Energy Supply System Architectures

Susanne Ochse, GEF Ingenieur AG

Germany

Energy Master Planning for Resilient Public Communities
Virtual Training Workshop, National Academies of Sciences, Washington
14th October 2020

Gefördert durch:

Bundesministerium
für Wirtschaft
und Energie

aufgrund eines Beschlusses
des Deutschen Bundestages

GEF Ingenieur AG
Ferdinand-Porsche-Straße 4a
D-69181 Leimen
info@gef.de
www.gef.de

Company Introduction

office in Leimen near Heidelberg

founded in 1984

office in Chemnitz

founded in 1990

Leading B2B Consultant for Planning District Heating in Germany

- more than 35 years experience with **all aspects of planning district heating systems**
- staff of 60 highly qualified specialists
- development of economic solutions with focus on the interest of our customers
- independent of construction and manufacturing companies

Part of the international team for IEA Annex 73

Energy Supply System Architectures

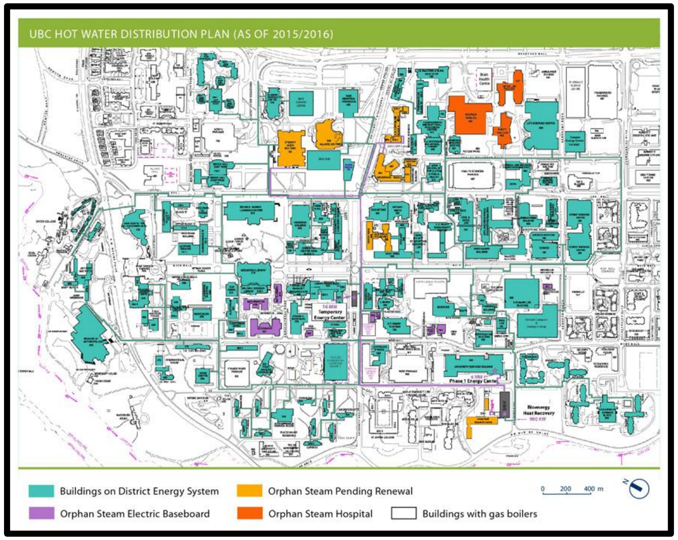
GEF Ingenieur AG

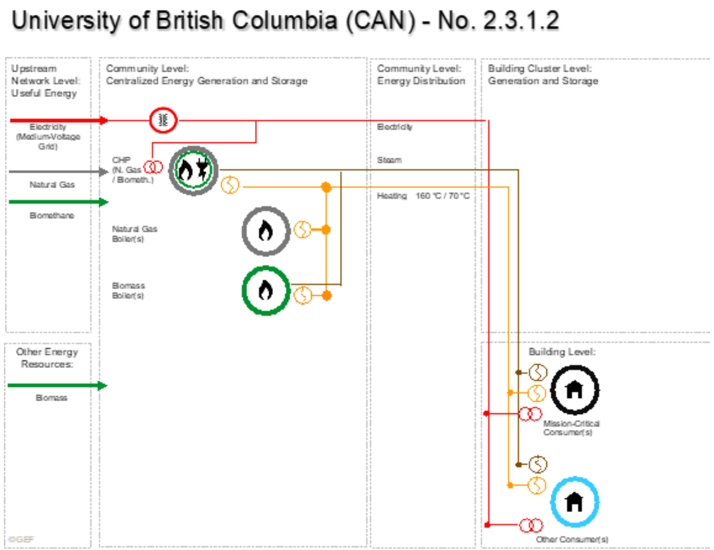
1. **What‘s the Idea behind Energy System Architectures**
2. Introduction to the Elements of the System Templates
3. Using System Architectures to illustrate System Transformation („Flip Book“)
4. Annex 73 Classification System for Energy System Architectures
5. Selecting Technological Components for Scenarios

Idea behind Energy System Architectures

1. Reduction of complexity

- Buildings: normal consumers, critical consumers
- Energy Sources: natural gas, oil, waste heat, solar energy, ….
- Generation Equipment: boilers, heat pumps, CHP, electric chillers, ….
- Grids: heating, cooling, electricity, micro grids
- Schematic spatial location of equipment, grids, buildings

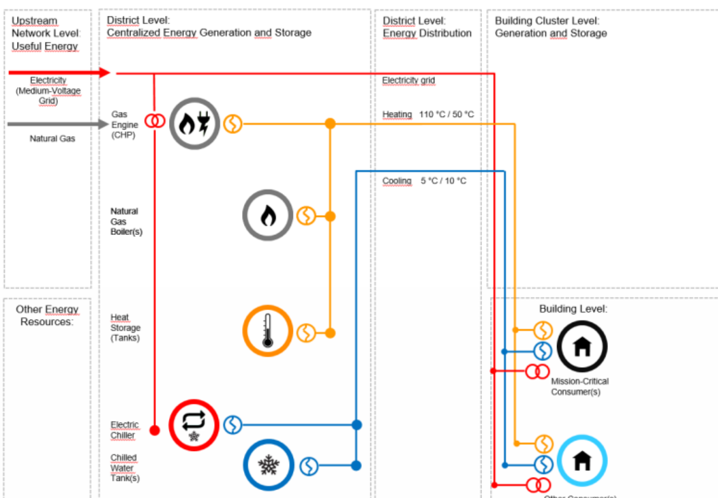




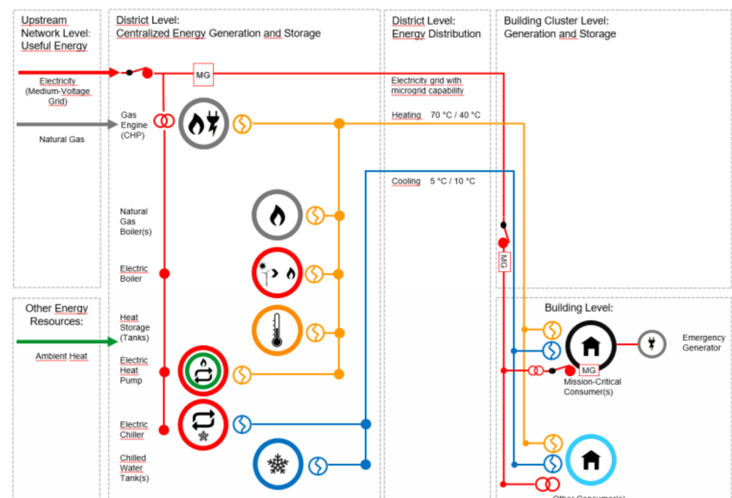
source: Big Ladder, Michael O'Keefe
source: http://energy.ubc.ca/projects/district-energy

Idea behind Energy System Architectures

2. **Clear representation of central elements when designing scenarios**
   - Baseline (current state of system)
   - Base case (most probable future system design)
   - Alternative 1, 2, 3, … (energy sources: natural gas, oil, waste heat, solar energy, ….)
3. **Schematic representation of system transformation**
4. **Templates for inspiration when designing new energy systems**



baseline system



possible future system

Energy Supply System Architectures

1. What‘s the Idea behind Energy System Architectures
2. **Introduction to the Elements of the System Templates**
3. Using System Architectures to illustrate System Transformation („Flip Book“)
4. Classification System for Energy System Architectures
5. Selecting Technological Components for Scenarios

System Architecture Elements

GEF Ingenieur AG

Upstream Network Level: Useful Energy

Electricity (Medium-Voltage Grid)

Natural Gas

Community Level: Centralized Energy Generation and Storage

Community Level: Energy Distribution

Building Cluster Level: Generation and Storage

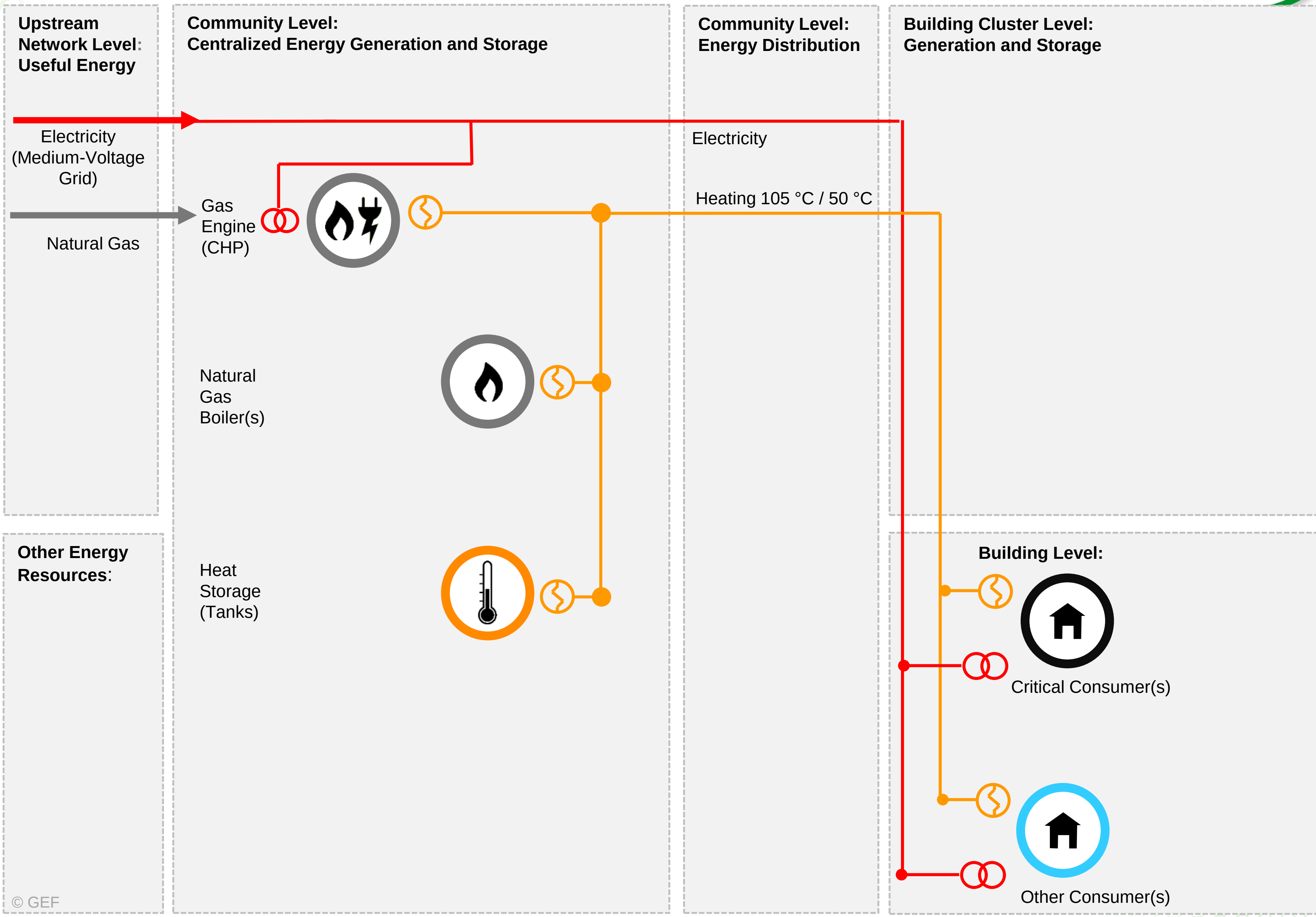
Other Energy Resources:

Building Level:

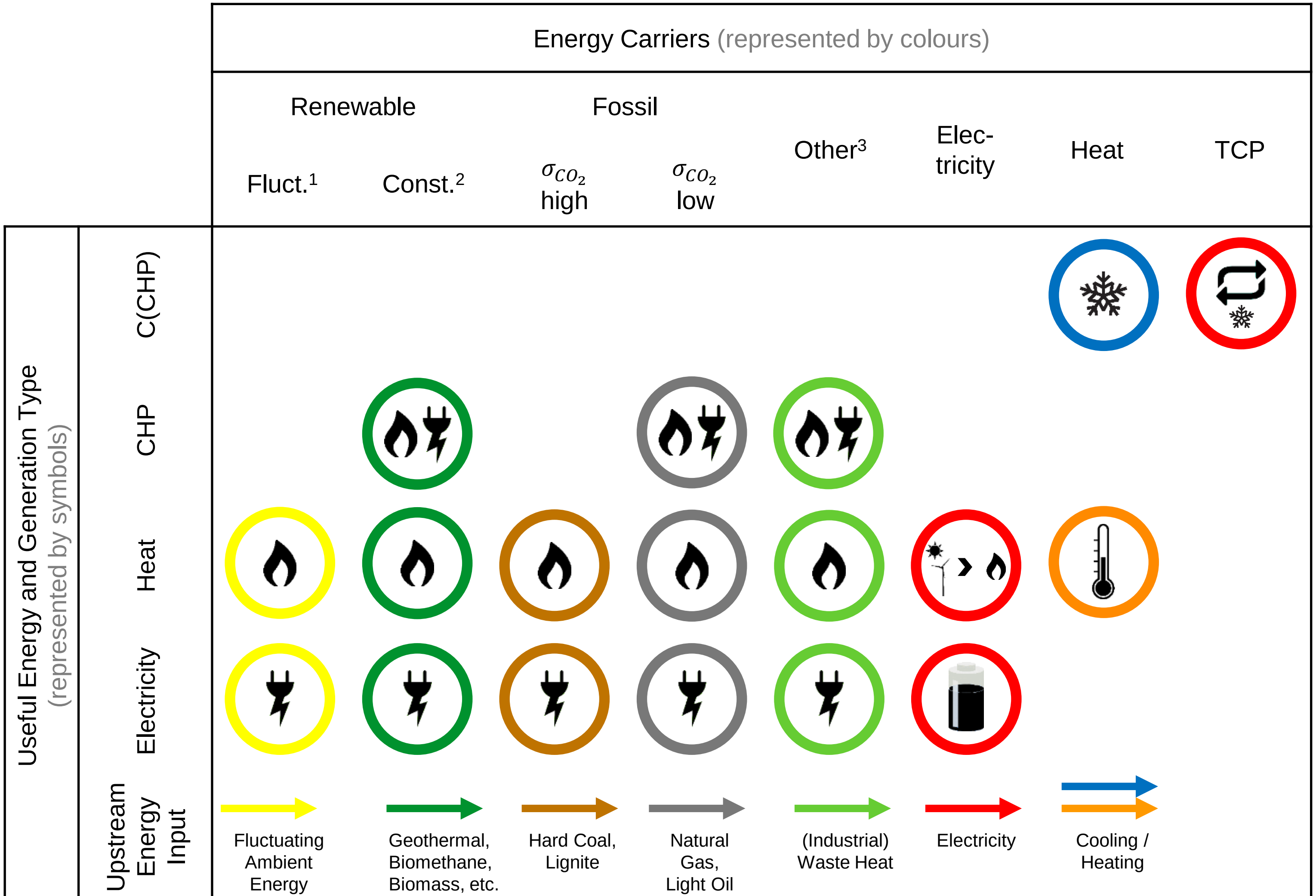
Critical Consumer(s)

Other Consumer(s)

System Design Template



Energy GenerationEnergy Storage and Grids
Superordinate Structure

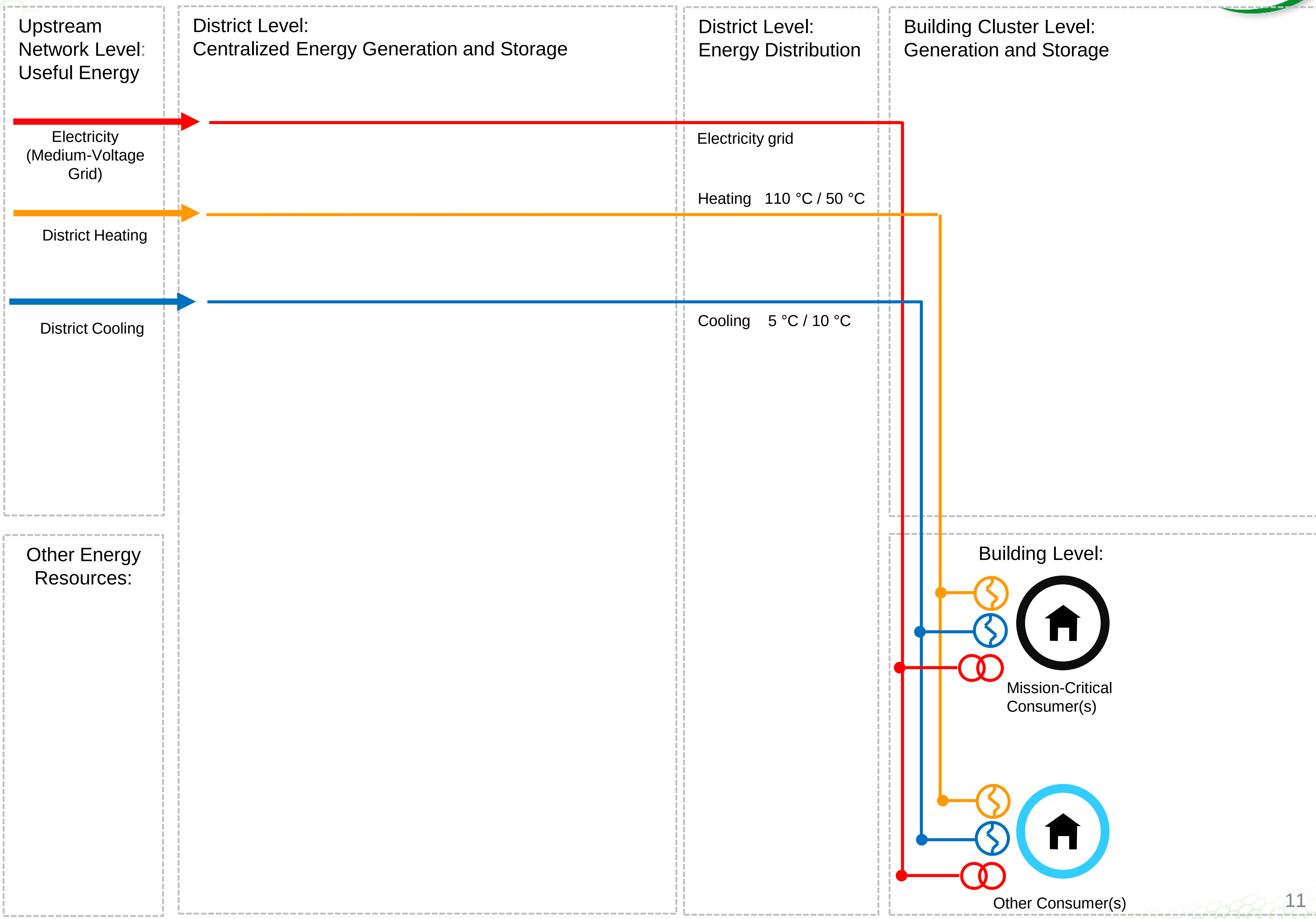


[1] Sun, Wind, Water, Rivers, Sewage
[2] Geothermal Power, Biomass
[3] Energetically Exploitable Waste, Waste Heat

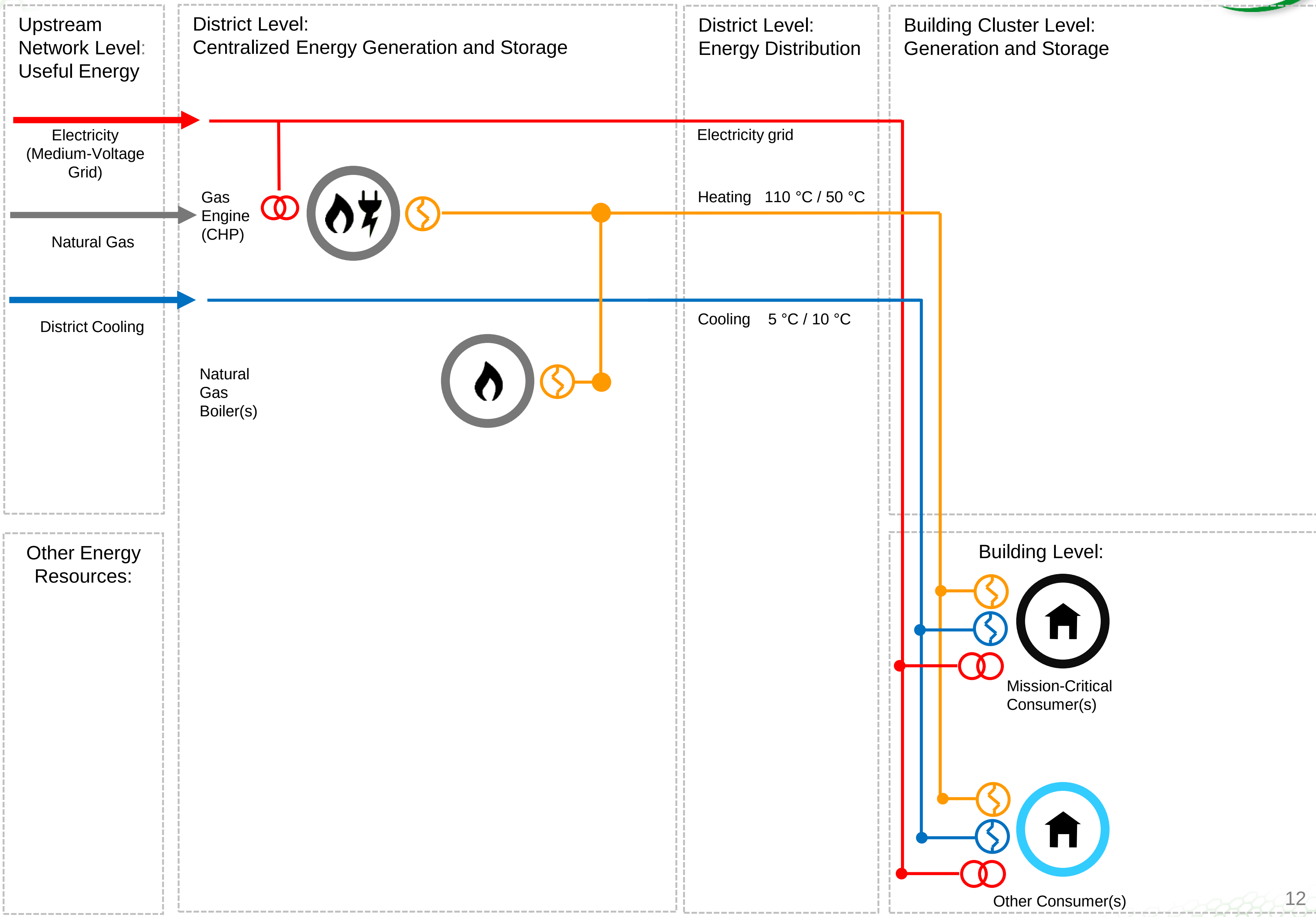
Energy Supply System Architectures

1. What‘s the Idea behind Energy System Architectures
2. Introduction to the Elements of the System Templates
3. **Using System Architectures to illustrate System Transformation („Flip Book“)**
4. Classification System for Energy System Architectures
5. Selecting Technological Components for Scenarios

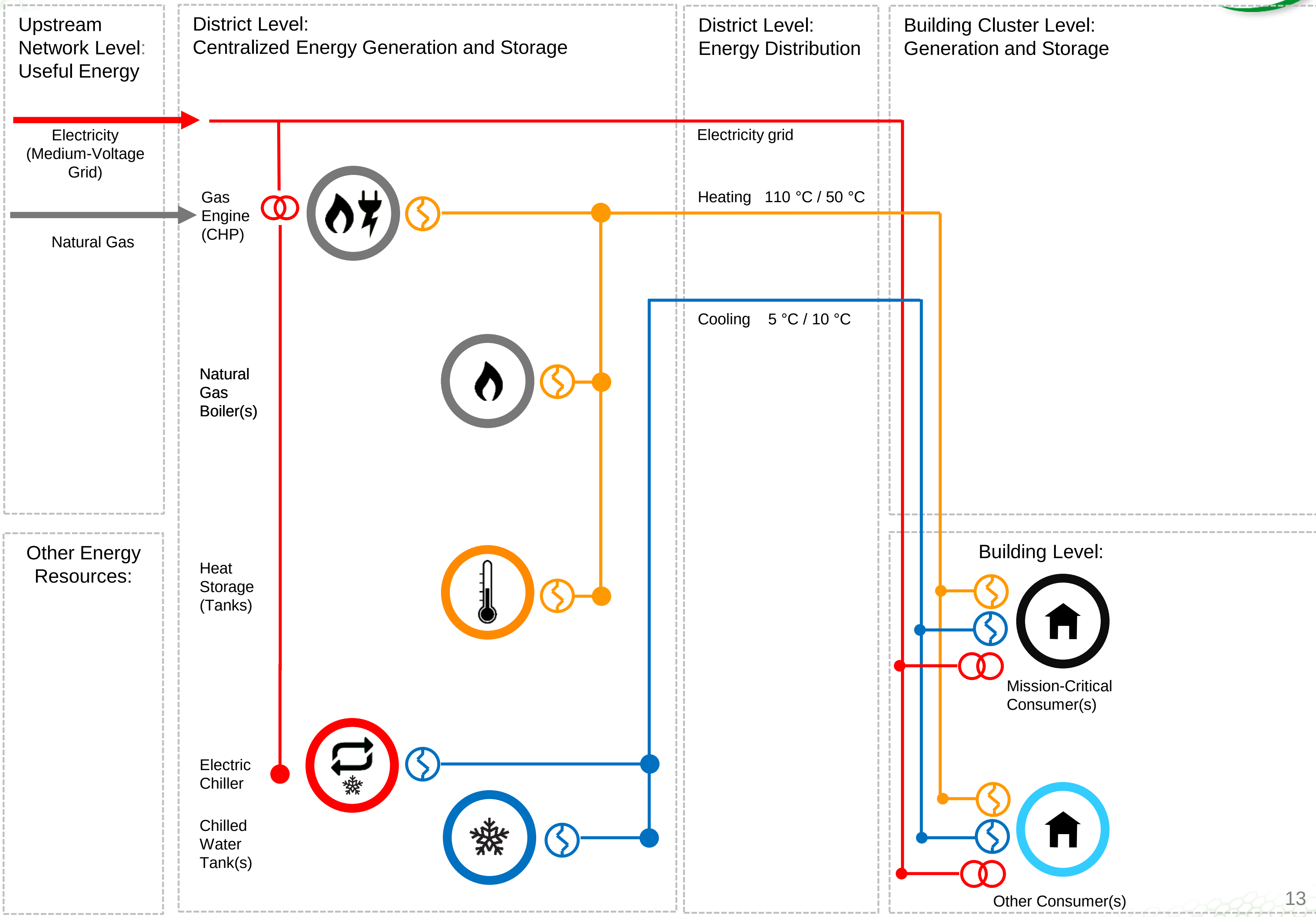
System Design Example



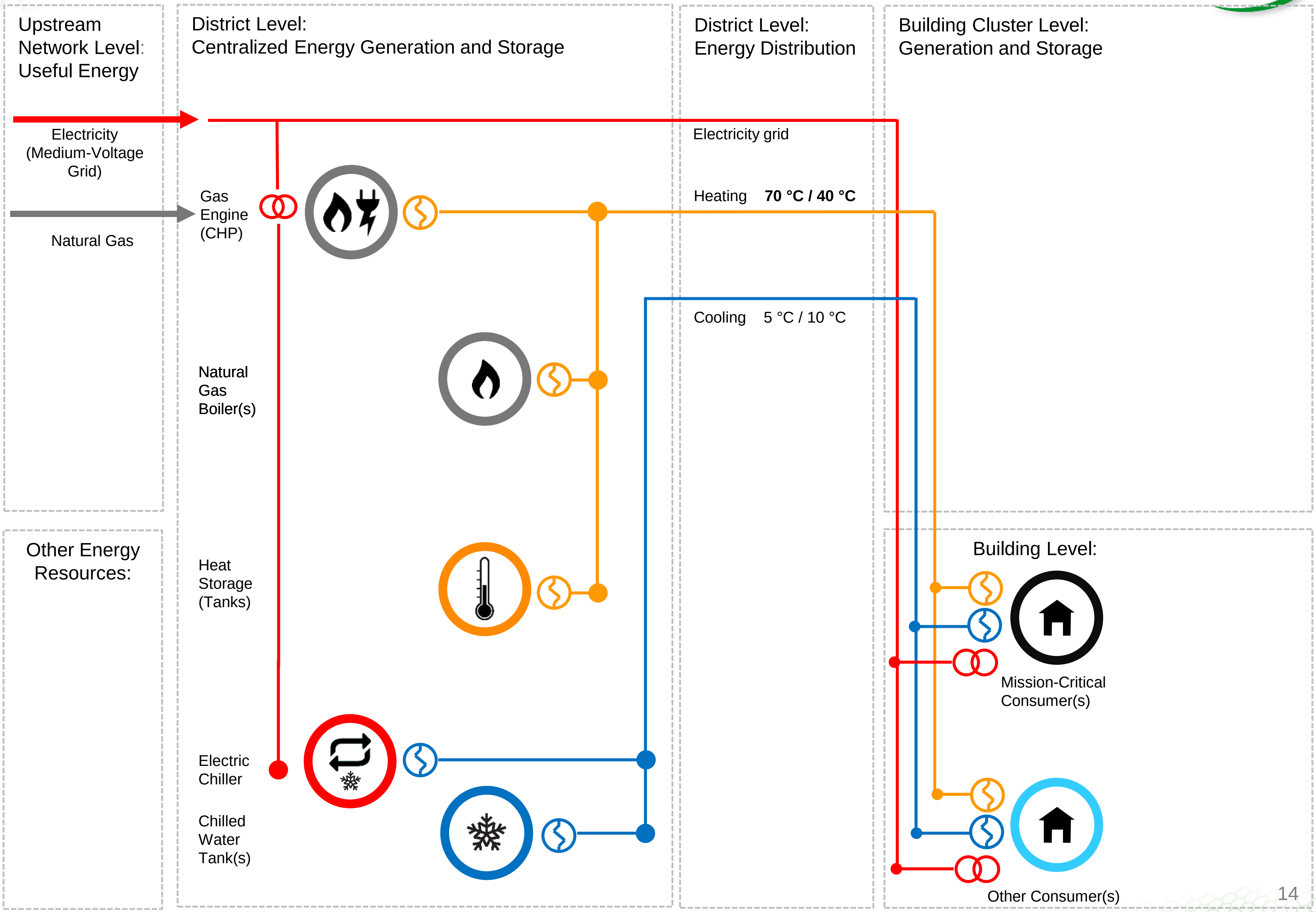
System Design Example



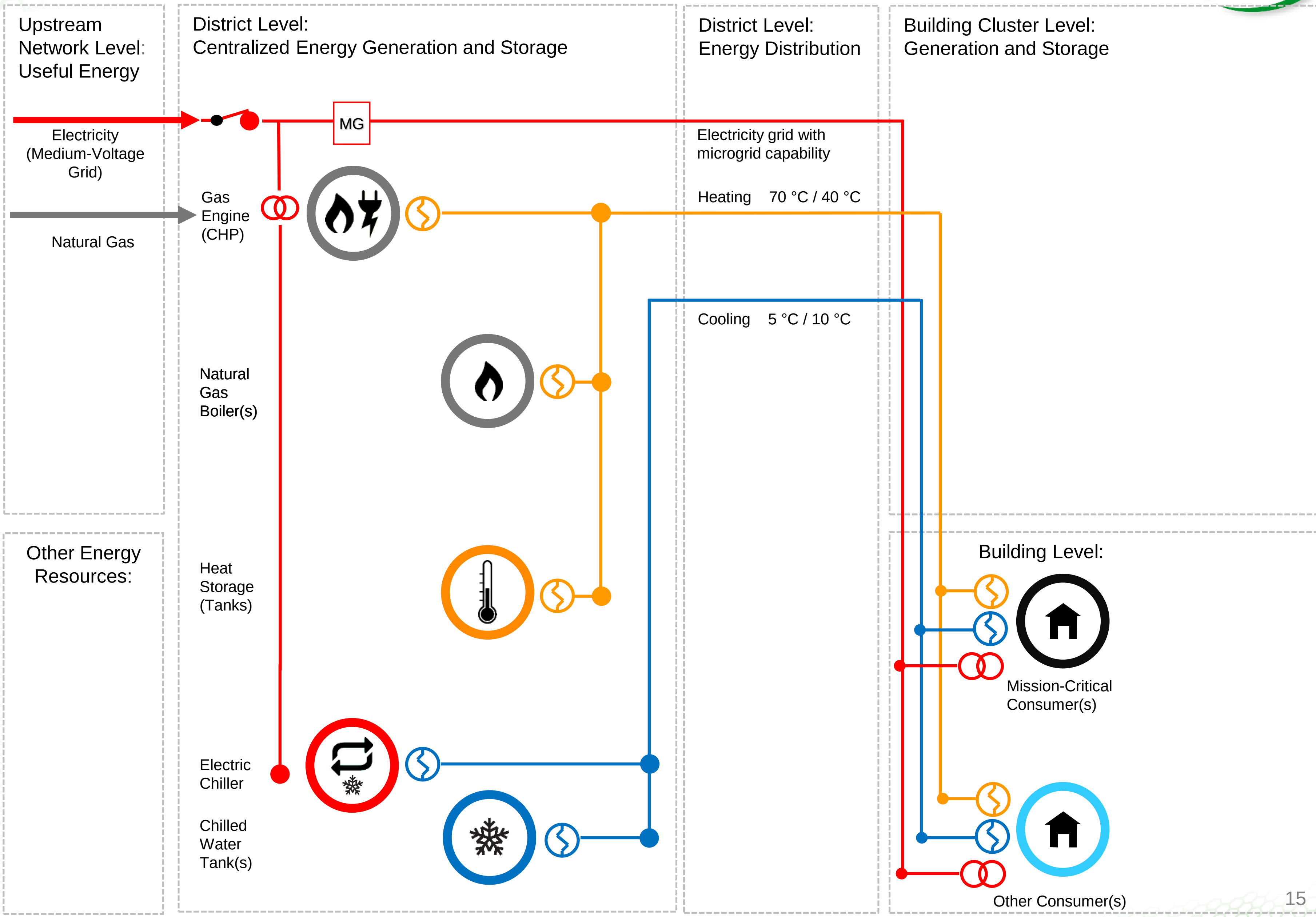
System Design Example



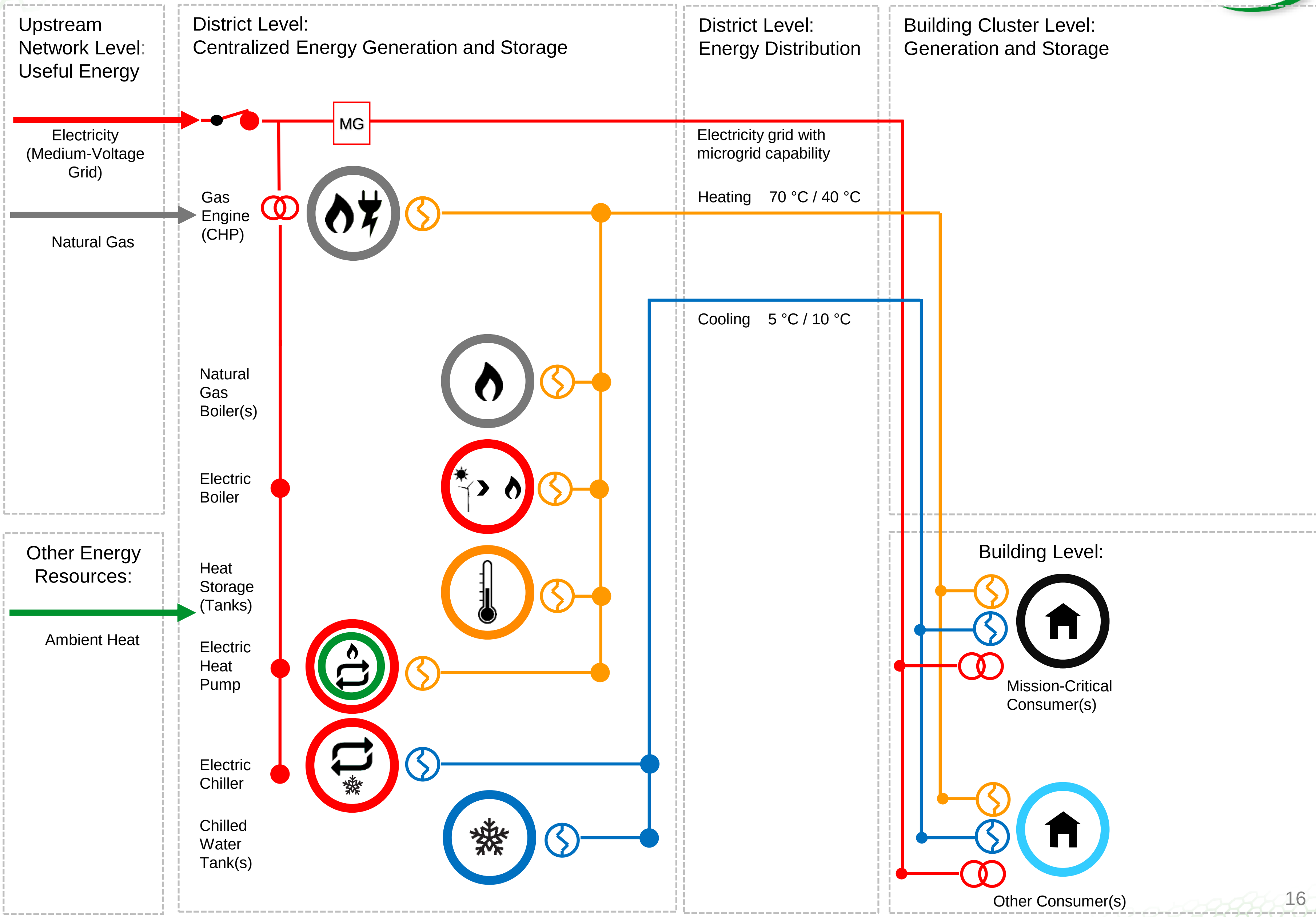
System Design Example



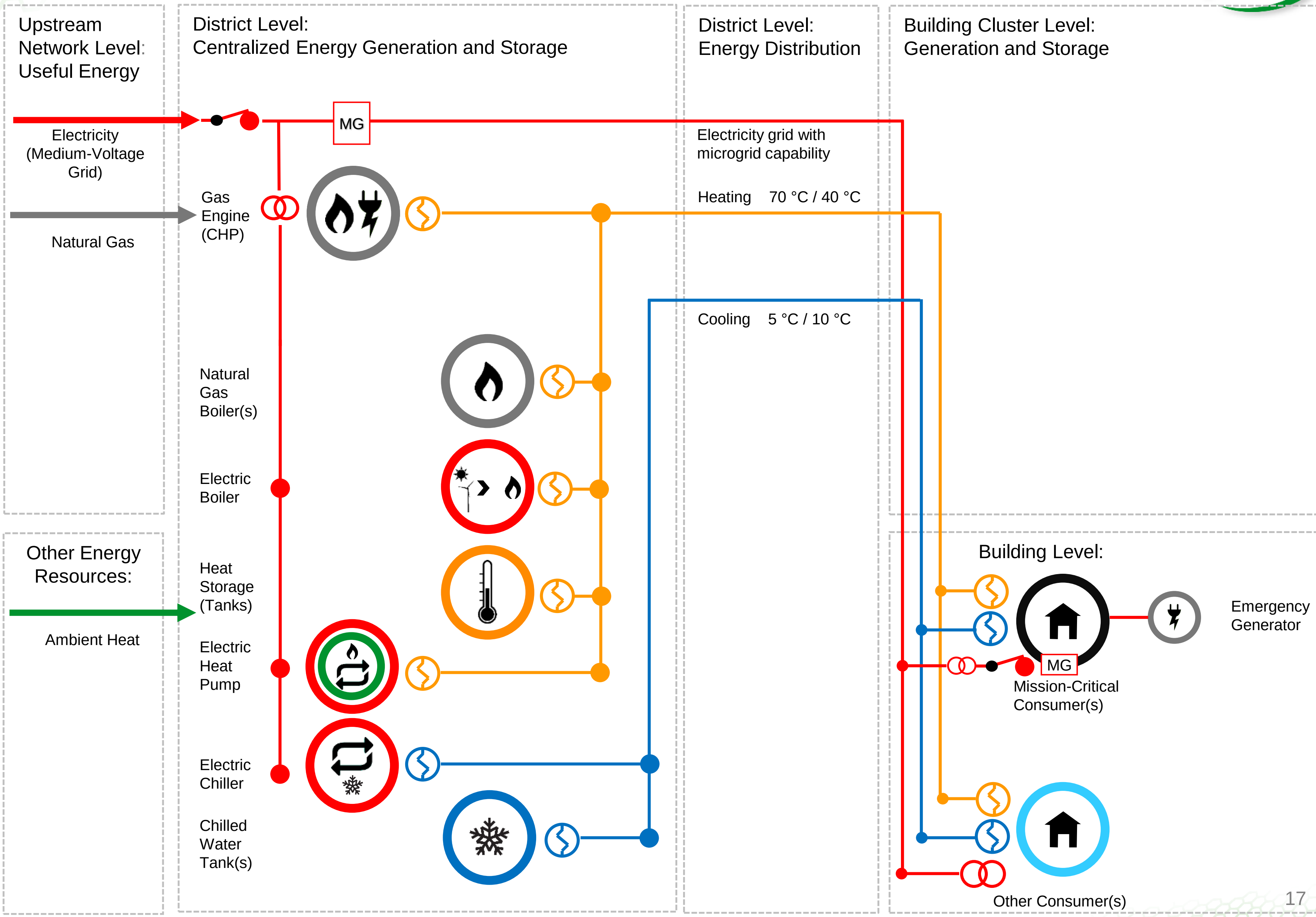
System Design Example



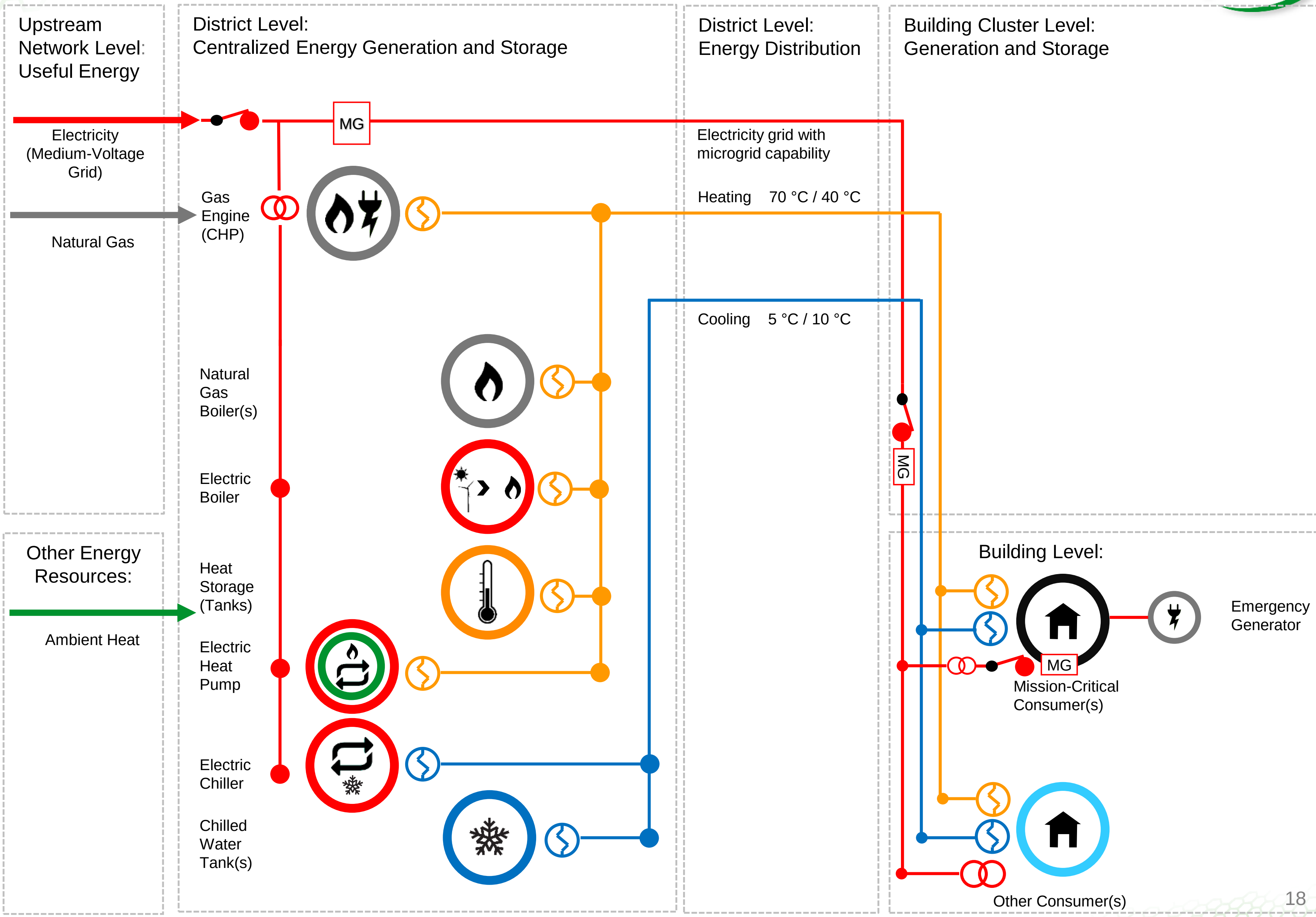
System Design Example



System Design Example



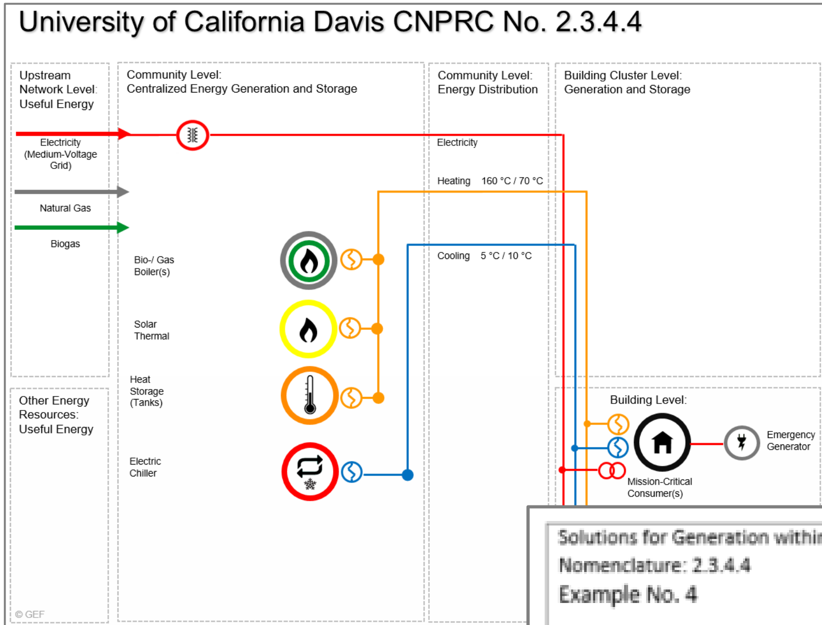
System Design Example



Energy Supply System Architectures

1. What‘s the Idea behind Energy System Architectures
2. Introduction to the Elements of the System Templates
3. Using System Architectures to illustrate System Transformation („Flip Book“)
4. **Annex 73 Classification System for Energy System Architectures**
5. Selecting Technological Components for Scenarios

Annex 73 Guide
Architecture Description in Appendix E



- classification
- more than 50 templates
- description, central equipment, capabilities, applications, advantages, disadvantages

Solutions for Generation within the Community Nomenclature: 2.3.4.4 Example No. 4	Location of Generation at .... Community Level	Buildings to be supplied from the outside with ... Power + Heating + Cooling

Description	Natural gas and biomethane boilers and solar thermal community level for heating, electrical cool
Central Equipment	Gas/biogas boiler, solar thermal, electric chillers
Capabilities	Reliable cooling and heat supply, can supply buildings with high temperature hot water and low temperature chilled water
Applications	Communities with high and medium heat and cool density
Advantages	Renewable energy, (n+1) redundancy for heating and cooling at community level, heat storage provides peak shaving for heat and additional resilience, emergency power generation for critical buildings
Disadvantages	gas grid necessary

Classification System

Classification by using four digits

Digit 1

1.x.x.x **Solutions for Generation within the Community (on community, cluster, building level or combination)**

2.x.x.x **Best Practice Examples**

3.x.x.x **Generation outside the Community**

4.x.x.x **Solutions for Remote Locations (island solutions)**

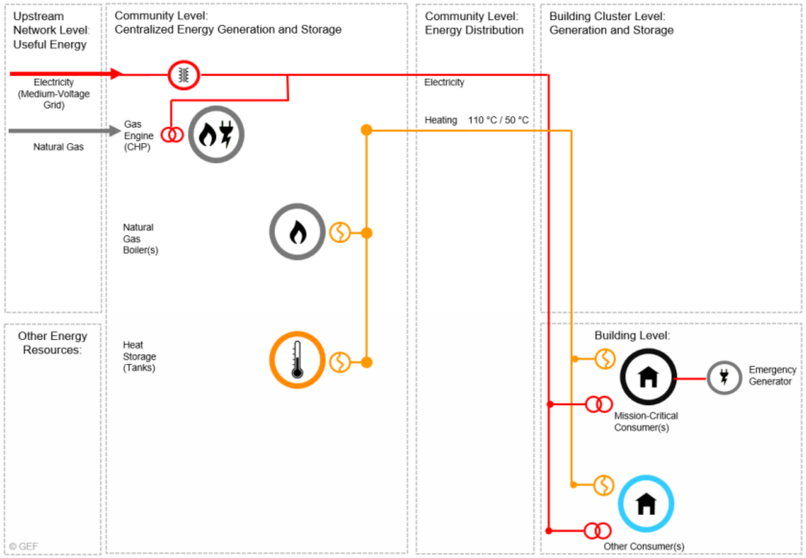
5.x.x.x **Systems with Electrical Enhancement**

Digit 2	Spatial location of heat generation with the community
x.1.x.x	at building level
x.2.x.x	at cluster level
x.3.x.x	at community level
x.4.x.x	combination

Digit 3	Building to be supplied from the outside with ….
x.x.1.x	power + heating
x.x.2.x	power + cooling
x.x.3.x	power
x.x.4.x	power + heating + cooling

Digit 4	No.. of Example
x.x.x.1	example 1
x.x.x.2	example 2

System Design Example No. 1.3.1.2



Classification System

Classification by using four digits

Digit 1	
1.x.x.x	**Solutions for Generation within the Community** (on community, cluster, building level or combination)
2.x.x.x	Best Practice Examples
3.x.x.x	Generation outside the Community
4.x.x.x	Solutions for Remote Locations (island solutions)
5.x.x.x	Systems with Electrical Enhancement

Digit 2	Spatial location of heat generation with the community
x.1.x.x	at building level
x.2.x.x	at cluster level
x.3.x.x	at community level
x.4.x.x	combination

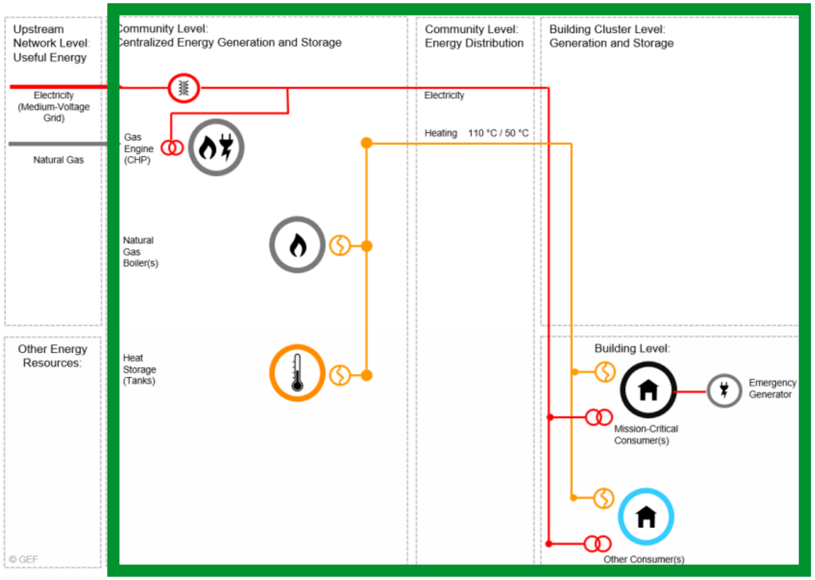
Digit 3	Building to be supplied from the outside with ….
x.x.1.x	power + heating
x.x.2.x	power + cooling
x.x.3.x	power
x.x.4.x	power + heating + cooling

Digit 4	No.. of Example
x.x.x.1	example 1
x.x.x.2	example 2

Example No. 1.3.1.2

1 = Heat Generation within the Community (not outside)

System Design Example No. 1.3.1.2



Classification System

Classification by using four digits

Digit 1	
1.x.x.x	Solutions for Generation within the Community (on community, cluster, building level or combination)
2.x.x.x	Best Practice Examples
3.x.x.x	Generation outside the Community
4.x.x.x	Solutions for Remote Locations (island solutions)
5.x.x.x	Systems with Electrical Enhancement

Digit 2	Spatial location of heat generation with the community
x.1.x.x	at building level
x.2.x.x	at cluster level
x.3.x.x	**at community level**
x.4.x.x	combination

Digit 3	Building to be supplied from the outside with ….
x.x.1.x	power + heating
x.x.2.x	power + cooling
x.x.3.x	power
x.x.4.x	power + heating + cooling

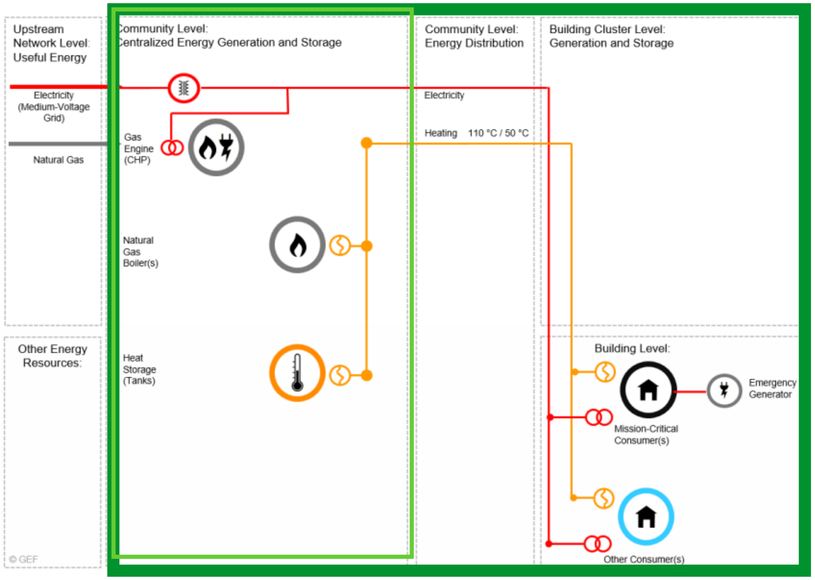
Digit 4	No.. of Example
x.x.x.1	example 1
x.x.x.2	example 2

Example No. 1.3.1.2

1 = Heat Generation within the Community

3 = Heat Generation at the Community Level (not at cluster level)

System Design Example No. 1.3.1.2



Classification System

GEF Ingenieur AG

Classification by using four digits

Digit 1	
1.x.x.x	Solutions for Generation within the Community (on community, cluster, building level or combination)
2.x.x.x	Best Practice Examples
3.x.x.x	Generation outside the Community
4.x.x.x	Solutions for Remote Locations (island solutions)
5.x.x.x	Systems with Electrical Enhancement
Digit 2	Spatial location of heat generation with the community
x.1.x.x	at building level
x.2.x.x	at cluster level
x.3.x.x	at community level
x.4.x.x	combination
Digit 3	Building to be supplied from the outside with ….
x.x.1.x	**power + heating**
x.x.2.x	power + cooling
x.x.3.x	power
x.x.4.x	power + heating + cooling
Digit 4	No.. of Example
x.x.x.1	example 1
x.x.x.2	example 2

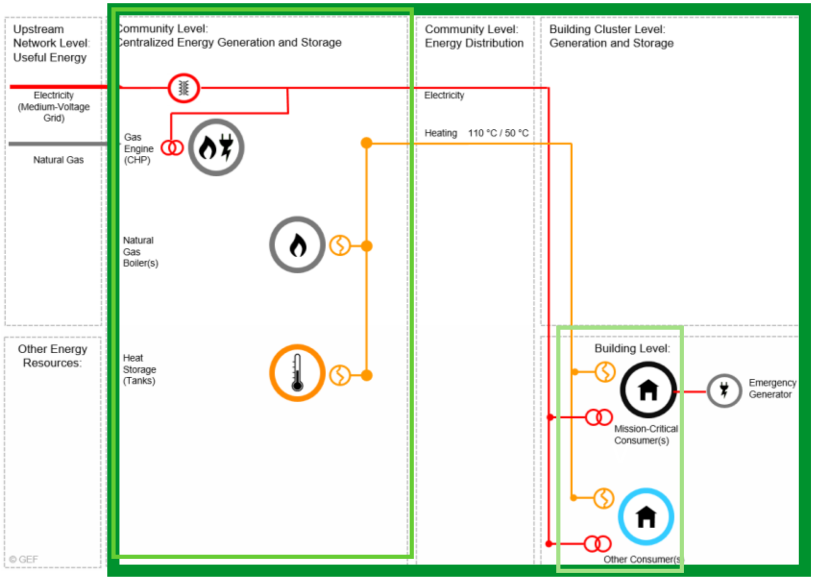
Example No. 1.3.1.2

1 = Heat Generation within the Community

3 = Heat Generation at the Community Level

1 = Building supplied from the outside with power and heating

System Design Example No. 1.3.1.2



Classification System

Classification by using four digits

Digit 1	
1.x.x.x	Solutions for Generation within the Community (on community, cluster, building level or combination)
2.x.x.x	Best Practice Examples
3.x.x.x	Generation outside the Community
4.x.x.x	Solutions for Remote Locations (island solutions)
5.x.x.x	Systems with Electrical Enhancement
Digit 2	Spatial location of heat generation with the community
x.1.x.x	at building level
x.2.x.x	at cluster level
x.3.x.x	at community level
x.4.x.x	combination
Digit 3	Building to be supplied from the outside with ….
x.x.1.x	power + heating
x.x.2.x	power + cooling
x.x.3.x	power
x.x.4.x	power + heating + cooling
Digit 4	No.. of Example
x.x.x.1	example 1
x.x.x.2	**example 2**

Example No. 1.3.1.2

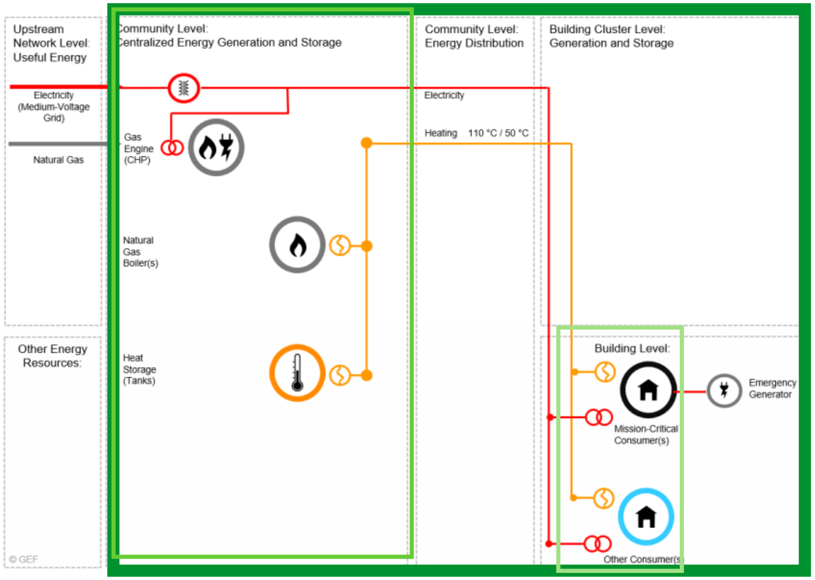
1 = Heat Generation within the Community

3 = Heat Generation at the Community Level

1 = Buidling supplied from the outside with power and heating

2 = Example No. 2 for the class

System Design Example No. 1.3.1.2



Energy Supply System Architectures

GEF Ingenieur AG

1. What‘s the Idea behind Energy System Architectures
2. Introduction to the Elements of the System Templates
3. Using System Architectures to illustrate System Transformation („Flip Book“)
4. Classification System for Energy System Architectures
5. **Selecting Technological Components for Scenarios**

How to approach energy system selection

1. Start by defining the existing energy system
2. Select the **architecture** that matches the existing energy system
3. Consider the relevant technologies for the new energy system
4. Find the relevant technologies in the database
5. Run energy system model and economic analysis
6. New energy system design **architecture**

baseline

base case & alternatives

Data Requirements for Analysis

Major categories of data required for the process of energy master planning and resilience analysis, which includes:

- General information
- Campus and building level information
- Information on building archetypes and topology
- HVAC systems
- Energy generation systems
- Existing distribution systems
- Basic fuel availability and potentials
- Analysis of constraints
- Possible synergies
- Information required for unique building modeling
- Information required for resilience analysis

Example: Selecting renewable energies for DH

table is designed to help with the question „which renewable energy fits my existing DH system?
1.) which renewables are available? 2.) do I need a CHP plant or a heat only plant? 3. how much thermal/elect. Capacity do I need 4.) which part of the load curve should be serviced by the plant 5.) which are my grid (= customer) temperatures

GEF Ingenieur AG

Integration of renewable energy into district heating

✓	available
	not available/does not make sense
	not applicable

Parameter/category *characteristic*	***woody biomass***			***biogas***			***bio synthetic natural gas***		***hydrothermal deep geothermal***		***solar thermal***		***heat pump (sewage)***
sufficient availability of renewable energy	Amount of biomass procurable? Problems with fine dust pollution at the location?			Amount of biogas available?			Amount of bio synthetic natural gas available?		Geothermal energy locally available?		solar thermal installation area 1500 m² or more		straight sewer section with > 1 m diameter, flow rate 15 l/s at dry weather (daily average)
Generator type	boiler	CHP steam power process	CHP ORC/KC	boiler	CHP CHP engine	CHP micro gas turbine	boiler	CHP all natural gas CHP plants possible	heat only	CHP ORC/KC	flat plate collector	vacuum tube collector	
therm. capacity													
up to 1 MW	✓		✓	(✓)1)	✓	✓	✓	✓			(✓) fluct.	(✓) fluct.	✓7)
1 to 5 MW	✓		✓	(✓)1)	✓	✓	✓	✓	capacity site specific (depending on temperature level, geothermal production rate)		(✓) fluct.	(✓) fluct.	✓7)
5 to 10 MW	✓		✓	(✓)1)	✓	1)	✓	✓			(✓) fluct.	(✓) fluct.	✓7)
10 to 20 MW	✓	✓	✓	(✓)1)	1)	1)	✓	✓					larger capacity when the waste heat potential (ocean water, industry) is larger
> 20 MW	✓	✓		(✓)1)	1)	1)	✓	✓					
electr. capacity													
up to 1 MW			✓		✓	✓		✓		✓5)			
1 to 5 MW			✓		✓	✓		✓		✓5)			
5 to 10 MW		✓			✓			✓					
10 to 20 MW		✓						✓					
> 20 MW		✓						✓					
load type													
peak load	(✓)8)	3)	3)	(✓)8)	3)	3)	✓	3)	4)	3)			4)
base load	✓	✓	✓	(✓)1)	✓	✓	✓	✓	✓	✓			✓
(daytime) summer load											✓	✓	
temperature level													
steam grid	✓	✓		(✓)1)		✓	✓	✓					
high temperature grid (T_{VL} > 140 °C)	✓	✓		(✓)1)		✓	✓	✓					
hot water grid (140 ° C > T_{VL} > 110 °C)	✓	✓		(✓)1)	✓2)	✓	✓	✓				✓6)	
110 °C > T_{VL} > 90 °C	✓	✓		(✓)1)	✓2)	✓	✓	✓	site specific		✓6)	✓6)	
LowEx grid	✓	✓	✓	(✓)1)	✓	✓	✓	✓			✓6)	✓6)	✓7)

Thank you very much

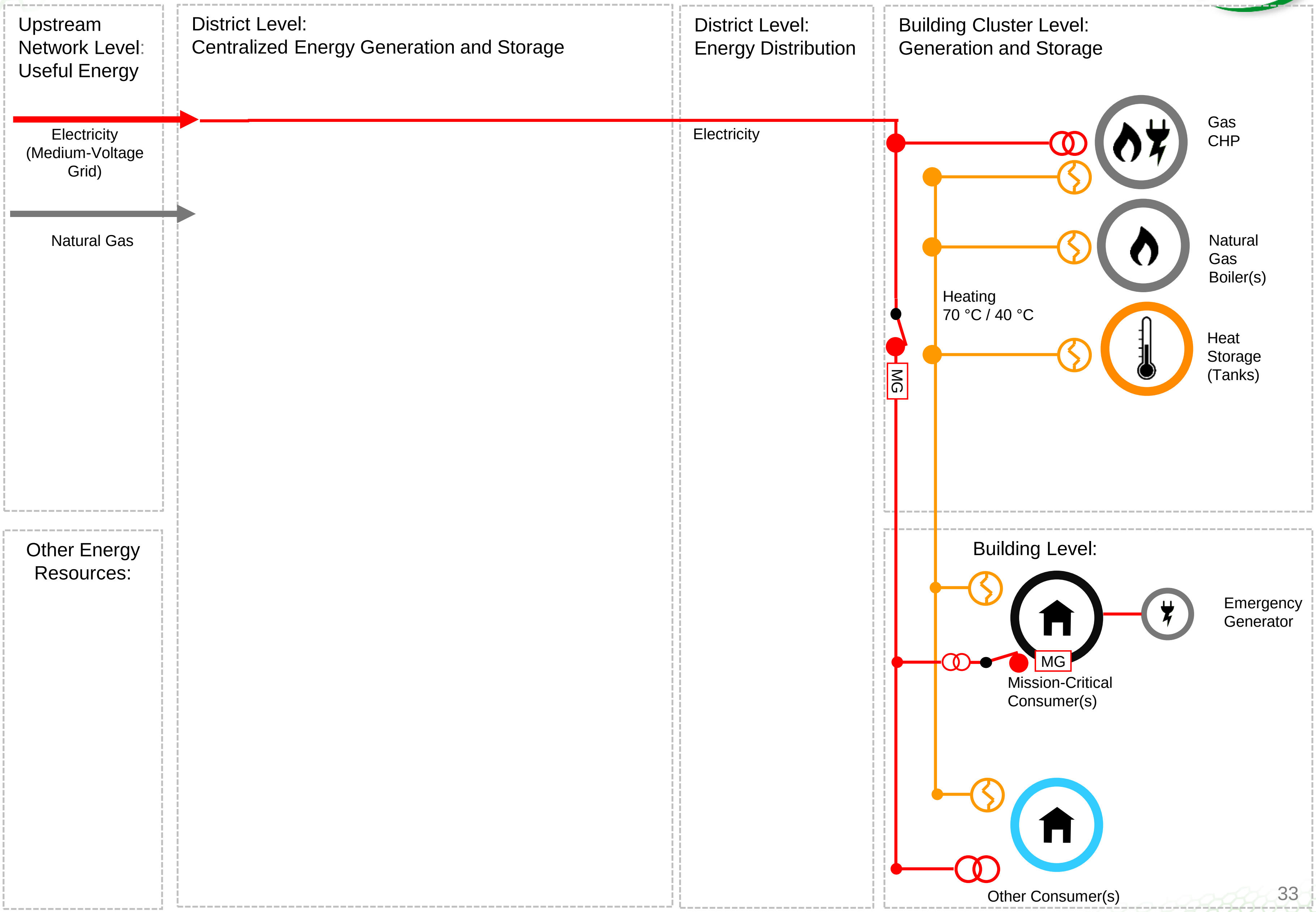
for your kind attention

GEF Ingenieur AG
Ferdinand-Porsche-Straße 4a
D-69181 Leimen
info@gef.de
www.gef.de

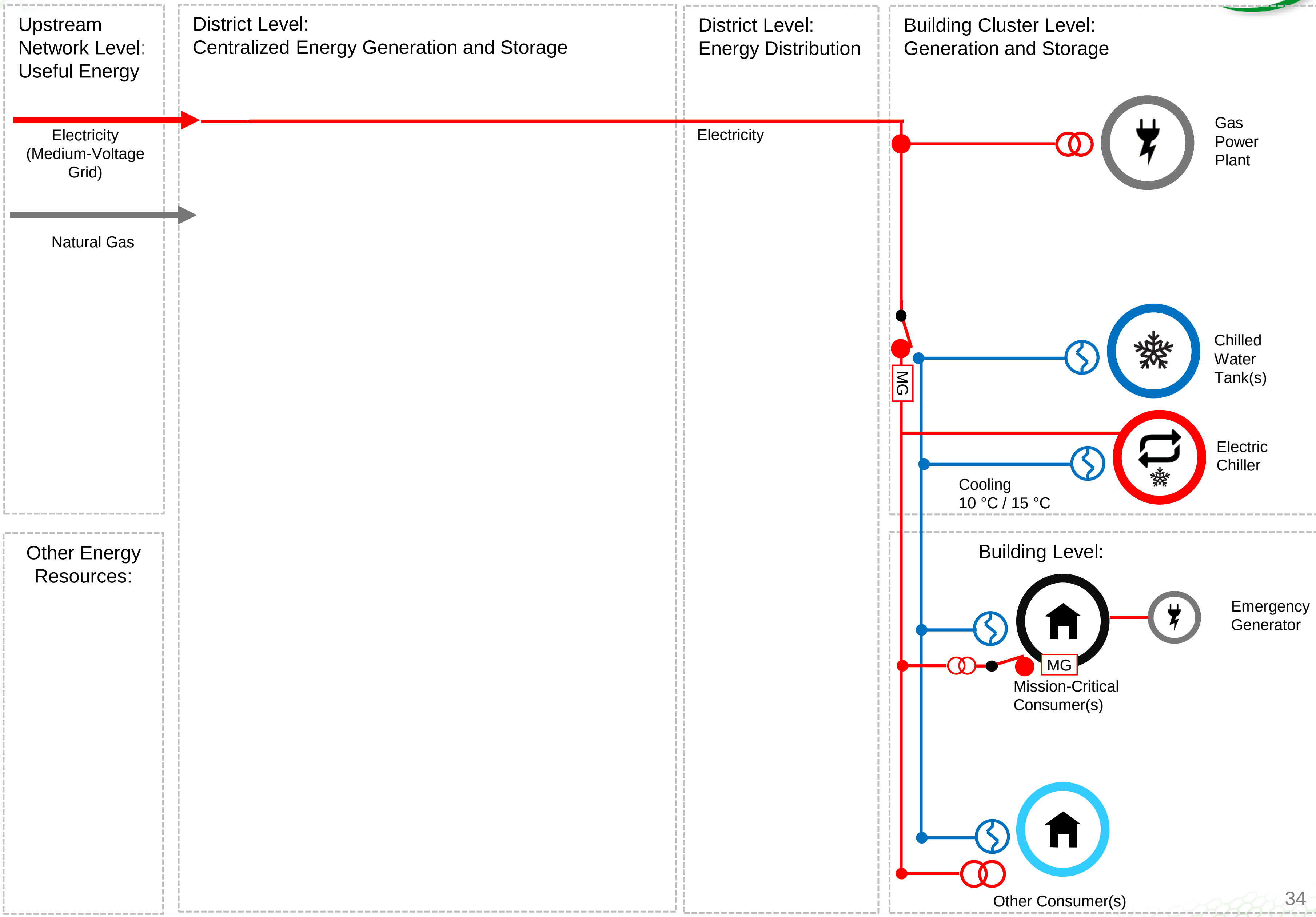
Additional Slides

Energy System Architecture Examples with generation on the cluster level

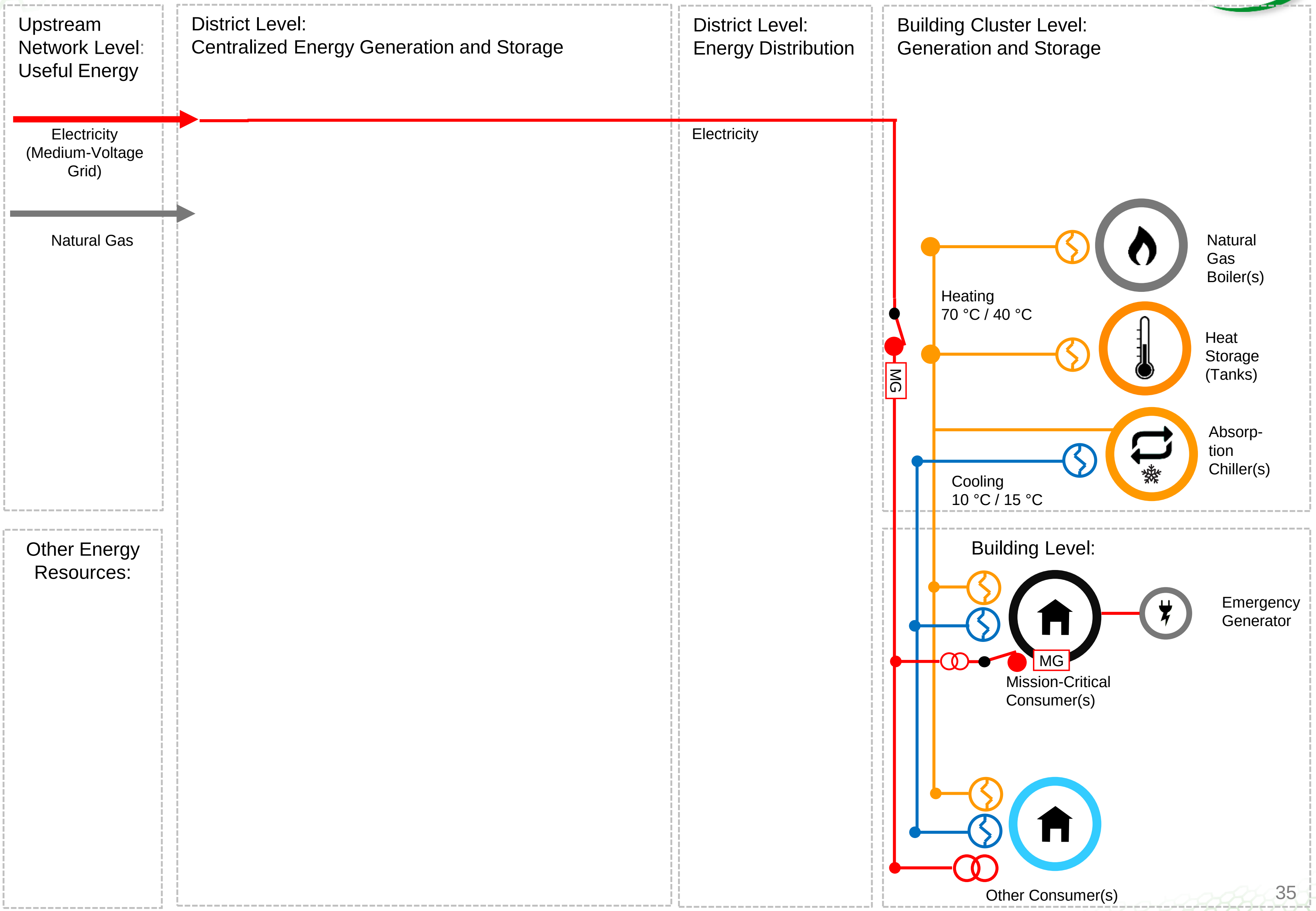
System Design Example



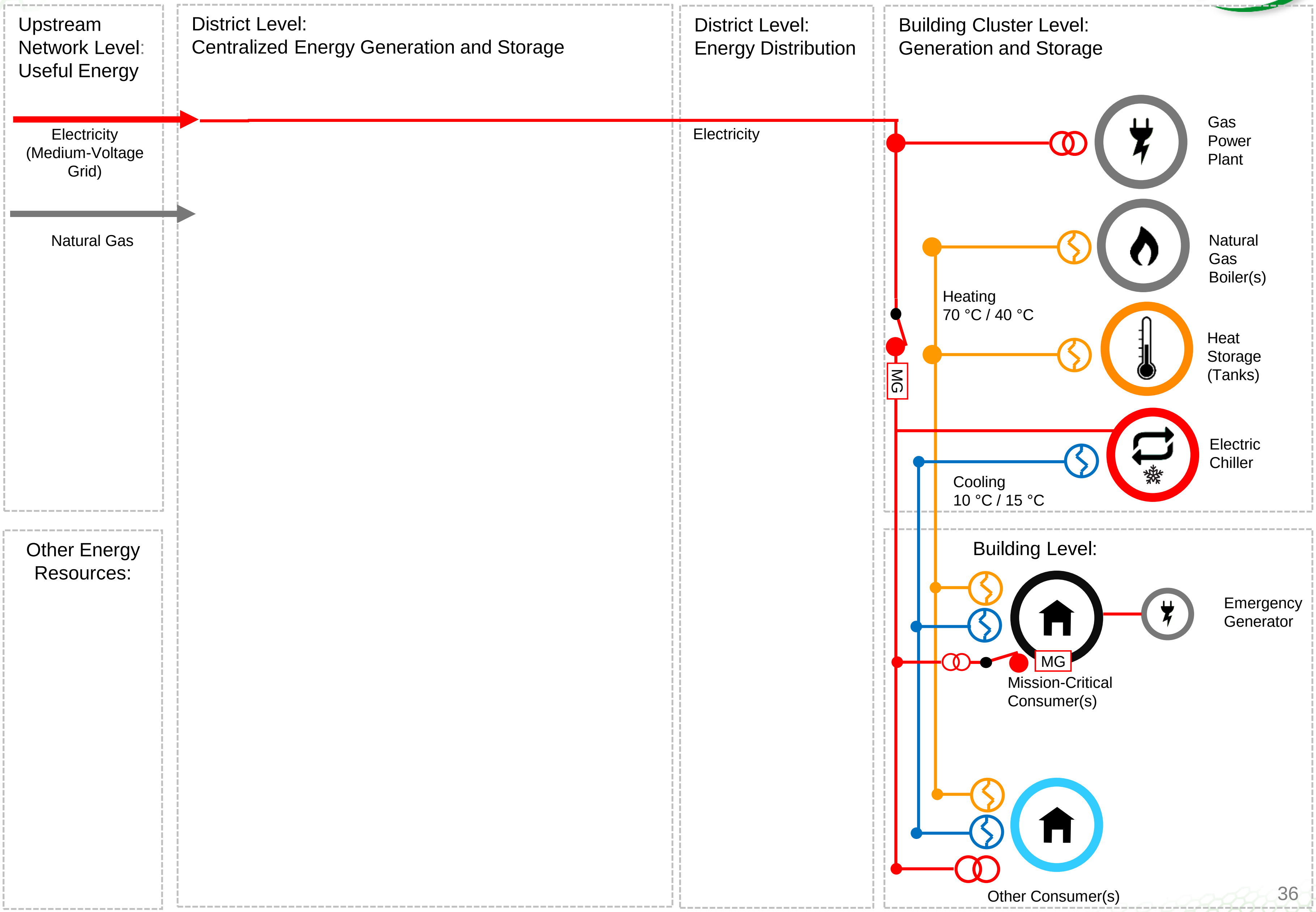
System Design Example



System Design Example



System Design Example



System Design Example