Energy Master Planning: Goals, Energy Targets, and Design Constraints

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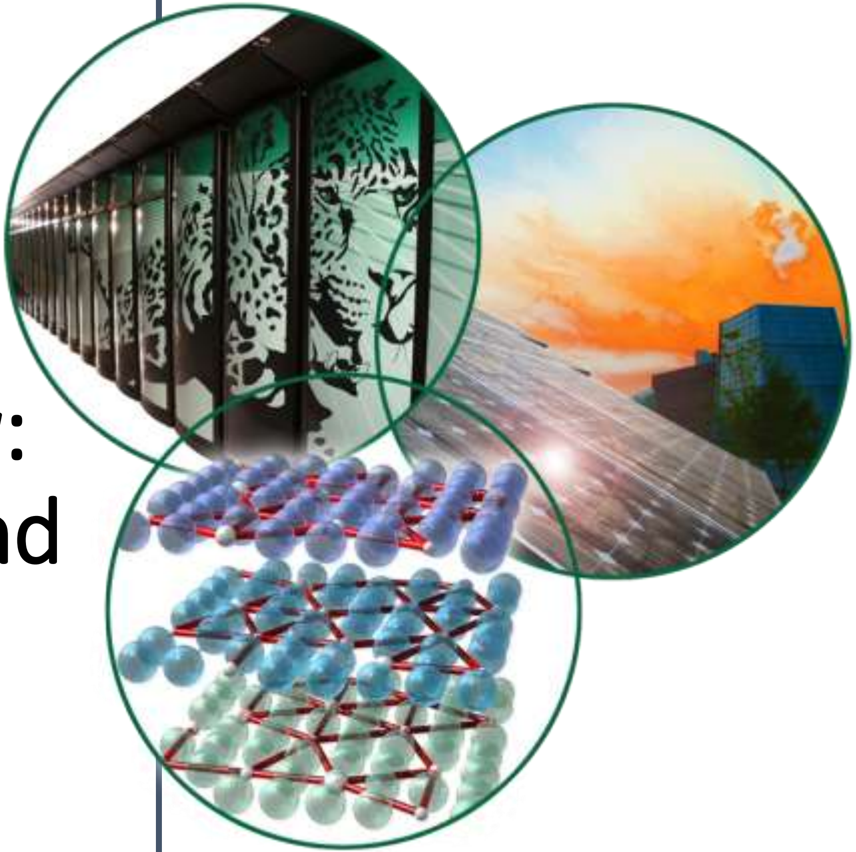

U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
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Learning Objectives

- Understand the importance of establishing terminology in setting goals and requirements
- Increase your knowledge about building energy use targets
- Understand how design requirements and constraints can be applied for systematic energy master planning (EMP)

1. Goals, Targets, and Requirements

Importance of Goals, Targets, and Requirements

- Support transformation of the market (building stock)
- Reduce costs or environmental impacts
- Enable baselines, benchmarking, or performance ratings
- Empower building owners/managers by helping them:
  - Identify the best opportunities (low performers)
  - Establish expectations (for building, campus, for audit team, …)
  - Track performance

Consistent EMP Terminology Is Important

- Goals, Objectives, and Targets - may be desired/optional
- Requirements & constraints - must be met

EXAMPLES:

State Building Code* – meet ANSI/ASHRAE/IESNA Standard 90.1 (requirement)

EU-EPBD** - New buildings nearly zero-energy by 2020 (Dir. 2018/884/EU) (goal)

U.S. 10CFR433 - Federal facilities designed to meet ASHRAE 90.1-2013 (regulation)

Campus be 100% renewable energy (target)

* State of Florida
**European Union – Energy Performance of Buildings Directive

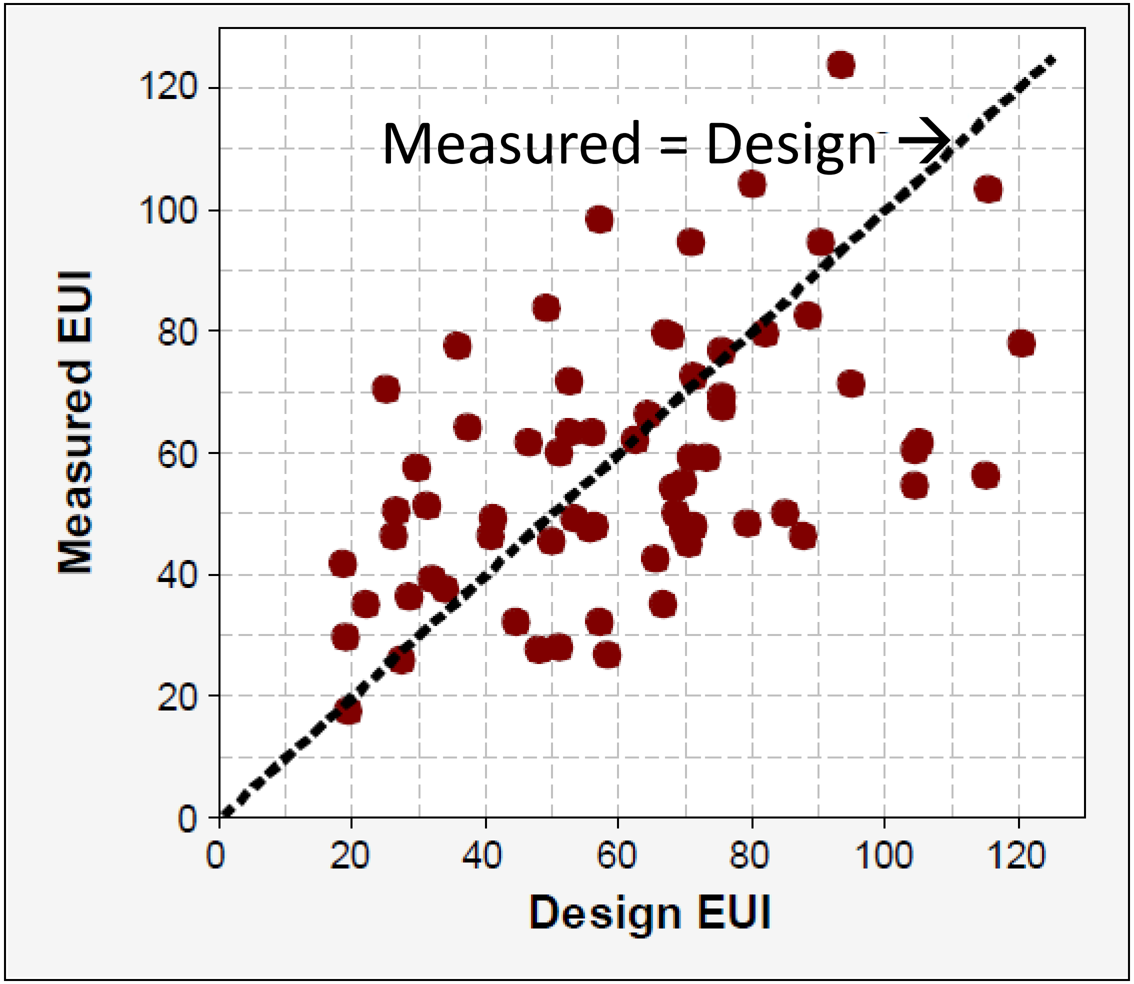
Example: Communicating Project Objectives

Identify and Classify Project Objectives -
This Step Clearly Identifies Your Overarching Design Boundaries

	Classification of Objective			
Energy Master Planning Objective	**Goal (Y/N)**	**Requirement (Y/N)**	**Value**	**Value (units)**
Environmental impact (% reduction in GHG)				%
Reduce source energy use (% reduction)				%
Reduce site energy use (% reduction)				%
Renewable energy generation (% of electricity use)				%
Backup/redundant systems for electric generation				
Grid-independent capability- mission critical				
System availability for mission-critical (uptime)				%
Water use limit				kgal/day
Particulate emissions limit				ppm
Maximum project cost				$k
Return on investment (ROI)				%
Ease of maintenance (simple, low cost, serviceable)				

2. Energy Use Targets

Underperformance Of New Buildings Is Driving The Move To Energy Use Targets



Example Building Energy Use Targets That Exist

Table A.1. Building Energy Use Maximums and Targets by Country[1]

Country:	United States	Australia	Austria	Denmark	Finland	Norway
Basis year:	2012	2019	2015	2018	2017	2017
Climate Zone	5A, 6A, 7		5A & 6A	5A	6A & 7	6A & 7
	Building Maximum Energy Use (kWh/m2 per year)[1]					
General Building Type	**Total primary energy use[3]**	**Heating and cooling energy use**	**Heating energy use**	**Total primary energy use**	**Total primary energy use**	**Total net energy use**
Office[2]	287-343	NA	47.6	41	100	115
School	251-429	NA	47.6	41	100	110
Apartment[2] (5+ units)	313-406	10.8-113	54.4	30	90/105	95
Dormitory	389-505	NA	54.4	30		
Hotel	342-384	NA	47.6	30	160	170

[1] The sources of maximum and target values for each country are:

Australia - National Construction Code based on minimum required NatHERS rating; 39-406 MJ/m2 per year.

Austria: Guidelines of the Austrian Institute of Building Technology 2015. Page 4, table in Section 4.2.2.

Denmark: Energy Requirements of BR18 (Danish Building Regulations 2018), calculated using Figure 4, Page 6.

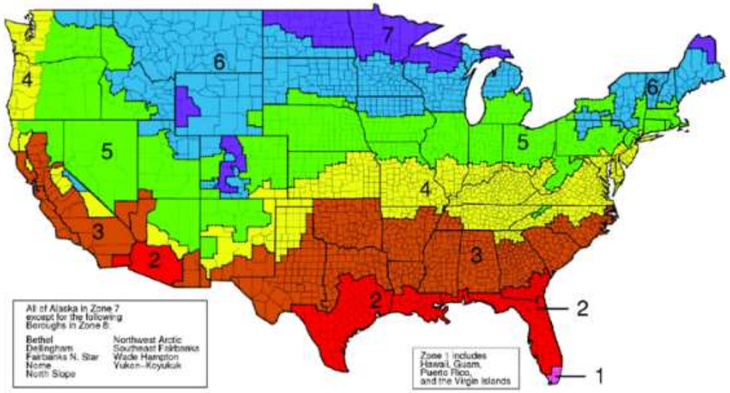
Finland: National Building Code of Finland, 1010/2017 Decree of the Ministry of the Environment on the Energy Performance of New Buildings, P. 3.

Norway: Regulations on technical requirements for construction works (Building Technical Regulations - TEK17), July 2017. Page 47.

U.S.: ASHRAE Standard 100 "Energy Efficiency in Existing Buildings", derived based on Table 7-2a.

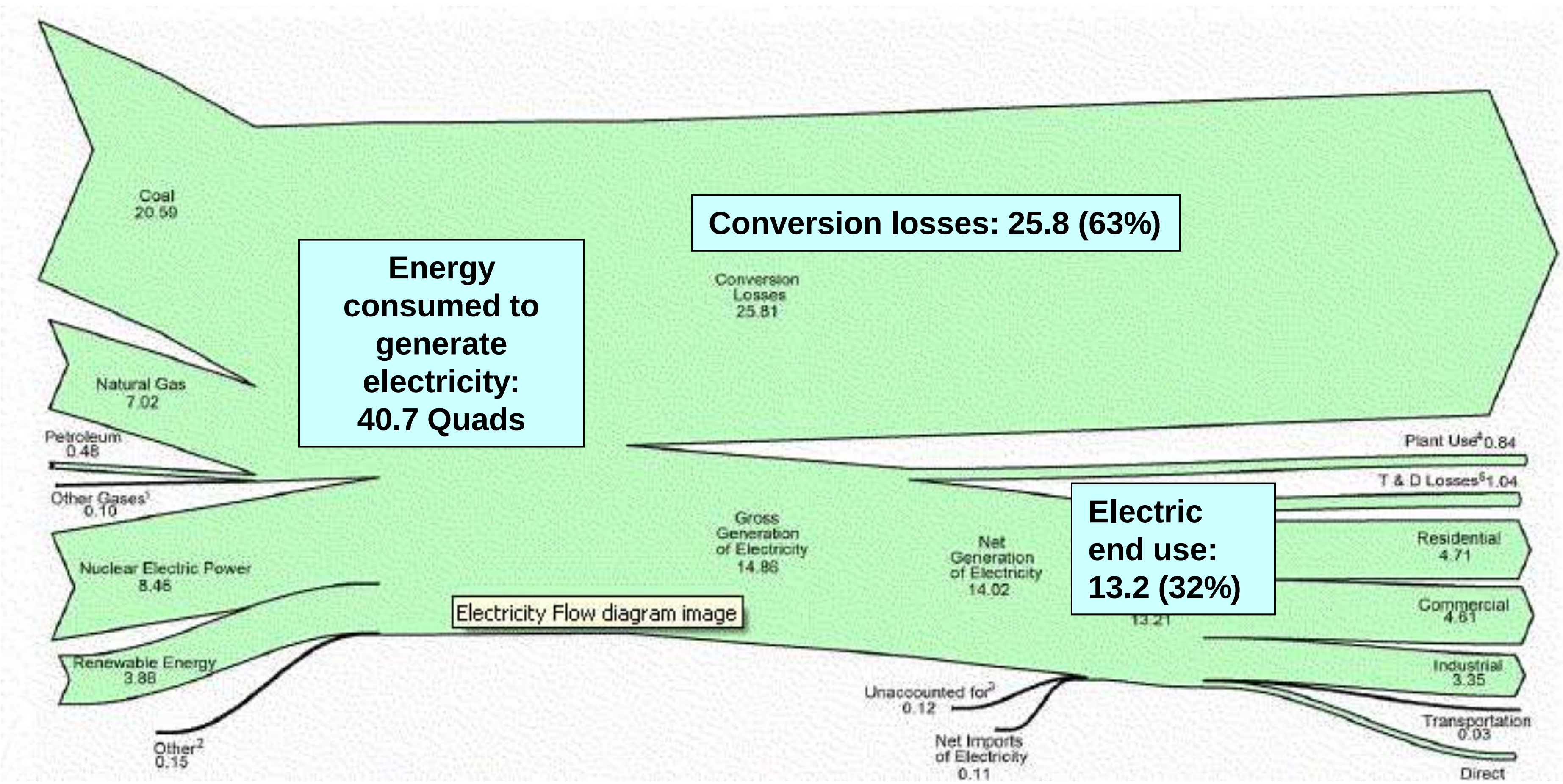
ASHRAE Standard 100 Energy Targets

Median Total Energy Use Intensities (EUIs) by ASHRAE Climate Zone by Commercial Building Type																	
ASHRAE Climate Zone:	1A	2A	2B	3A	3B	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Building Type	Median Source EUI by ASHRAE Climate Zone (kBtu/yr-sqft)																
Admin/professional office	176	181	177	164	132	175	140	129	124	126	131	116	87	148	138	165	220
Bank/other financial	250	257	251	233	188	248	198	183	175	179	186	165	124	211	196	234	312
Government office	220	226	221	205	165	218	174	161	154	158	163	145	109	185	173	206	275
Medical office (non-diagnostic)	150	154	151	140	113	149	119	110	105	107	111	99	74	126	118	141	187
Mixed-use office	204	210	205	190	153	202	161	149	143	146	151	135	101	172	160	191	254
Other office	170	175	171	158	128	169	135	124	119	122	126	112	84	143	134	160	212
Laboratory	785	794	774	707	602	766	647	550	545	553	559	513	403	626	600	692	875
Distribution/shipping center	55	71	74	79	43	80	60	76	71	68	96	83	53	136	118	172	306
Non-refrigerated warehouse	27	34	36	38	21	39	29	37	34	33	47	40	26	66	57	83	148

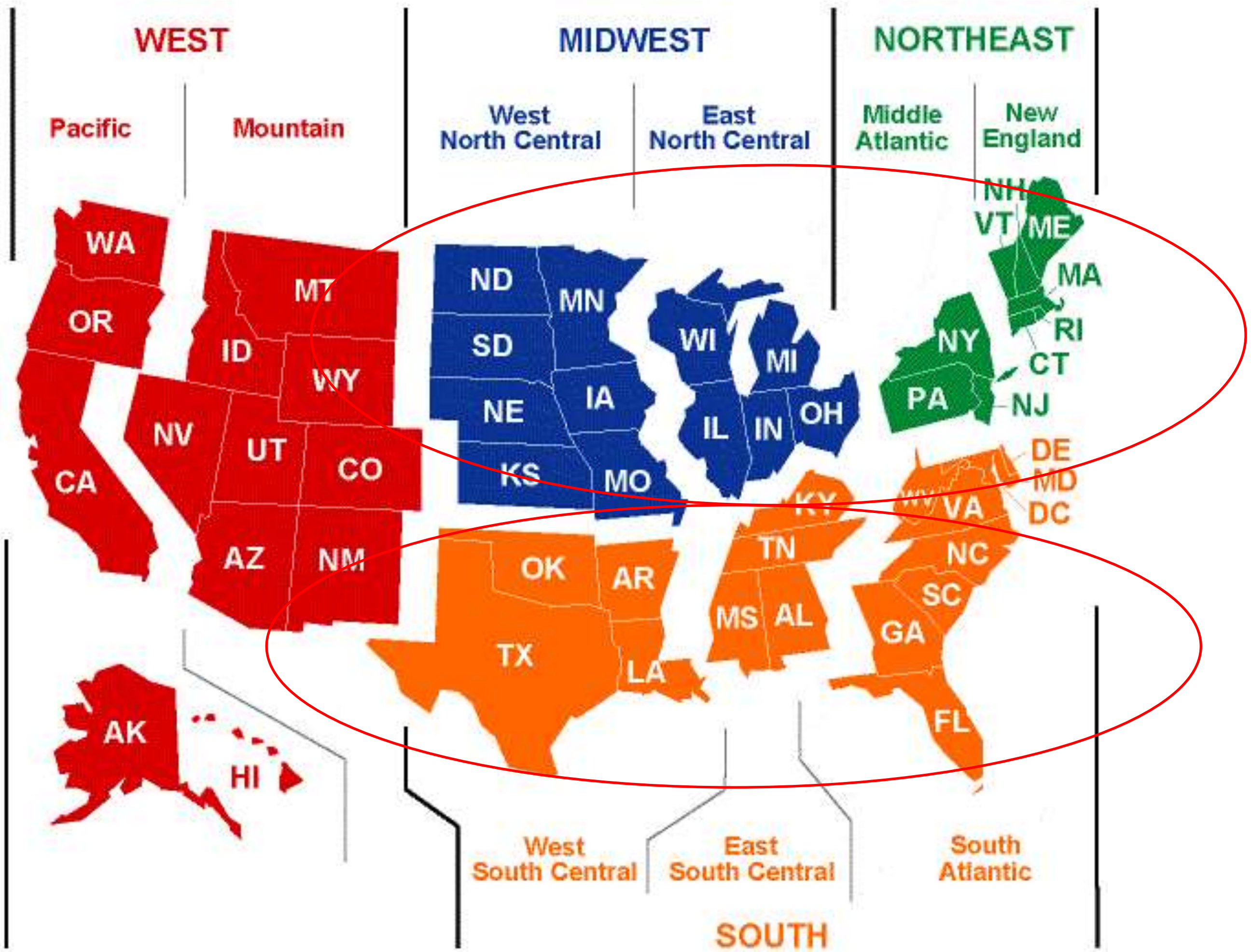


Energy Use Targets: Site or Primary Energy Basis?

An Issue: In the U.S., About 1/3 of Energy Used at Power Plant Reaches Building



Site vs. Primary (Source) EUI Comparison: Based on Measured Data in U.S. CBECS* Database



*CBECS – Commercial Buildings Energy Consumption Survey

Is Population of EUIs Different for All-Electric Buildings? Statistics Say "Yes" If Site-Energy-Based

Office Buildings		Part-electric Mean, kBtu/sf-yr	Part-electric N	All-electric Mean, kBtu/sf-yr	All-electric N	Statist-ically different?	Pr > t
North	eui	85	203	44	23	Y	0.0001
North	euiso	157	203	126	23	N	0.083
South	eui	88	98	54	54	Y	0.0007
South	euiso	186	98	164	54	N	0.2339

Notes: eui = total site-based energy use intensity, kBtu/sf-yr
euiso = total source-based energy use intensity, kBtu/sf-yr

North = CBECS Census Divisions 2,3,4
South = CBECS Census Divisions 5,6,7

Conclusions for Site- Versus Primary- Energy-Use-Based Targets

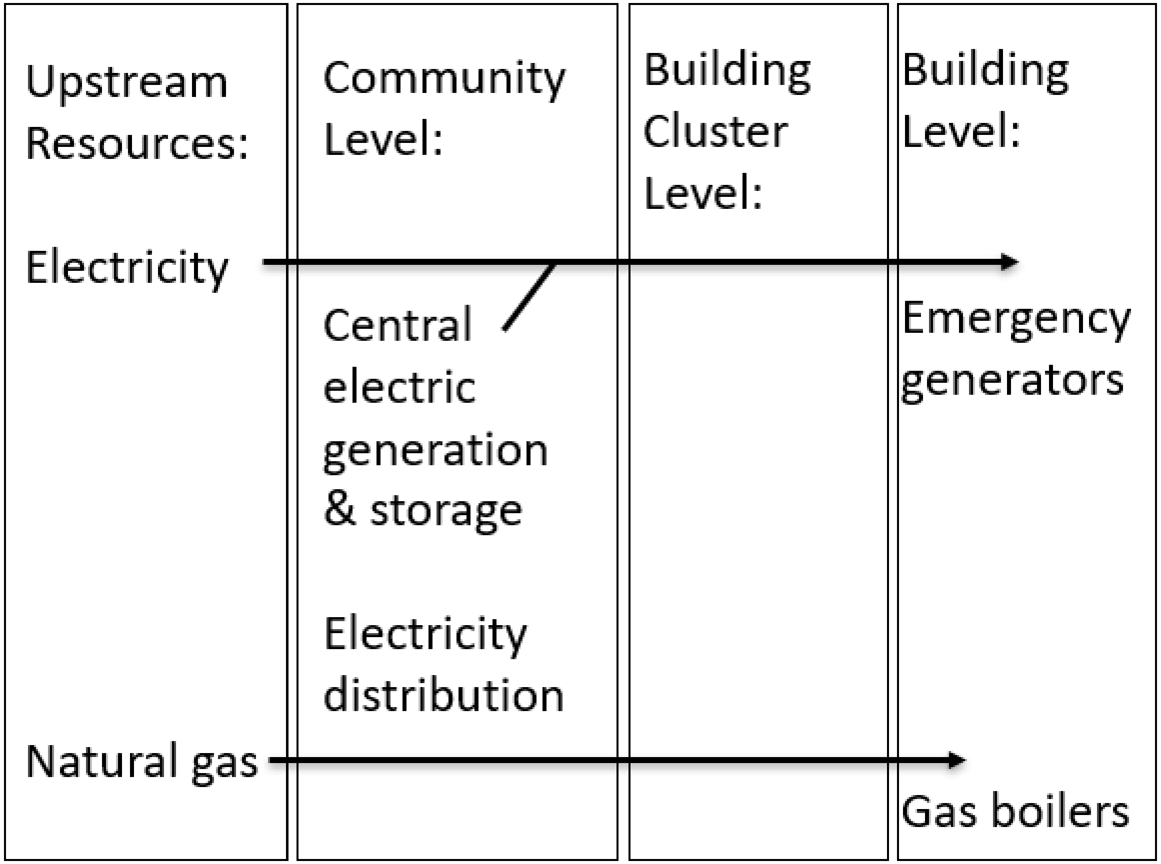
- In contrast to primary energy use-based targets, site energy-based targets:
  - Ignore 2 of the ~3 Btus of energy used to provide electricity
  - Are far less reliable as an overall building performance indicator – vary widely from location to location and building to building
  - Often move opposite the direction of your total utility costs (can make local electric generation appear very unattractive and fossil-fuel-based technologies appear non-competitive)
  - Should be used with considerable caution

3. Design Constraints

Design Constraints

- Type 1: Those that define or constrain your architecture
- Type 2: Those that constrain your technology options

Example Simple Community Architecture



Type 1: Resources and Constraints That Characterize Your System Architecture

	Identify Resources and Constraints for Your System Architecture	Resource or Constraint Exists (Yes/No)	Constraint Limit (capacity, quantity, or maximum)	Constraint Limit (units)
1	**External Services and Networks Available**			
	Steam available from external thermal network			klbs/hr
	Gas supply available			dkt/day
	Renewable-energy-based electrical energy available			kW
2	**Fuels Available**			
	Natural gas			MMBtu/hr
	Biomass			tons/day
3	**Existing Energy Systems On Site**			
	Central steam heating plant			MMBtu/hr
	Distribution lines for natural gas			Dth/day
	Emergency generators			kW
4	**Energy & Water Storage Systems**			
	Electricity storage			kWh
	Fuel oil storage			gal
5	**Personnel & Staffing**			
	Type of trained operators available			NA

Models Fitting Your Architecture Resources and Constraints

	Spatial location of generation	Building supplied from outside with …	Number of examples
1	**Solutions for generation within community**		
1.1.3	Generation at building level	Power	4
1.2.1	Generation at building cluster level	Power + heat	1
1.2.4	Generation at building cluster level	Power + heat + cool	4
1.3.1	Generation at community level	Power + heat	3
1.3.2	Generation at community level	Power + cool	1
1.3.4	Generation at community level	Power + heat + cool	8
1.4.1	Generation at multiple spatial levels	Mix	6
2	**Best practice examples**		
2.3.1	Generation at community level	Power + heat	9 (2 levels; 5 - Denmark, Canada, Greenland, 2-U.S.)
2.4.1	Generation at multiple spatial levels	Power + heat	1 (Australia)
3	**Generation outside the community**	Power + heat + cool	1 (1 level)
4	**Solutions for remote locations**	Mix	8 (2 levels)

Type 2: Resources and Constraints That Narrow Your Technology Options

Master Plan: "A plan to guide development and future growth"

"Alternatives analysis" which relies on constraint identification and impact assessment occurs here →

Energy Master Planning Steps*

1. Project scoping and goal setting
2. Baseline assessment
3. Identify potential opportunities
4. Develop project recommendations
5. Develop implementation plan
6. Monitor, measure, and evaluate

*Ranger 2015

Constraints That Narrow Your Technology Options

Natural Constraints		*Imposed Constraints*				
Constraint Category	***Constraint****	***Constraint Category***		***Constraint****	***Constraint Category***	***Constraint****
1. Locational Threats	Regional or local air quality	***3. Energy & Water Distribution & Storage Systems***		Natural Gas	***5. Indoor Environ-ment***	Space temperature
	Low-lying area (flooding)			Electricity		Humidity
	Extreme temperatures			Fuel Oil		Illumination levels
	Extreme humidities			Chilled water		Radon
	High winds			Hot water/steam		Ventilation
	Fire			Water		
	Lightning					
	Ground threats (volcano, mud,sinkhole,earthquake)	***4. Building and Facility***	*4a. Energy Use*	Energy use (site)	***6. Equipment in Buildings and District Systems***	Space heating
				Energy use (primary)		Space cooling
2. Locational Resources	Solar insolation			Energy efficiency		Ventilation
	Wind		*4b. Environ mental*	Renewables		Humidity control
	Biomass			Emissions		Water heating
	Land area		*4c. Opera-tional*	Resilience		Food preparation
	Roof area			Financial/Cost		Waste handling
	Natural Gas			Maintenance limits (e.g., simple, low cost)		Control systems
	Electricity					Electric generation
	Liquid fuels (oil, LPG, etc.)			Work force limitations		District steam
	Chilled water			Critical facility		District hot water
	Hot water/steam			Other planner/building owner limiting factor		District chilled water
	Water					

* Constraint that could limit technology selection

Example Constraint Limits: The Limits Of Each Constraint Must Be Quantified To Assess Their Impact

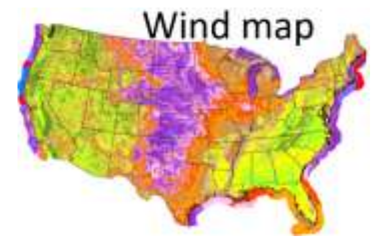
Constraint	*Potential Limits*
Resource: Natural gas	No availability/service
Distribution system	Chiller/boiler capacity Distribution capacity Unconnected buildings
Environmental: emissions	Local air quality Equipment limits No/limited fossil-fuel based systems allowed

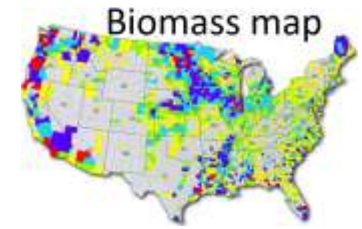
Constraints That Can Reduce Your EMP Technology Options

Constraint	Resource, System, or Constraint Exists (Y/N)	Constraint Limit (capacity/ quantity)	Constraint Limit (units)
1. LOCATIONAL RESOURCES			
1a. External Energy and Water Resources			
Natural gas			Dth/day
Fuel oil			kl/day
1b. External Renewable & Non-Fuel-Based Energy Resources			
Direct normal solar radiation available (annual average)			kWh/m2/day
Wind speed (annual average at 80 meters)			m/sec
Biomass			ktons/yr
1c. Space Availabilities for Installing Technologies			
Space for central heating plant			m2
Space for solar PV			m2
Space for geothermal wells			m2
Space for thermal energy storage tanks (area)			m2
2. BUILDING LEVEL FACILITY CONSTRAINTS			
Building energy use (site-based)			kBtu/sf-yr
Building energy use limit (primary or source-based)			kBtu/sf-yr
Renewables required			kBtu/sf-yr

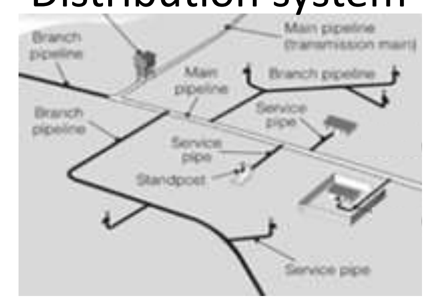
Quantifying Constraint Limits (examples)

- Resource limits
  - Local utilities can identify capacities/limits
  - Resource maps can identify availabilities
- Energy distribution & storage limits
  - System operators can identify capacities/limits
- Building/Facility limits
  - National/local regulations identify efficiency & energy use limits
  - Codes/laws/directives identify renewable & resilience limits
  - Owners define cost and critical facility limits





Distribution system

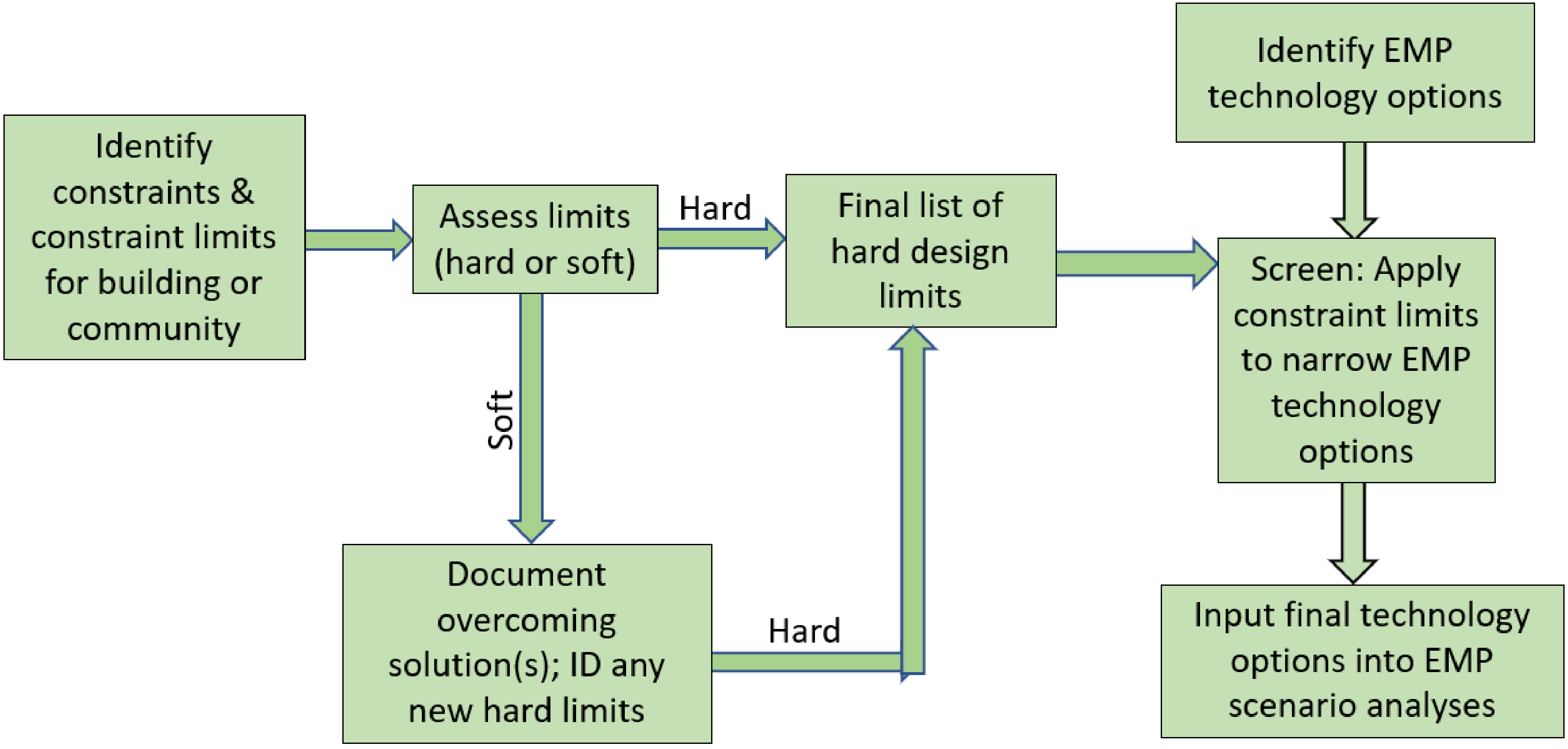


Assessing The Rigidity Of Constraint Limits (hard or soft?)

Definitions: A hard limit cannot be overcome, a soft limit can

- Potential soft limits
  - No or limited natural gas service
  - Limited fuel oil storage capacity
  - No district energy system
  - District energy system does not serve building/campus
- Example hard limits
  - Net zero energy use requirement
  - 100% renewable energy requirement
  - Insufficient insolation for viable PV systems
  - Insufficient wind for viable wind technologies
  - Biomass unavailable

Workflow for Applying Constraint Limits to Down Select Technology Options to Optimize EMP Scenario Analysis



Conclusions Around Design Constraints

- It is essential to identify and assess constraints that frame an EMP solution
- Early screening of technologies via constraints can better focus an EMP team
- Constraint limits should be evaluated as either hard or soft to avoid the unnecessary elimination of technologies
- To maintain consistent quality in the EMP process, the identification of constraints and their limits, and perhaps their evaluation, should be standardized

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