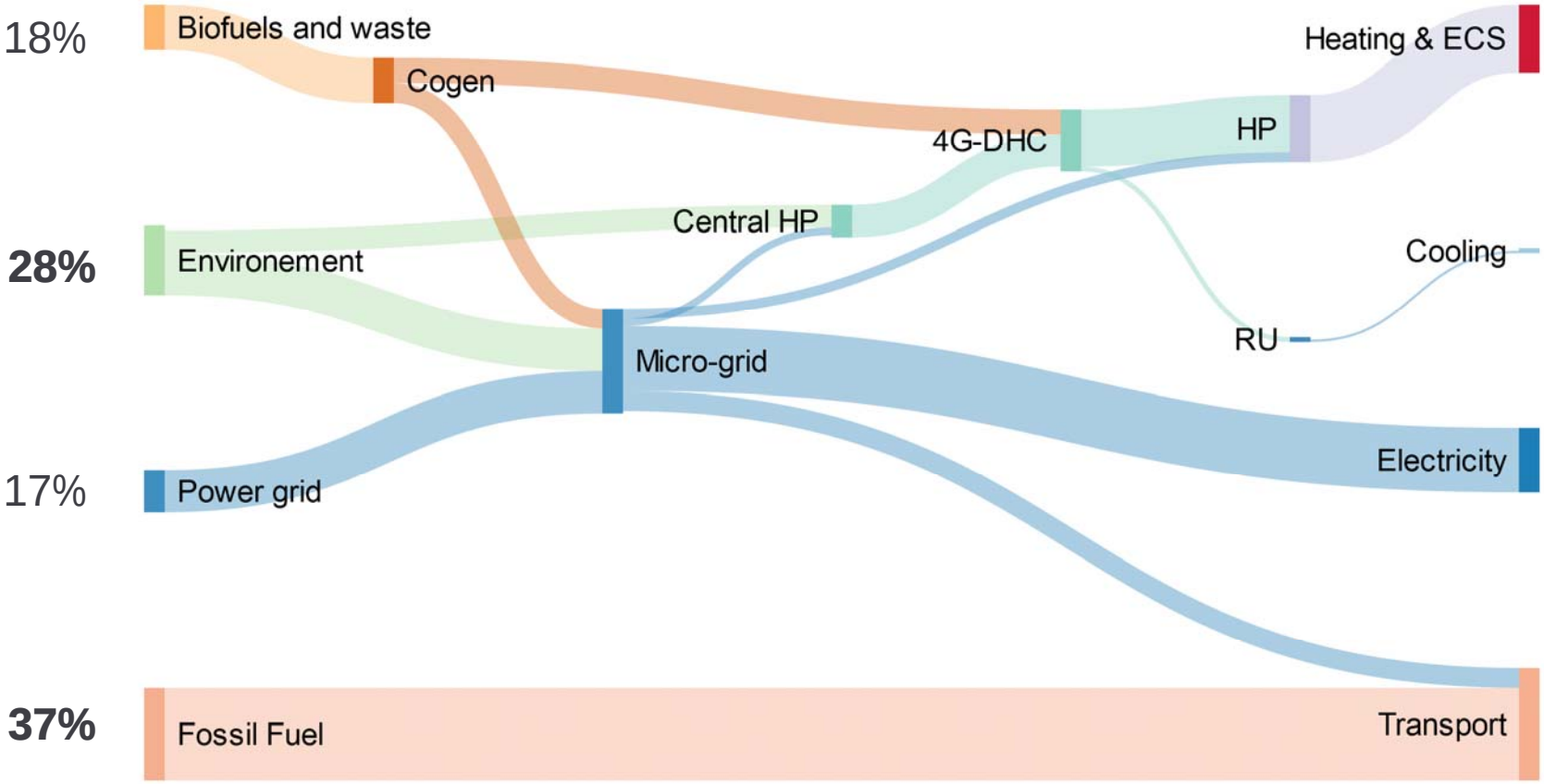
## 3G-DH: Distribute heat at the highest Temp. demand




*Environment: Lake/River/Geothermal/Solar /Wind/Tide

# DHC SYSTEMS
# Present technologies

## 4G-DH: Efficient integration of renewables H&C*




*Environment: Lake/River/Geothermal/Solar /Wind/Tide

# OVERVIEW
# Trends in EU (II)

Joint International Energy Agency/Eurostat/United Nations Economic Commission for Europe annual questionnaire on electricity and heat, Jun 2016.