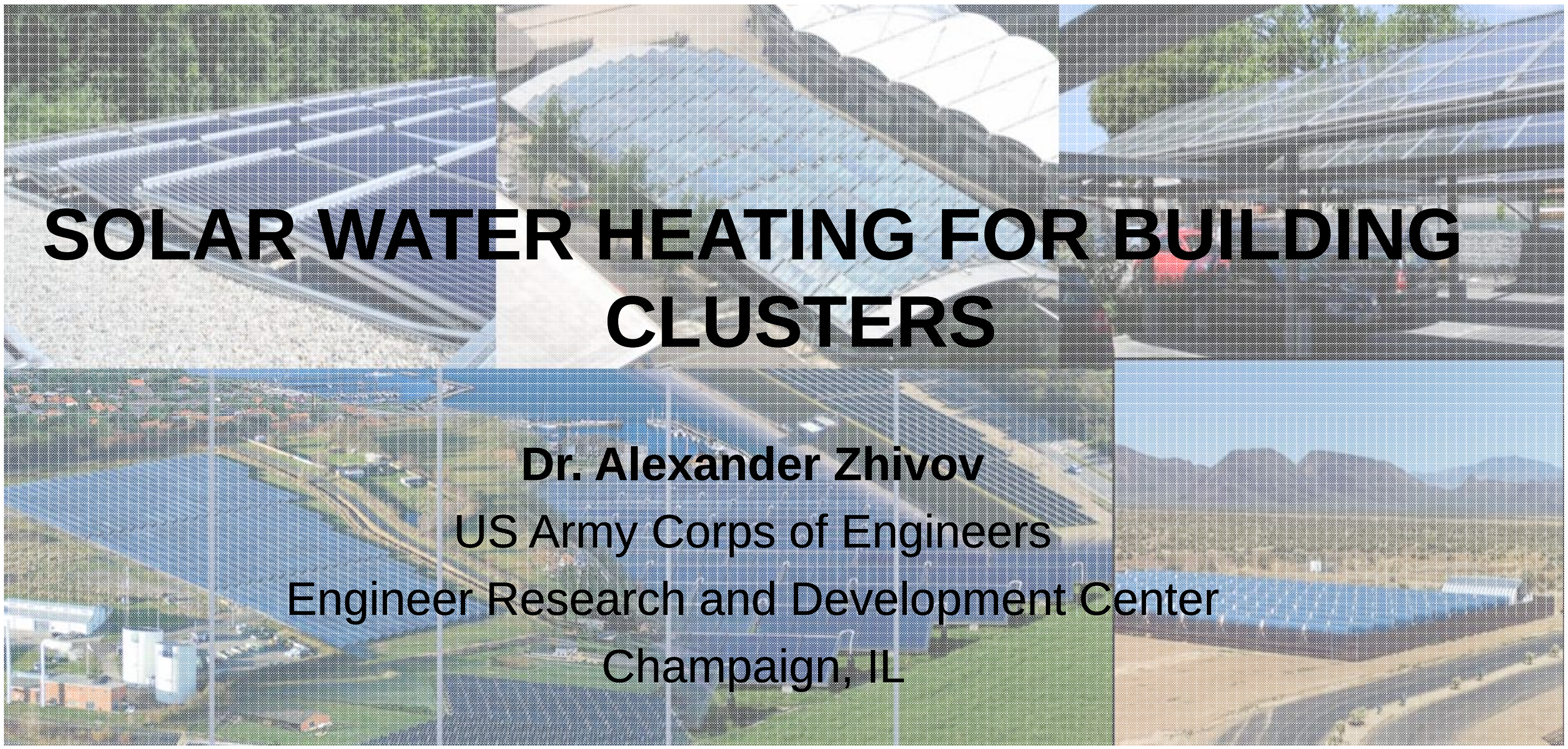
US Army Corps of Engineers

SOLAR WATER HEATING FOR BUILDING CLUSTERS



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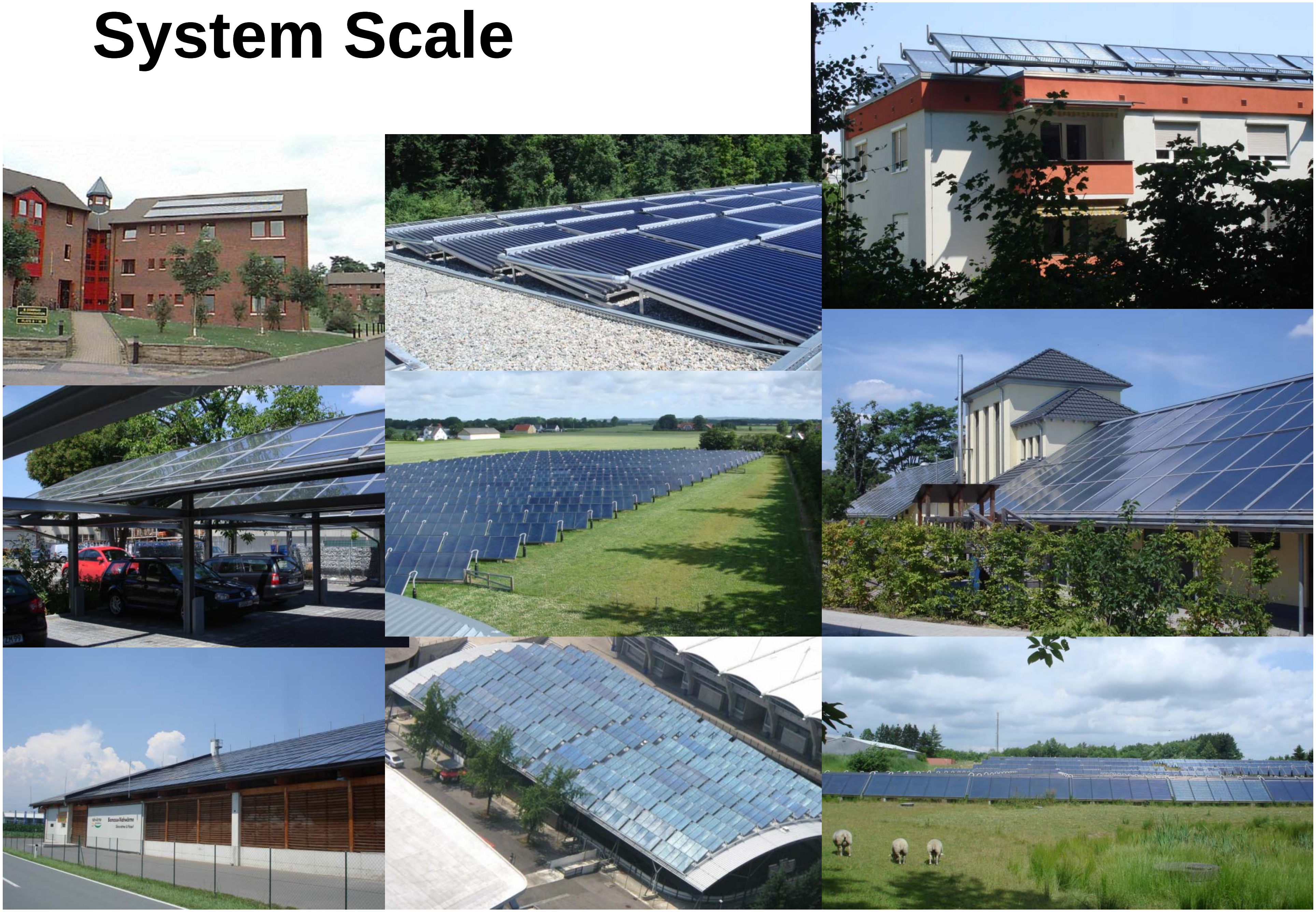
Objective

- Develop design specs and guidelines for solar water heating systems for the Army and other government agencies' building clusters with significant usage of DHW (e.g., barracks, dining facilities, CDC, hospitals, Gyms) operating in combination with central heating systems to meet EISA 2007 SEC. 523 requirement: "if lifecycle cost-effective, as compared to other reasonably available technologies, not less than 30 percent of the hot water demand for each new Federal building or Federal building undergoing a major renovation be met through the installation and use of solar hot water heaters.''
- This guide is not intended for single residential buildings or clusters with the solar filed area less than 2000 ft^2

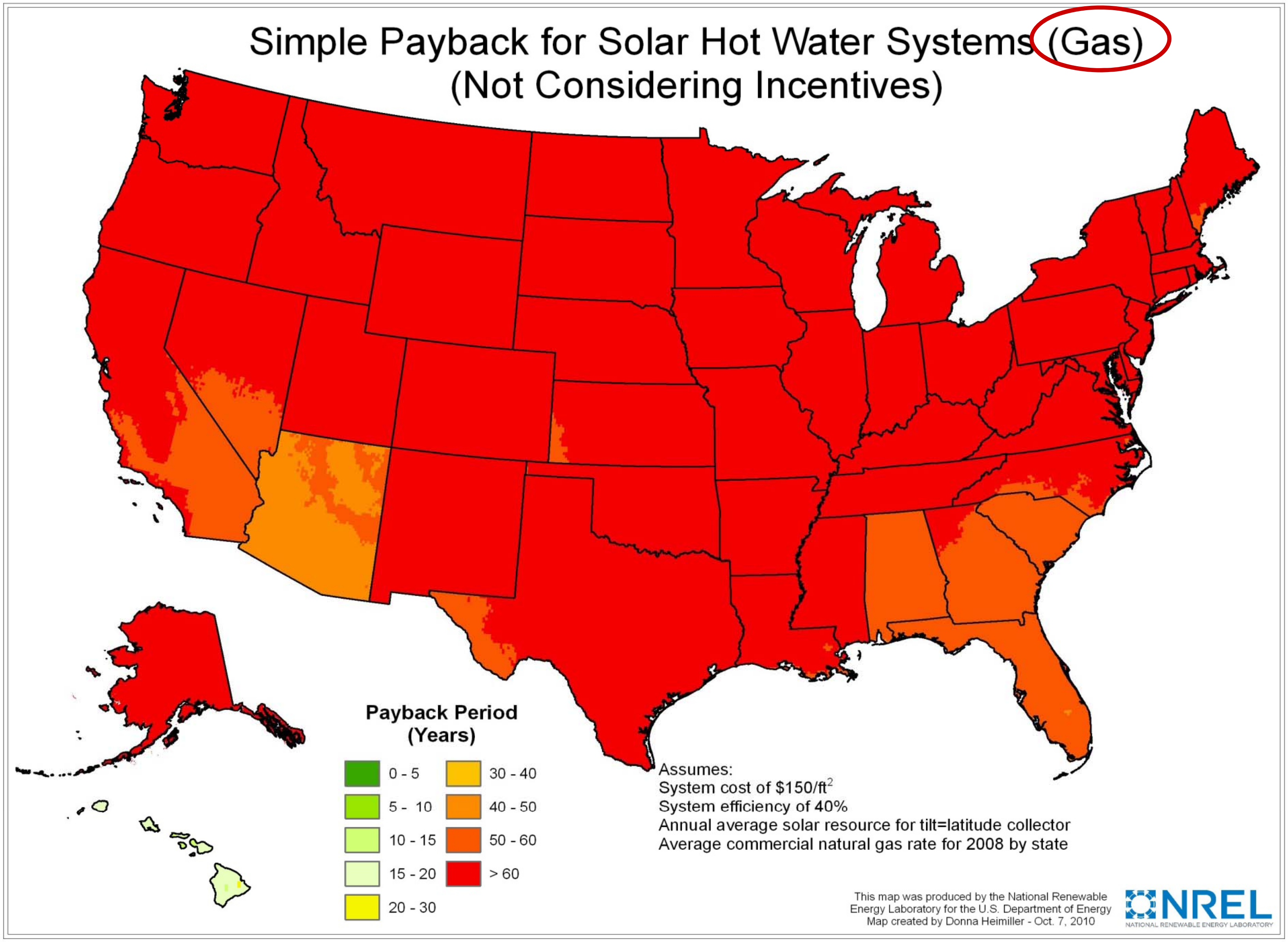
System Scale



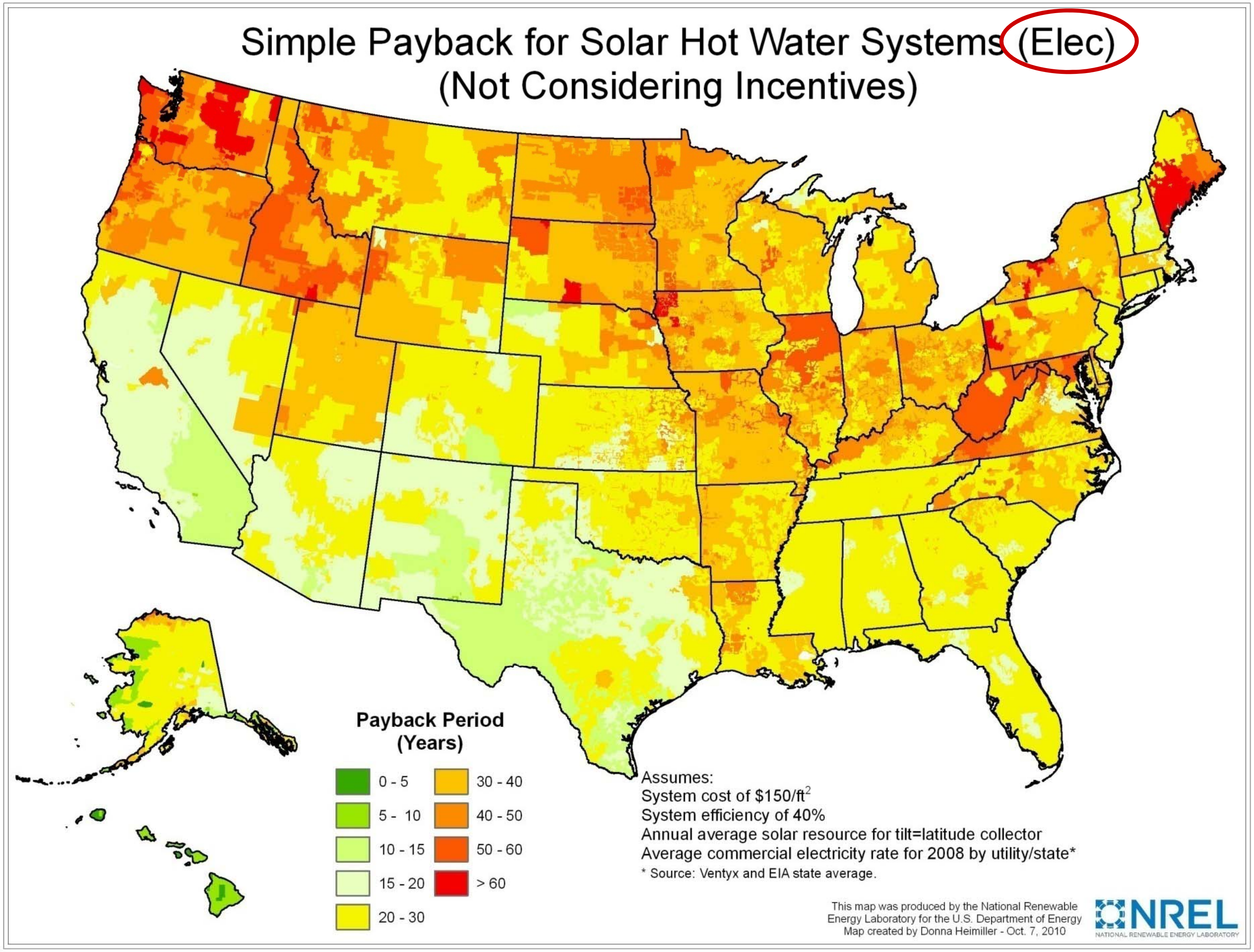
Major Drivers

- Section 523 of EISA 2007 requires that at least 30% of the hot water demand for each new federal building (or major renovations to existing federal buildings) be met through the use of solar hot water heating **(if life-cycle cost-effective).**
- All new construction and major renovation projects with an average daily non-industrial hot water requirements of 50 gal or more, and located in an area receiving an annual average of 4kWh/m^2/day or more will be designed to provide at least 30% of the facility's hot water demand by solar water heating per EISA 2007 (OASA, 2010)

Small (single building) SWH Systems



Small (single building) SWH Systems



Sponsors

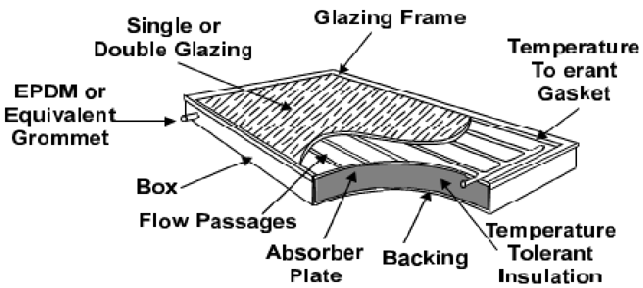
- Installations Management Command, HQ
- US Army Corps of Engineers, HQ
- US Department of Energy, FEMP

Guide Outline

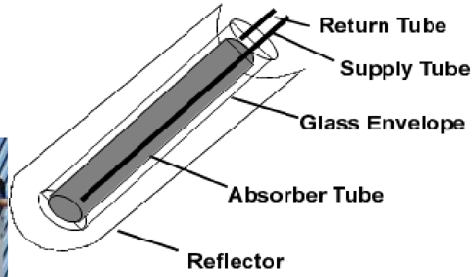
- **Introduction**
- **Solar Energy:** Solar radiation intensity, Cloud cover, Site latitude, Orientation to path of sun, Shading, Collector placement in building cluster
- **Solar Hot Water Collector System**: Collector performance indices, Types of hot water solar systems, Solar collectors, Heat transfer fluid, Piping arrangements, Storage tank, Legionella considerations, Heat exchangers, Pumps, Expansion tank, Back-up/supplemental heater, Controls
- **U.S. Department of Defense (DOD) Installation Solar Hot Water Applications**: Areas of potential Army use; Building hot water demands; Basic solar system design; Cost effectiveness; Case studies;
- **Design Considerations:** Collector site placement; Structural; Mechanical; System start – up considerations
- **Appendix A**: Solar Hot Water Case Studies
- **Appendix B**: Examples of design options (Fort Bliss / Fort Bragg)
- **Appendix C**: Market Price Scenario Europe – Climate related Economic Comparisons of Solar Systems
- **Appendix D**: Sample SRCC Rating Page

Types of Solar Water Collectors discussed in the Guide

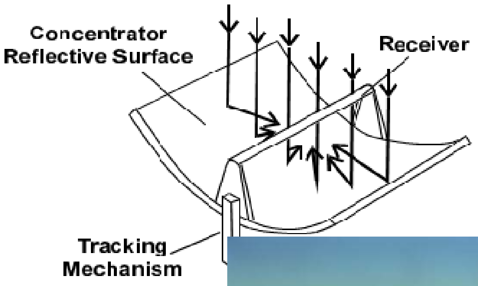
Flat Plate



Evacuated Tubes



Parabolic Trough



European Large Scale Solar Water Heating Systems

- 15 large scale plants for district heating approx. 100.000m^2

Rang	Name	Country	Size	Built by	Year
1	Marstal	Denmark	18.300	ARCON	1996/02
2	Kungälv	Sweden	10.000	ARCON	2000
3	Gram	Denmark	10.000	ARCON	2009
4	Broager	Denmark	10.000	ARCON	2009
5	Brædstrup	Denmark	8.000	ARCON	2007
6	Strandby	Denmark	8.000	ARCON	2008
8	Nykvarn	Sweden	7.500	Scan solar	1984
7	Tørring	Denmark	7.300	SUNMARK	2009
9	Sønderborg	Denmark	6.000	SUNMARK	2008
10	Solar Graz	Austria	5.600	SOLID	2006

History of Solar District Heating

- Started in the mid 80's in Denmark and Sweden
- First demonstration projects with subsidy
- Sweden and especially Denmark have extensive use of district heating
- In Denmark many local networks (500+)

  60 % of all houses are connected to district heating

Location	Year	Size
Nykvern (S)	1984	7.500 m^2
Saltum (DK)	1988	1.000 m^2
Ingelstad (S)	1988	1.000 m^2
Flakenberg (S)	1989	5.500 m^2

Saltum District heating, 1988

Falkenberg, 1989

Demonstration and testing in the 90's

- Still mainly Denmark and Sweden
- Other markets are starting up (Germany)

Location	Year	Size
Nykvern (S)	1990	3.500 m^2
Tibberupvænget (DK)	1990	1.025 m^2
Otterupgaard(DK)	1994	560 m^2
Højslev skole (DK)	1994	375 m^2
Marstal (DK)	1996	8.000 m^2
Wiggenhausen (D)	1996	2.400 m^2
Ærøskøbing(DK)	1998	2.000 m^2
Ry (DK)	1999	3.000 m^2

Marstal Fjernvarme, 1996

Ry Fjernvarme, 1999

Large Scale Systems in the new Century

- Large scale systems
- Market picks up in Denmark
- Still subsidy based demonstration projects
- Developing into a prooven and recognized technology for district heating
- More countries start up demonstration projects

Location	Year	Size
Kungälv (S)	2000	10.000 m^2
Norby Samsø (DK)	2001	2.500 m^2
Necklarsulm (D)	2001	1.100 m^2
Rise (DK)	2001	3.600 m^2
Marstal (DK)	2002	10.000 m^2
Graz (AT)	2002	1.400 m^2
Ulsted (DK)	2006	5.000 m^2
Graz (AT)	2006	5.600 m^2
Calgary (CN)	2007	2.300 m^2
Brædstrup (DK)	2007	8.000 m^2

Standard Solar Thermal Systems Combined with District Heating Technology in Denmark

- District heating – beyond testing
- Solar has become a recognized technology for district heating
- Working on commercial terms without subsidy in Denmark

Location	Year	Size
Hillerød (DK)	2008	3.000 m^2
Strandby (DK)	2008	8.000 m^2
Sønderborg (DK)	2008/9	6.000 m^2
Tørring (DK)	2009	7.500 m^2
Gram (DK)	2009	10.000m^2
Broager (DK)	2009	10.000m^2
Andritz (AT)	2009	3.800 m^2
Ærøskøbing (DK)	2009	2.200 m^2

Strandby, 2008

Hillerød, 2008

2010 - Record Year for Large Scale Solar

- Denmark is booming
- Systems are becoming larger
- Other markets are coming
- Industry is maturing
- New storage technologies are being tested to increase solar fraction
- Next step is Solar fraction of 40% to 50%

Location	Size
Dronninglund (DK)	35.000 m^2
Marstal (DK)	18.000 m^2
Ringkøbing (DK)	15.000 m^2
Jægerspris (DK)	10.000 m^2
Oksbøl (DK)	10.000 m^2
Brædstrup (DK)	8.000 m^2
Almera (NL)	7.000 m^2
Tistrup (DK)	5.500 m^2
Hejnsvig (DK)	3.000 m^2

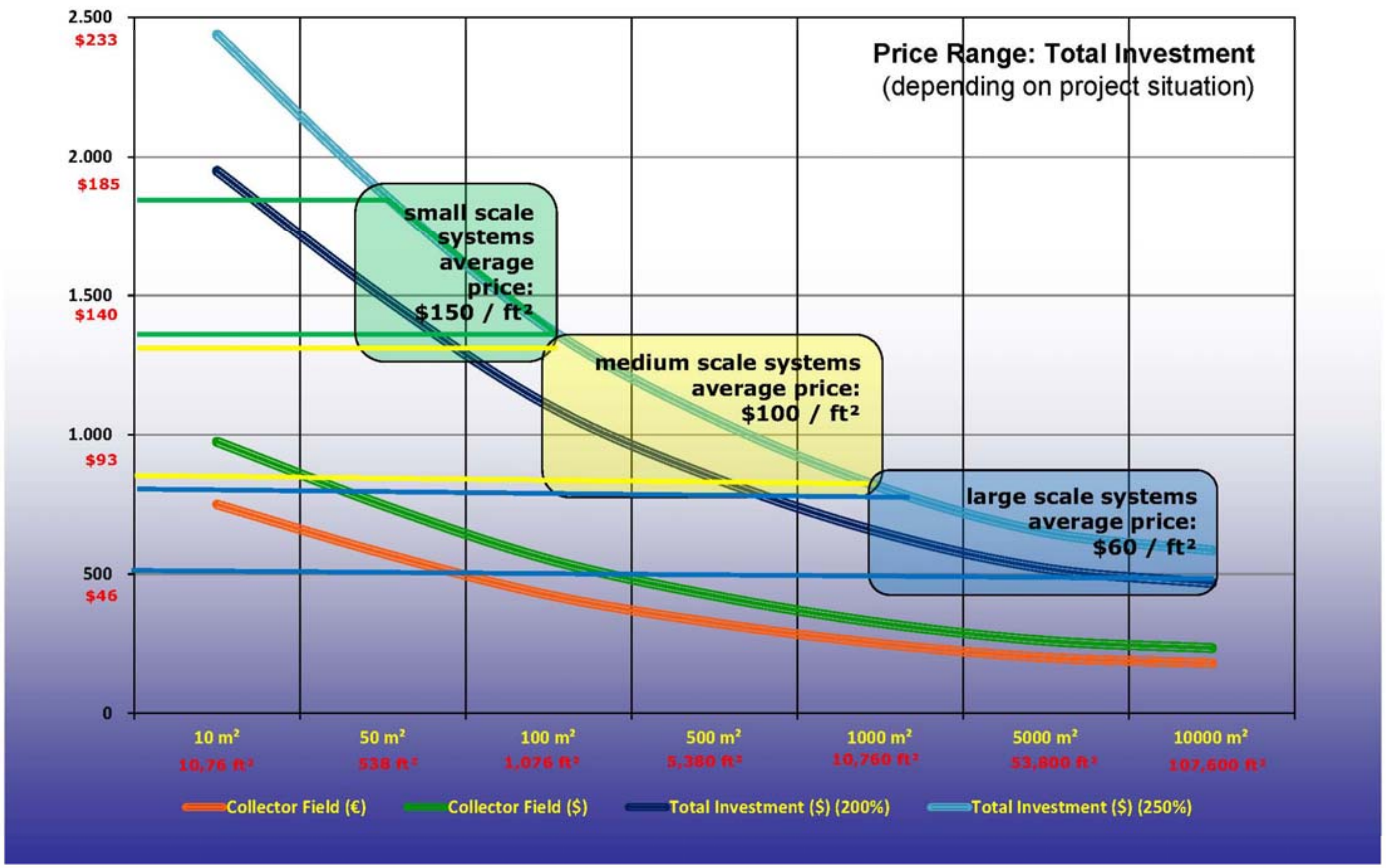
Why to combine SHW with district heating ?

- Most cost effective application of Solar Thermal Energy
- Investment of 25% to 50% of one family house systems
- High annually yield possible (> 500 kWh/m^2 annually)
- Low fixed energy costs (down to approx. 25 EUR/MWh)
- Proven technology (+20 years in operation)
- Easy to implement
- Easy to operate
- Minimal maintenance
- Solution which can bring large CO_2 reduction

Key Factors of a Successful System

- Experienced advisor/planner or Turn-key supplier
- Experienced suppliers
- High performance collectors designed for large scale systems
- Low return temperature in district heating grid (30^{o}C to 40^{o}C is normal)
- Optimized control system

System cost Vs. System Size



Energy price based on 3% interest rate and 500 kWh/m^2 annually
All prices are excluding subsidy / grants

Case Studies

Location	Type Collector	Size, SF	Storage Vol. gal	Cost	Solar Energy Collected, MBtu/yr/SF	System Temp., out/in °F
Gneis Moos, Salzburg, Austria	Flat Plate	4,412	26,420	$218,530	119.9	149/86-95
Wasserwerk Andritz, Austria	Flat Plate	41,481	17,067	$1,950,000	131.6	167-248/140
UPC arena Graz-Liebenau, Austria	Flat Plate	15,139	-	$223,860	114.2	167-248/140
Wels, Austria	Evac Tube	39,629	No	$3,000,000	146.4	194-239/167-221
Ulsted, Denmark	Flat Plate	53,929	-	$1,700,000	377.1	167-248/140
Strandby, Denmark	Flat Plate	86,769	396,423	$2,900,000	314.0	194-185/68-50
Frederikshavn, Denmark	Flat Plate	1,614	1,320	$50,000	149.1	140/60
Skørping, Denmark	Flat Plate	5,918	396,423	$190,000	124.7	149/77
Braedstrup, Demark	Flat Plate	86,769	528,564	$2,500,000	125.9	158-194/95-101
Frankfurt/Main, Germany	Flat Plate	2,712	2,775	182,838€	83.1	DHW
Old Slaughterhouse Speyer, Germany	Flat Plate	5,864	26,428	357,020€	59.4	153/90-99
Residential area Speyer, Germany	Flat Plate	3,077	6,607	189,200€	92.9	160-180/126-140
Residential area Nordemey, Germany	Flat Plate	2,098	2,640	208,851€	97.9	149-176/132-135
Residential area Hennigsdorf, Germany	Flat Plate	9,218	10,570	549,570€	129.1	149-203/97-106
Residential area Heilbronn, Germany	Flat Plate	4,049	11,100	234,561€	100.3	155-161/113-123
Apt. Bldgs. Hannover, Germany	Flat Plate	1,333	1,586	99,410€	99.8	162-175/117-135
Residential area Stuttgart, Germany	Flat Plate	16,613	23,780	797,788€	96.7	171/122

Case Studies (Continued)

Location	Type Collector	Size, SF	Storage Vol. gal	Cost	Solar Energy Collected, MBtu/yr/SF	System Temp., out/in °F
Trade Park, Housing Estate Ritter, Karlsbad, Germany	Evac Tube	667	1,585	$52,500	168.8	140-194/77-140
Festo, Esslingen, Germany	Evac Tube	14,310	4,491	$825,000	124	176-203/167-185
Alta Leipziger, Oberunsel, Germany	Evac Tube	1,268	1,849	$135,000	145.3	149-194/95-158
Panoramasauna, Holzweiler, Germany	Evac Tube	1,057	No	$84,000	193.4	158-194/149-176
Wohnheim Langendamm, Nienburg, Germany	Evac Tube	505	1,321	$38,000	162.2	140-194/95-158
Kraftwerk, Halle, Germany	Evac Tube	241,024	9,511,200	$12,900,000	124.6	176-203/131-149
AWO Rastede, Oldenburg, Germany	Evac Tube	1,054	No	$112,500	174.4	167-185/140-158
METRO Istanbul, Turkey	Evac Tube	11,063	3,963	$760,000	200.1	176-203/167-185
Cooney Island, NY	Evac Tube	1,761	3,963	No	203.4	140-194/77-140
Edison, NJ	Evac Tube	150	280	$26,000	121.7	150/60
Philadelphia, PA	Evac Tube	576	No	$58,000	248.3	140/60
Phoenix, AZ	Parabolic	17,040	23,000	$650,000	3964	140/60
Modesto, CA	Parabolic	57,969	No	-	14600	460/420

Examples of ARCON Large Scale Systems

Ulsted, Denmark

- District heating plant
- Wood Chip district heating
- Total Investment of approx. $2 M

System components
Piping

System components
Collector foundation

System components
Collector mounting

System components
Pump unit

CASE STUDY: Brædstrup District Heating

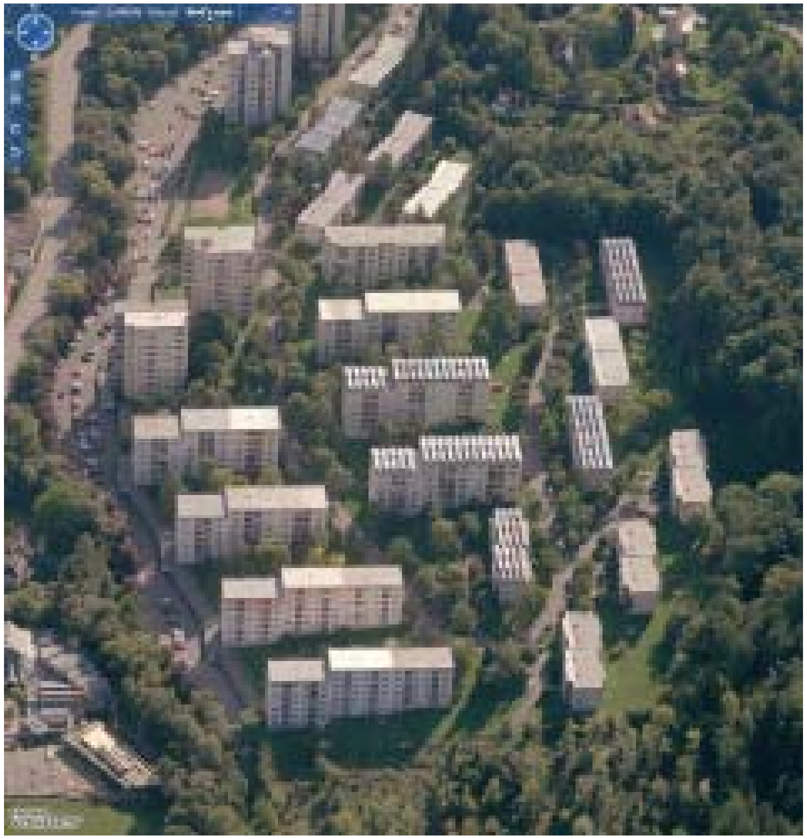
- District heating system of the Town of Brædstrup, Denmark
- Approx. 1.400 households
- Approx. 3.000 inhabitants
- Annual heat demand of 41.000 MWh
- Natural gas district heating
- Combination of CHP and gas boilers
- Installed 8.000 m2 (6 MW_{th} peak) solar plant in 2007
- To cover 8% of annual demand

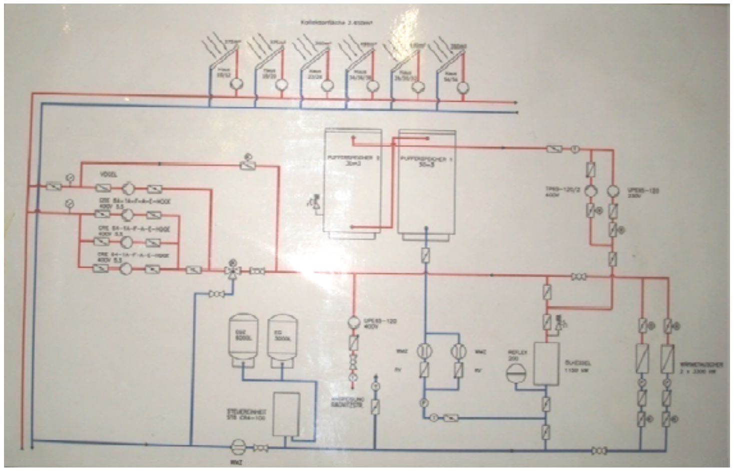
Location
Latitude: 55 57.58 N
Longitude : 9.36.26 E
Corresponds to Northern Canada

Lessons Learned from Austria

- Electricity and maintenance costs are low
  - 2kWh electricity per MWh heat
  - 1.000 USD in annual maintenance
- Simulation of performance very close to actual production
- Solar works well in combination with CHP and high temperature storage
- Optimal control system is important to get the best performance of the systems (ability to utilize low temperatures)
- Turn-key suppliers support smooth implementation
- You need to be in control of the project management yourself (not leave everything to the advisors and suppliers)

SOLID (Austria) District Heating, Graz, (Berliner Ring)





27 Buildings/750 apartments. Solar Panels are installed on 6 roofs, 2500 m^2/26876 ft^2

SOLID (Austria) - District Heating Gleinstartten (biomass + SWH)

District heating system + using heat to dry wood chips. Solar water heating covers most of the summer load on the district heating grid. Solar panels 1300 m^2/13875 ft^2 , 90m^3 buffer tank

SOLID (Austria) - Gatorade (Pepsi Cola) Project, Phoenix , AZ, (2008)

Solar Water heating for Industrial processes. One the biggest solar process heat system in North America - 893 m^2/9600 ft^2

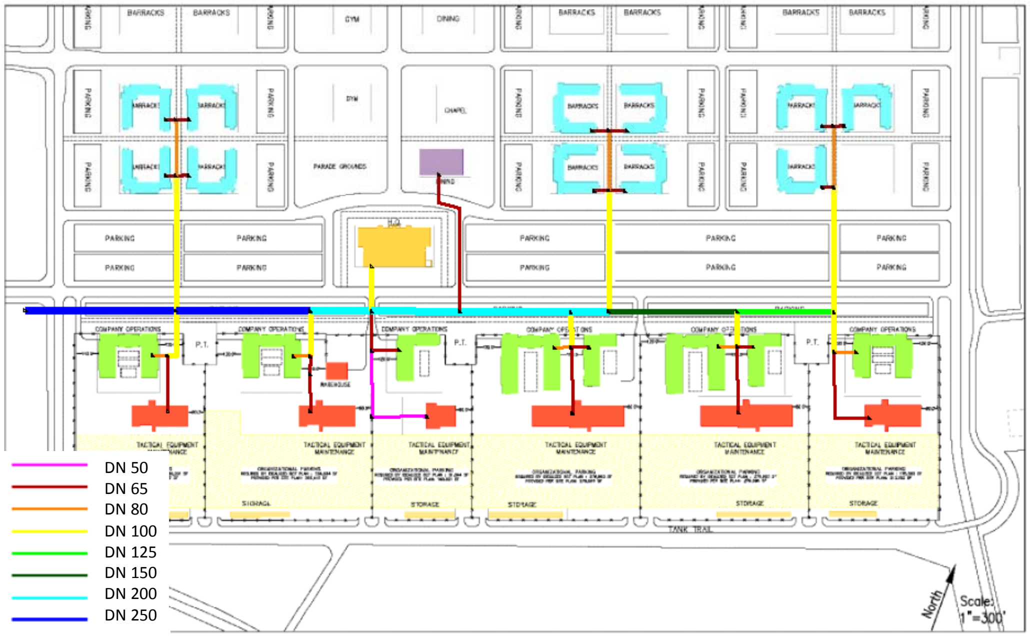
District Energy St Paul, MN

TKDA
ENGINEERING • ARCHITECTURE • PLANNING
The right time. The right people. The right company.

Completion:
March 2011
Project Cost:
$2,000,000

Solar Water Heating system with 144 collectors 20 ft by 8 ft) having 1MW peak capacity are producing hot water for space heating and domestic hot water usage primarily for the St Paul River Centre and sending excess energy to the District Energy heating network. District Energy heats more than 185 buildings and 300 single -family homes (31.1 M ft2) and cools more than 95 buildings (18.8 M ft2) in downtown Saint Paul, MN and adjacent areas. Heating network is connected to a CHP plant fueled by wood chips producing 25 MW of electricity and 65 MW of thermal energy.

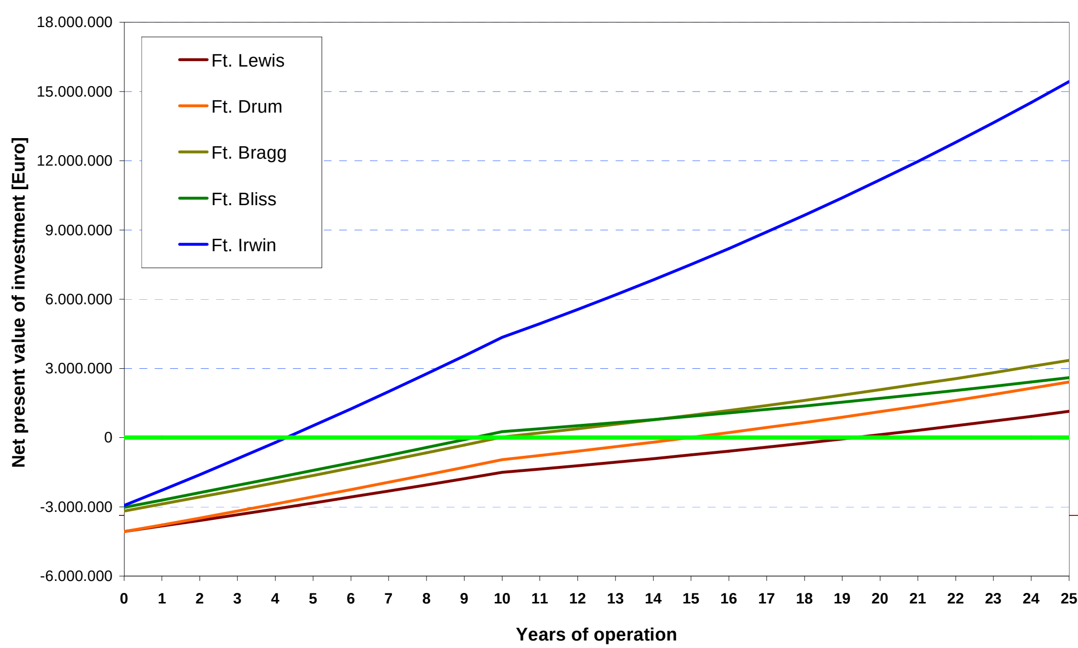
CEP Concept for Brigade Combat Team (BCT), Ft. Bliss



11 Barracks
1 Dining Facility
1 Brigade Headquarter Building
8 Company Operation Facilities
7 Tactical Equipment Maintenance Facilities

- CEP results in first cost reduction for heating equipment , but also has a first cost increase for cooling equipment
- Annual heating and cooling costs with a CEP are lower
- Central heating plant solution includes co-generation for the base heating load, which results in generation of 4.3 MWh_{el}/a in electricity.
- Higher efficiency of cooling equipment results in electricity use reduction. The total annual electricity savings are 5.7MWh_{el}/yr.
- CEP will reduce 19.3 MWh_t (65.9MBtu) of fossil fuel, or 67 Btu/ft2 for the total BCT4 buildings complex area.
- Central heating and cooling solution has lower O&M costs and will become even more attractive with the energy cost increase and provides a cost effective application of solar water heating when integrated into a central heating/DHW concept.

SWH Collector Field Arrangement Options



NPV of investment considering a discount rate of 0 %

Ft Irwin

Ft Bliss

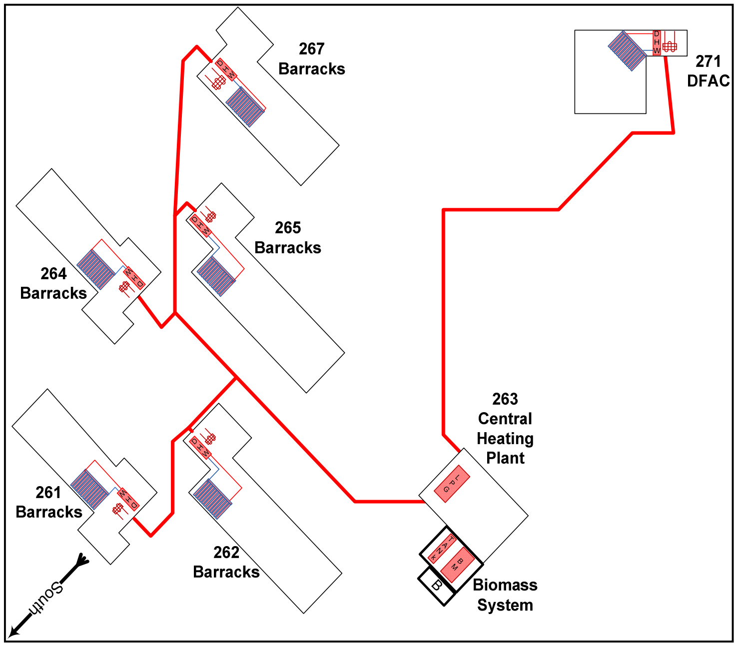
Ft Bragg

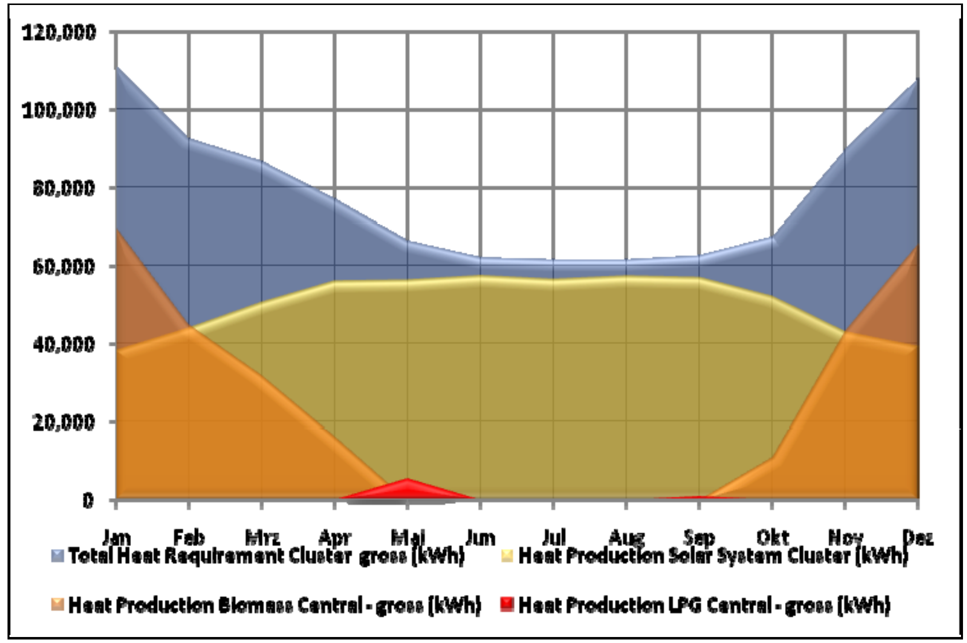
Ft Drum

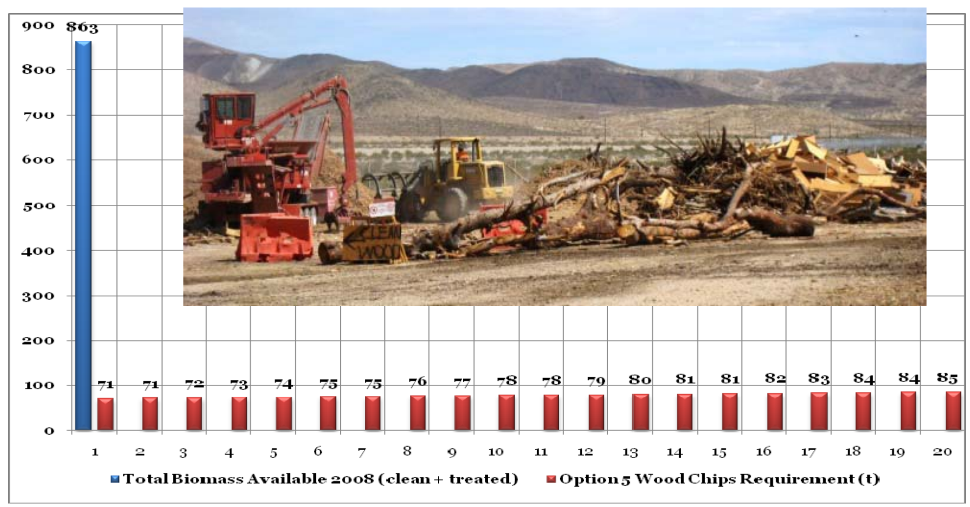
Ft Lewis

Cluster of Building at Ft. Irwin – Analysis Results

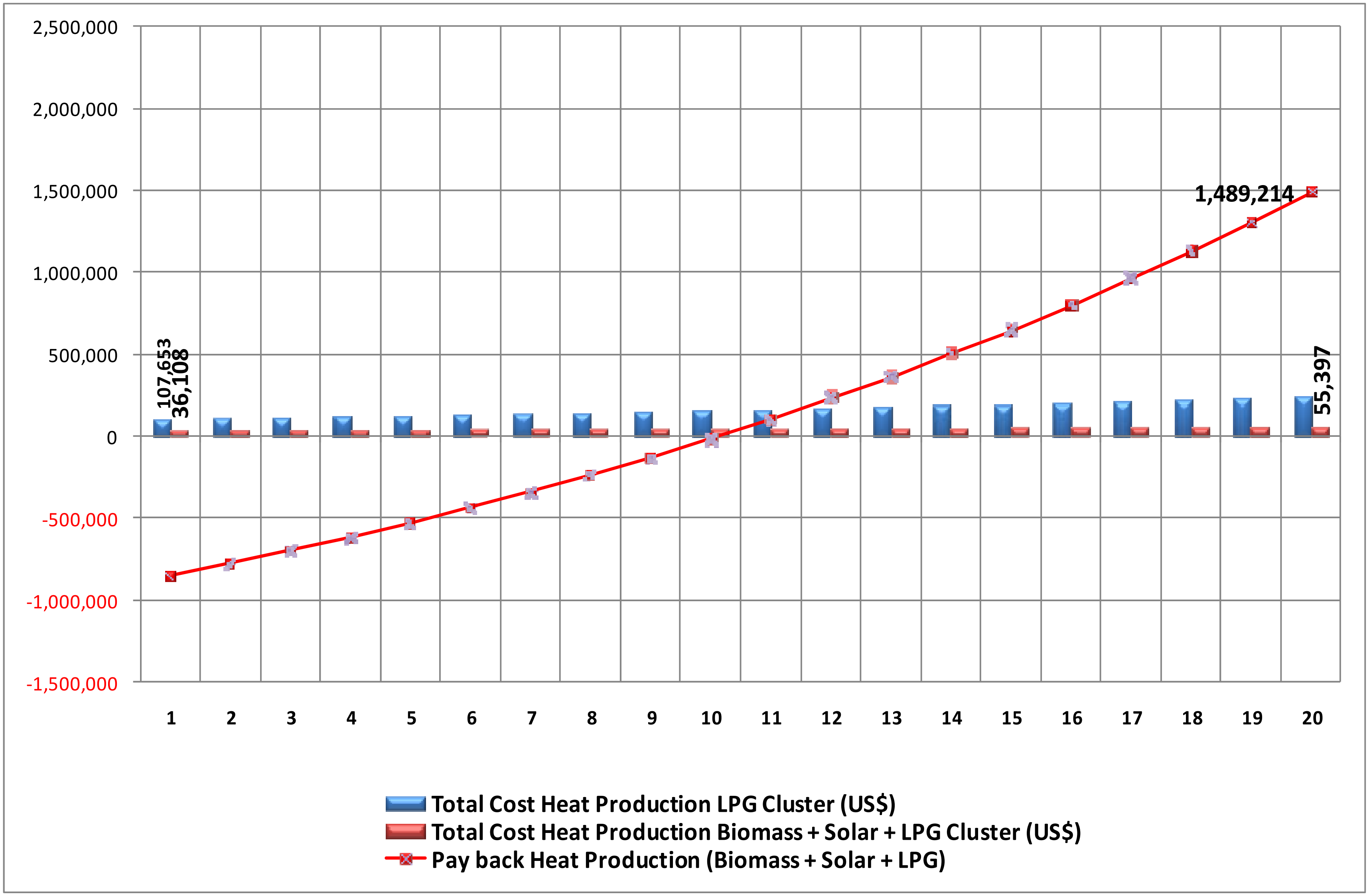
Bldg Upgrade with Radiant cooling, DOAS & EC (Dir & Indir) LPG vs. Bldg Upgrade with Radiant cooling, DOAS & EC (Dir & Indir) Biomass + Solar Thermal Systems + LPG



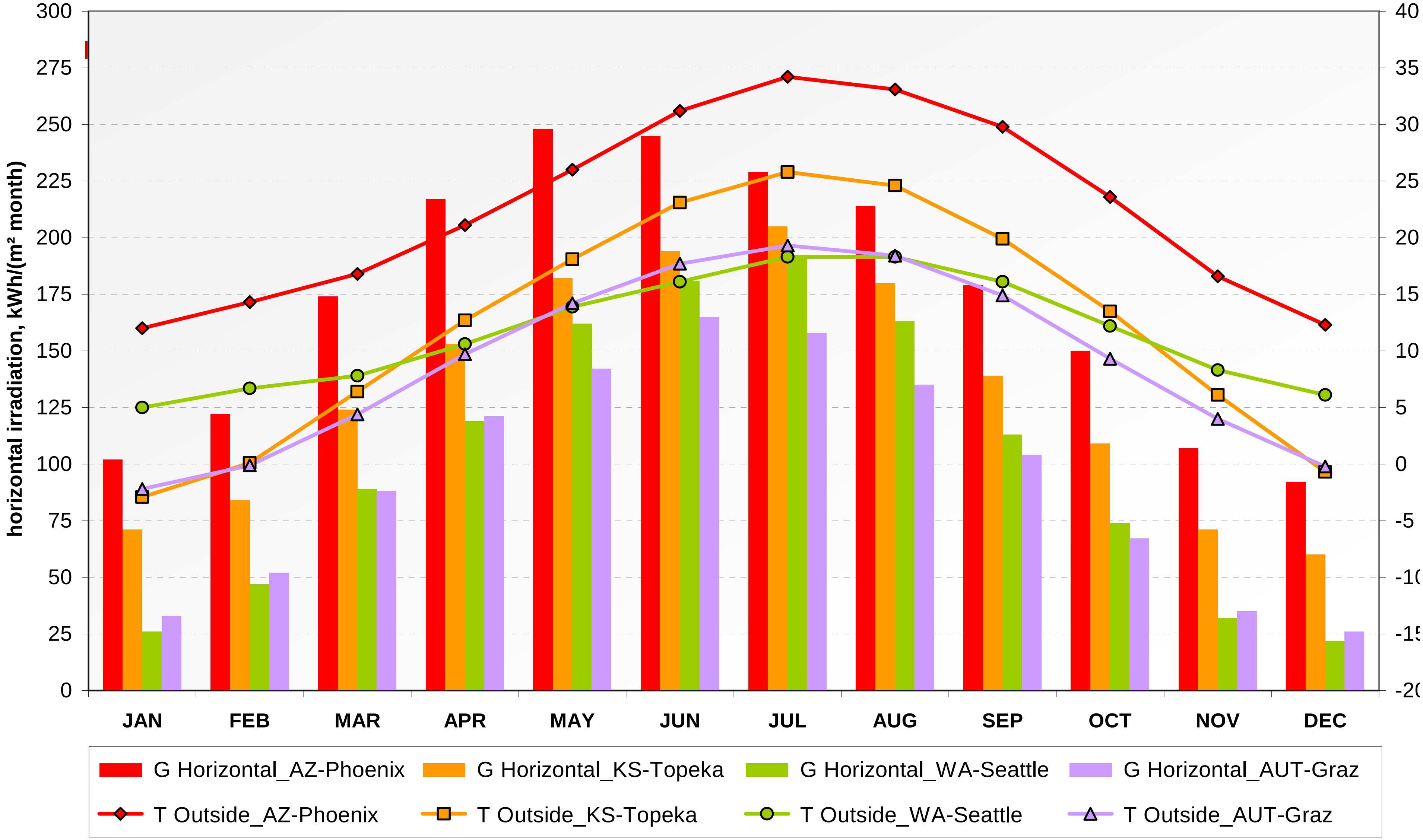




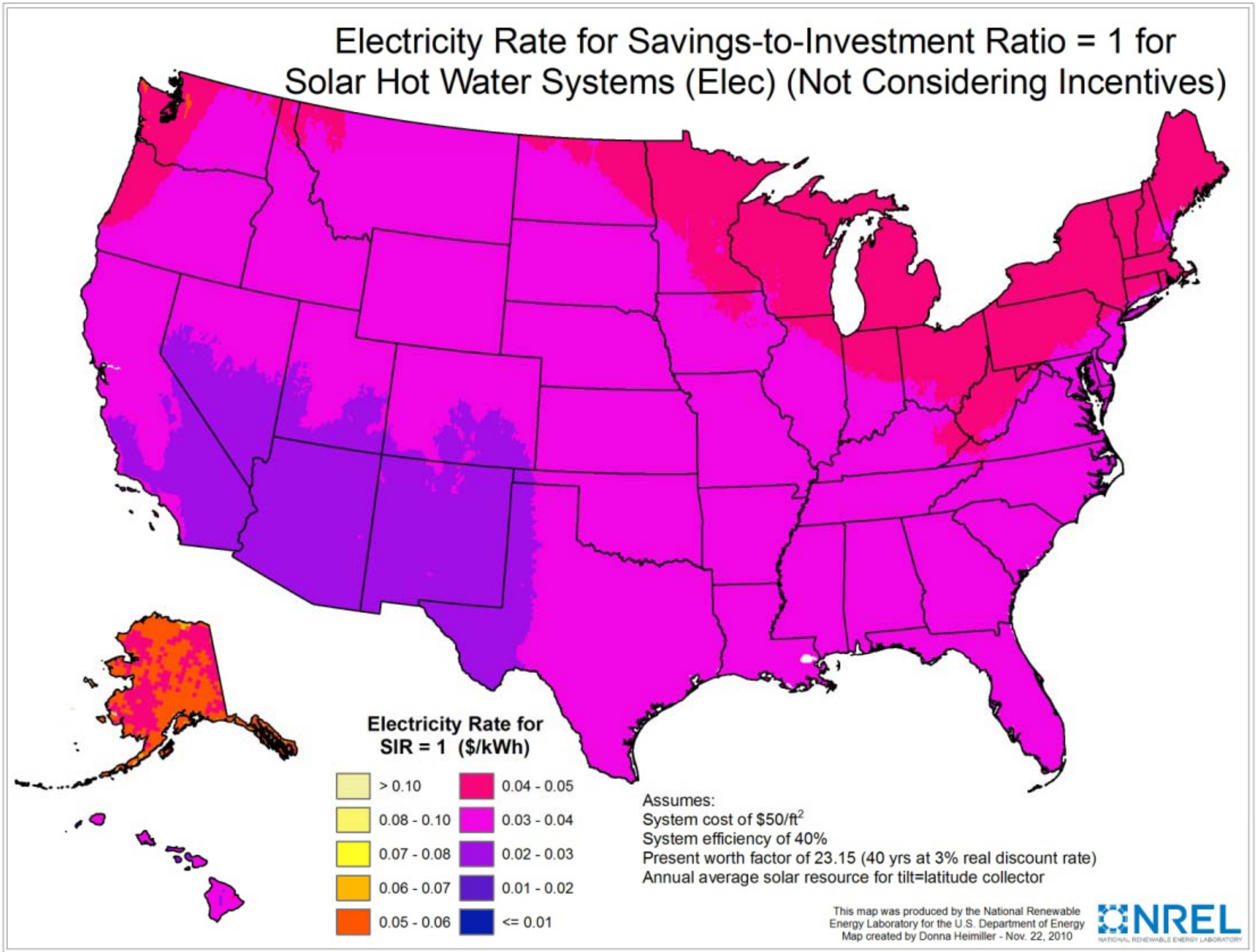
Bldg Upgrade with Radiant cooling, DOAS & EC (Dir & Indir) LPG vs. Bldg Upgrade with Radiant cooling, DOAS & EC (Dir & Indir) Biomass + Solar Thermal Systems + LPG



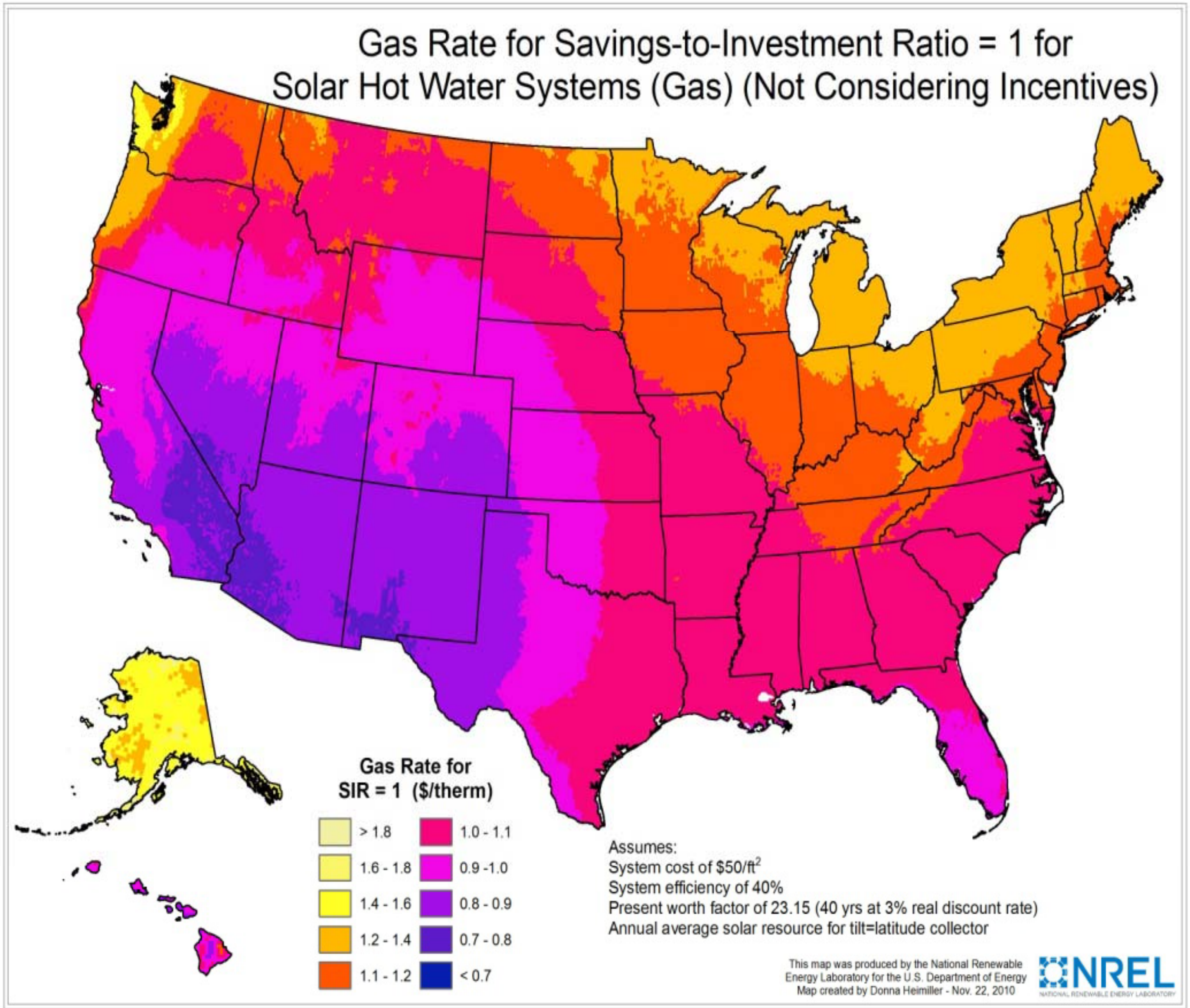
Monthly climate data for different locations in the United States and in Graz, Austria



COST EFFECTIVENESS OF SOLAR HOT WATER SYSTEMS PRICED AT $50/FT² REPLACING ELECTRICAL HEATING USE



COST EFFECTIVENESS OF SOLAR HOT WATER SYSTEMS PRICED AT $50/FT^2 REPLACING GAS-FIRED HEATING USE



Questions?