Carbon Footprinting Your Buildings

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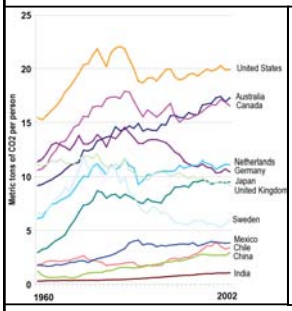


Fig 1: CO_2 emission per capita

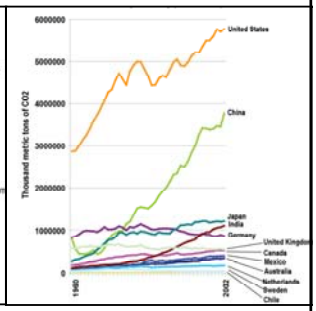
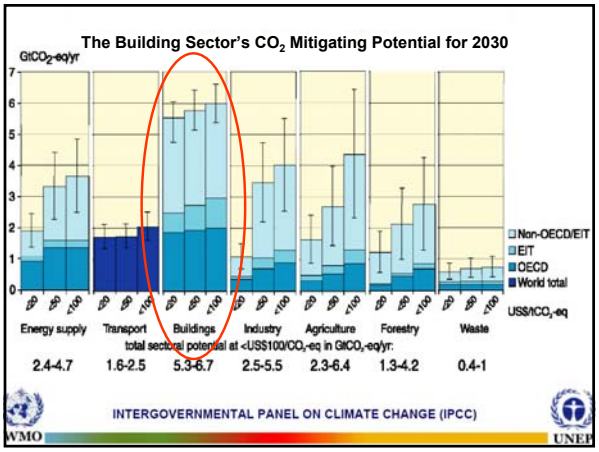


Fig 2: CO_2 emission per country

Source: World resources institute



Why should we establish CO_2 Benchmarks?

- Because everyone is doing it (EU Directive, 2030).
- Energy standards are beginning to use CO_2 as a metric (GBI/ANSI & ASHRAE 189P).
- California's AB32 the Country's most progressive Global Warming legislation (Title 24 is moving toward CO_2).
- Congress is presently considering Global Warming legislation (most likely some form Carbon Cap & Trade system will emerge). Since buildings are a big part of the problem they will undoubtedly be included.

Establishing the Benchmark?

Is 10 MPG high or low for an Automobile?

Fuel Efficiency MPG

What is a comparable metric to MPG for a building?

It is called Energy Use Intensity (EUI)

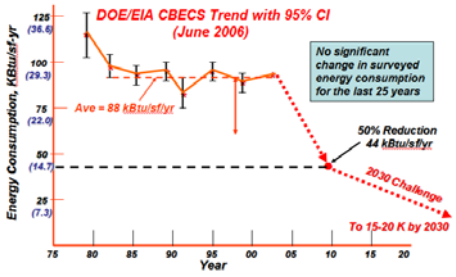
It is measured in kBtu/sf/yr or kWh/sf/yr

for SI units it is in kWh/m^2/yr

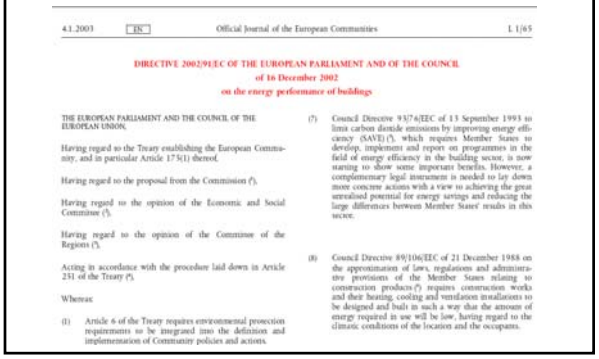
What would be a good EUI?

Is 80 kBtu/sf/yr high or low
for an Office Building?

DOE has been Measuring EUI's for 30 years



After: James Woods



4.1.2003 EN Official Journal of the European Communities L 1/65

DIRECTIVE 2002/91/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL
of 16 December 2002
on the energy performance of buildings

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty establishing the European Community, and in particular Article 175(1) thereof,

Having regard to the proposal from the Commission (1),

Having regard to the opinion of the Economic and Social Committee (2),

Having regard to the opinion of the Committee of the Regions (3),

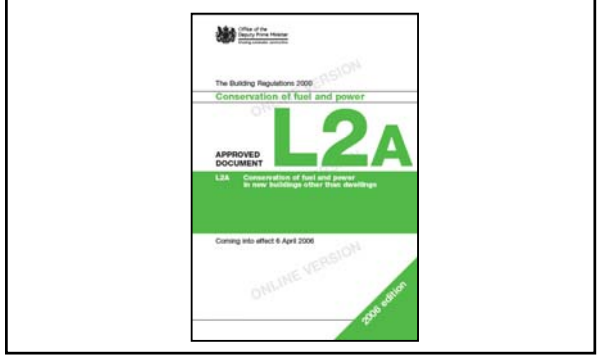
Acting in accordance with the procedure laid down in Article 251 of the Treaty (4),

Whereas:

(1) Article 6 of the Treaty requires environmental protection requirements to be integrated into the definition and implementation of Community policies and actions.

(7) Council Directive 93/76/EEC of 13 September 1993 to limit carbon dioxide emissions by improving energy efficiency (SAVE) (5), which requires Member States to develop, implement and report on programmes in the field of energy efficiency in the building sector, is now starting to show some important benefits. However, a complementary legal instrument is needed to lay down more concrete actions with a view to achieving the great unrealised potential for energy savings and reducing the large differences between Member States' results in this sector.

(8) Council Directive 89/106/EEC of 21 December 1988 on the approximation of laws, regulations and administrative provisions of the Member States relating to construction products (6) requires construction works and their heating, cooling and ventilation installations to be designed and built in such a way that the amount of energy required in use will be low, having regard to the climatic conditions of the location and the occupants.



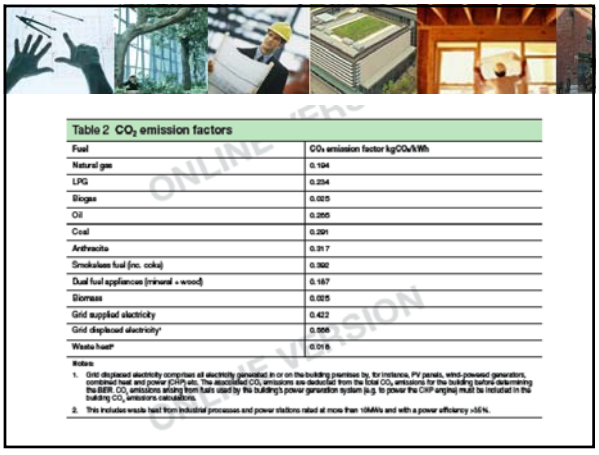


Table 2 CO_2 emission factors

Fuel	CO_2 emission factor kgCO_2/kWh
Natural gas	0.194
LPG	0.234
Biogas	0.025
Oil	0.265
Coal	0.291
Anthracite	0.317
Smokeless fuel (inc. coke)	0.392
Dual fuel appliances (mineral + wood)	0.167
Biomass	0.025
Grid supplied electricity	0.422
Grid displaced electricity*	0.568
Waste heat*	0.016

Notes:
1. Grid displaced electricity comprises all electricity generated in or on the building premises by, for instance, PV panels, wind-powered generators, combined heat and power (CHP) etc. The associated CO_2 emissions are deducted from the total CO_2 emissions for the building before determining the BER. CO_2 emissions arising from fuels used by the building's power generation system (e.g. to power the CHP engine) must be included in the building CO_2 emissions calculations.
2. This includes waste heat from industrial processes and power stations rated at more than 10MWe and with a power efficiency >35%.

ONLINE VERSION

Where to Draw the Boundary?

Is it at the property line of the building?
What features do we include?

- Building energy
- Transportation
- Source or site?
- Embodied ene
- Water use?
- Supplied servic
- etc.

What Do These Features Mean?

Each feature contributes

- Building energy – The one real obvious one
- Transportation? – Indirectly; owner occupied?
  - Transportation Management Plan
- Source or site? – Full accounting ➔ source
- Embodied energy? – Energy expended to build
- Water use? – both at direct and indirect, eg., water used in energy generation
- Supplied services? – But these are 3rd parties?!
- etc. – Materials purchase, cleaning,

Energy – The Obvious Big Item

Site versus Source Emissions

Site
On-site combustion
Electricity used on-site, but is generated elsewhere

Source
Where to draw boundary here?

Energy Consumption – Emissions Factors

Quiz

For every 1 kWh of electricity consumed, what is the average resulting CO_2 emissions from this?

A. ½ lb of CO_2?
B. 1.0 lb of CO_2?
C. 2.0 lb of CO_2?
D. Don't have a clue?

Energy Consumption – Emissions Factors

Quiz

For every 1 kWh of electricity consumed, what is the average resulting CO_2 emissions from this?

A. ½ lb of CO_2?
B. 1.0 lb of CO_2?
C. 2.0 lb of CO_2?
D. Don't have a clue?

Building Project Energy Source	CO_2e kg/kWh (lb/kWh)
Grid delivered electricity	0.758 (1.670)
LPG or propane	0.274 (0.602)
Fuel oil (residual)	0.312 (0.686)
Fuel oil (distillate)	0.279 (0.614)
Coal (except lignite)	0.373 (0.822)
Coal (lignite)	0.583 (1.287)
Gasoline	0.309 (0.681)
Natural gas	0.232 (0.510)

from: ASHRAE 189.1

The EPA than Developed a Web-based Building Benchmarking Tool for New Buildings called Energy Star Target Finder

www.energystar.gov/index.cfm?c=new_bldg_design.bus_target_finder

or just Google: Target Finder

First Step: For Existing Buildings Compile Energy Consumption

Utility Meter for Existing Buildings

Electricity Meter #3
Account ID 129 **Location** Main Library Annex **PPD** 62000
Account Number 30-872-086 **Building** 0054

Billing Period FY 2006	Days	kWh	per Day	Peak kW	Amount	Cost per Day
6/30/05 - 7/27/05	27	352,000	13,037	680	$17,600	$651.85
7/27/05 - 8/30/05	34	380,000	11,176	720	$19,000	$558.82
8/30/05 - 9/28/05	29	373,200	12,869	720	$18,660	$643.45
9/28/05 - 10/28/05	30	296,000	9,867	640	$14,800	$493.33
10/28/05 - 11/29/05	32	336,000	10,500	600	$16,800	$525.00
11/29/05 - 1/3/06	35	283,600	8,103	880	$14,180	$405.14
1/3/06 - 1/30/06	27	271,600	10,059	680	$13,580	$502.96
1/30/06 - 2/28/06	29	284,000	9,793	720	$14,200	$489.66
2/28/06 - 3/30/06	30	322,800	10,760	680	$16,140	$538.00
3/30/06 - 4/27/06	28	318,000	11,357	680	$15,900	$567.86
4/27/06 - 5/30/06	33	348,400	10,558	640	$17,420	$527.88
5/30/06 - 6/13/06	14	140,800	10,057	600	$7,040	$502.86
Total		**3,706,400**	**10,651**		**$185,320**	**$532.53**

Did you Forget About…?

- **Transportation**
- **Water usage**
  - **From one major city: 2.31 lb CO2 per 1,000 gallons potable water provided (not counting sewage)**
- **Embodied energy**

Other Stuff (cont'd)

- **Embodied energy (still developing)**

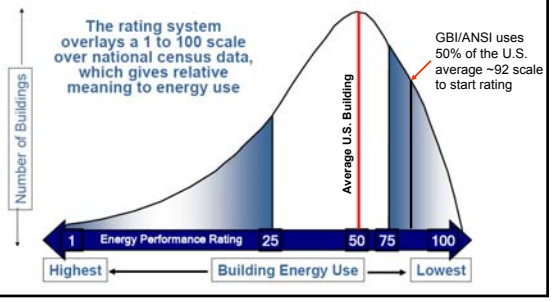
Average Total Initial Embodied Energy 4.82 GJ/m²

MATERIAL	EMBODIED ENERGY MJ/kg	MJ/m3
Aggregate	0.10	150
Straw bale	0.24	31
Soil-cement	0.42	819
Stone (local)	0.79	2030
Concrete block	0.94	2350
Concrete (30 Mpa)	1.3	3180
Concrete precast	2.0	2760
Lumber	2.5	1380
Brick	2.5	5170
Cellulose insulation	3.3	112
Gypsum wallboard	6.1	5890
Particle board	8.0	4400
Aluminum (recycled)	8.1	21870
Steel (recycled)	8.9	37210
Shingles (asphalt)	9.0	4930
Plywood	10.4	5720
Mineral wool insulation	14.6	139
Glass	15.9	37550
Fiberglass insulation	30.3	970
Steel	32.0	251200
Zinc	51.0	371280
Brass	62.0	519360
PVC	70.0	93620
Copper	70.6	631164
Paint	93.3	117500
Linoleum	116	150930
Polystyrene Insulation	117	3770
Carpet (synthetic)	148	84900
Aluminum	227	515700

NOTE: Embodied energy values based on several international sources - local values may vary

GBI/ANSI CO_2 Calculation Approach

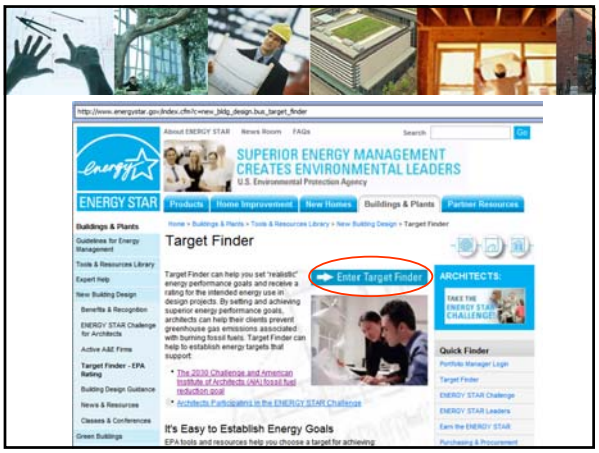
The EPA Modified the CBECS database

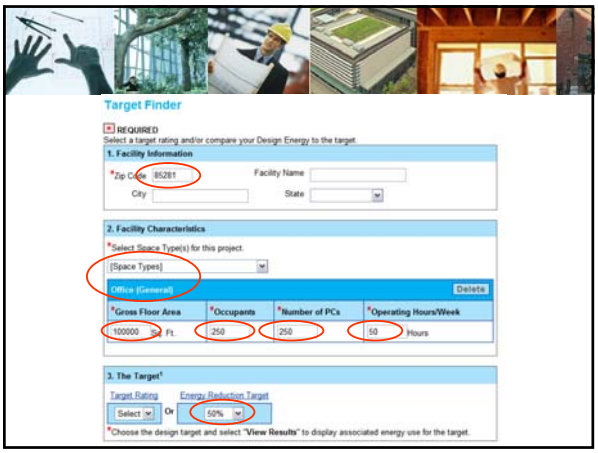


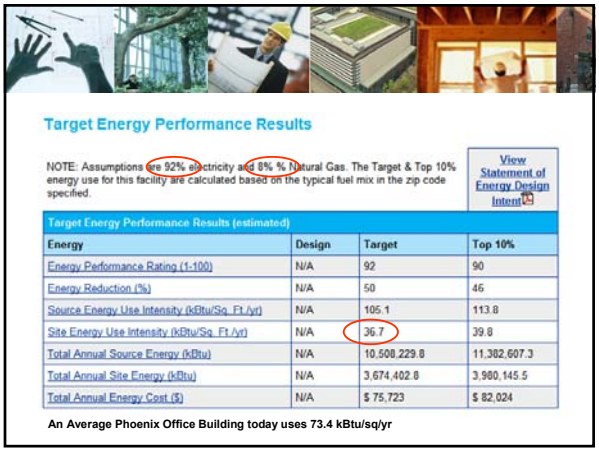
Energy Star Target Finder

Generates an EUI for your design based on normalizes energy consumption of the entire national building stock, using:

- Local weather data
- Space type
- Hours of operation
- Occupant density
- Internal load







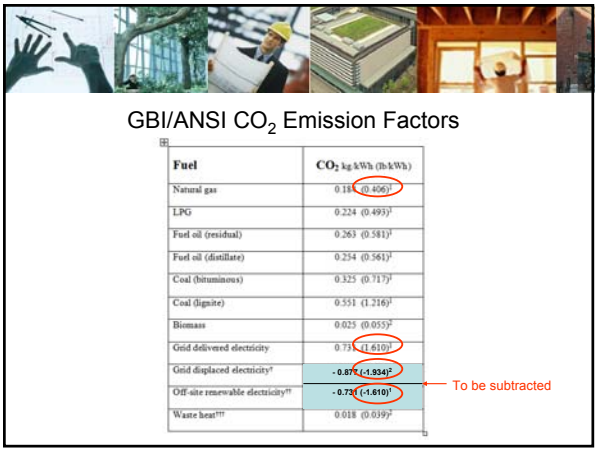
Target Energy Performance Results

NOTE: Assumptions are 92% electricity and 8% % Natural Gas. The Target & Top 10% energy use for this facility are calculated based on the typical fuel mix in the zip code specified.

View Statement of Energy Design Intent

Target Energy Performance Results (estimated)			
Energy	Design	Target	Top 10%
Energy Performance Rating (1-100)	N/A	92	90
Energy Reduction (%)	N/A	50	46
Source Energy Use Intensity (kBtu/Sq. Ft./yr)	N/A	105.1	113.8
Site Energy Use Intensity (kBtu/Sq. Ft./yr)	N/A	36.7	39.8
Total Annual Source Energy (kBtu)	N/A	10,508,229.8	11,382,607.3
Total Annual Site Energy (kBtu)	N/A	3,674,402.8	3,980,145.5
Total Annual Energy Cost ($)	N/A	$ 75,723	$ 82,024

An Average Phoenix Office Building today uses 73.4 kBtu/sq/yr



GBI/ANSI CO_2 Emission Factors

Fuel	CO_2 kg/kWh (lb/kWh)
Natural gas	0.184 (0.406)[1]
LPG	0.224 (0.493)[1]
Fuel oil (residual)	0.263 (0.581)[1]
Fuel oil (distillate)	0.254 (0.561)[1]
Coal (bituminous)	0.325 (0.717)[1]
Coal (lignite)	0.551 (1.216)[1]
Biomass	0.025 (0.055)[2]
Grid delivered electricity	0.73 (1.610)[2]
Grid displaced electricity[3]	- 0.87 (-1.934)[2]
Off-site renewable electricity[3]	- 0.73 (-1.610)[1]
Waste heat[3][4]	0.018 (0.039)[2]

To be subtracted

GBI/ANSI CO_2 Benchmarking Calculation

For Electricity

$\frac{.92 \times 36.7 \text{ kBtu/sf/yr}}{3.414 \text{ kBtu/kWh}}$ = 9.89 kWh/sf/yr x 1.610 lbs/kWh = 15.92 lbs/sf/yr

For Natural Gas

$\frac{.08 \times 36.7 \text{ kBtu/sf/yr}}{3.414 \text{ kBtu/kWh}}$ = 0.86 kWh/sf/yr x 0.406 lbs/kWh = 0.35 lbs/sf/yr

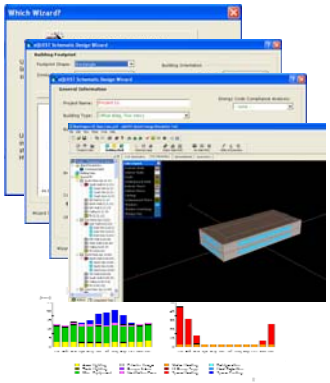
16.27 lbs/sf/yr

16.27 lbs/sf/yr x 100,000 sf = 1,627,000 lbs of CO_2

or 814 tons of CO_2

(Average Phoenix Building used 1628 tons of CO_2)

Energy Modeling



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Building Creation Wizard

Energy Efficiency Measure Wizard

Graphical Results Display

eQUEST Modeling for Proposed Building

Annual Energy Consumption by Enduse

	Electricity kWh (x000)	Natural Gas MBtu	Steam Btu	Chilled Water Btu
Space Cool	225.22	-	-	-
Heat Reject.	6.11	-	-	-
Refrigeration	-	-	-	-
Space Heat	-	69.20	-	-
HP Supp.	-	-	-	-
Hot Water	-	123.39	-	-
Vent. Fans	109.46	-	-	-
Pumps & Aux.	67.65	-	-	-
Ext. Usage	-	-	-	-
Misc. Equip.	367.51	-	-	-
Task Lights	-	-	-	-
Area Lights	175.82	-	-	-
Total	951.77	192.59	-	-

GBI/ANSI CO_2 -- For Proposed Building

For Electricity

9.518 kWh/sf/yr x 1.610 lbs/kWh = 15.32 lbs/sf/yr

For Natural Gas

1.926 kBtu/sf/yr / 3.414 kBtu/kWh = 0.564 kWh/sf/yr x 0.406 lbs/kWh = 0. 23 lbs/sf/yr

15.55 lbs/sf/yr

15.55 lbs/sf/yr x 100,000 sf = 1,555,000 lbs of CO_2

or 778 tons of CO_2

GBI/ANSI CO_2 – Add Renewables

Let us assume that 25% of this buildings electricity can be supplied by On-Site Photovoltaics

Let us assume that another 25% of this buildings electricity can be supplied by the purchase of Green Tags or REC

How much more CO_2 can be reduced?

GBI/ANSI CO_2 – Add Renewables

For Electricity
9.518 kWh/sf/yr x 1.610 lbs/kWh = 15.32 lbs/sf/yr

For Natural Gas
1.926 kBtu/sf/yr / 3.414 kBtu/kWh = 0.564 kWh/sf/yr x 0.406 lbs/kWh = 0.23 lbs/sf/yr

15.55 lbs/sf/yr

Grid Displaced Electricity (On-Site Photovoltaics)
.25 x 9.518 kWh/sf/yr x -1.934 lbs/kWh = - 4.60 lbs/sf/yr

Off-Site Renewable Electricity (Purchase of Green Tags)
.25 x 9.518 kWh/sf/yr x -1.610 lbs/kWh = - 3.83 lbs/sf/yr

7.12 lbs/sf/yr

GBI/ANSI CO_2 -- Final Calculation

7.12 lbs/sf/yr x 100,000 sf = 712,000 lbs of CO_2

or 356 tons of CO_2

A 458 ton or a 56% reduction in CO_2

Remember:

An Average Phoenix Office Building uses today 1,628 tons of CO_2

A 1272 ton or a 78% reduction in CO_2

GBI/ANSI CO_2 Point Distribution

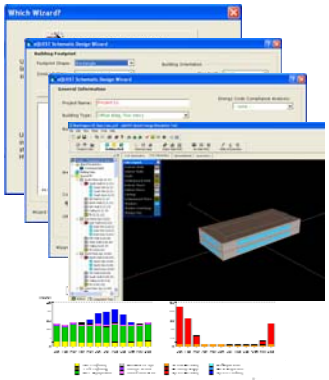
Maximum Points = 250 Points

CO_2 Reduction	Points
□ 50%	25
□ 55%	50
□ 60%	75
□ 65%	100
□ 70%	125
□ **75%**	**150**
□ 80%	175
□ 85%	200
□ 90%	225
□+95%	250

ASHRAE 189P CO_2 Calculation Approach

ASHRAE Appendix G (D in 189P)

Energy Modeling



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Building Creation Wizard

Energy Efficiency Measure Wizard

Graphical Results Display

eQUEST Modeling for Benchmark Building

Annual Energy Consumption by Enduse

	Electricity kWh (x000)	Natural Gas MBtu	Steam Btu	Chilled Water Btu
Space Cool	225.22	-	-	-
Heat Reject.	6.11	-	-	-
Refrigeration	-	-	-	-
Space Heat	-	69.20	-	-
HP Supp.	-	-	-	-
Hot Water	-	123.39	-	-
Vent. Fans	109.46	-	-	-
Pumps & Aux.	67.65	-	-	-
Ext. Usage	-	-	-	-
Misc. Equip.	367.51	-	-	-
Task Lights	-	-	-	-
Area Lights	175.82	-	-	-
Total	951.77	192.59	-	-

SPC 189 CO_2e Emission Factors

Fuel	CO_2e kg/kWh (lb/kWh)
Grid delivered electricity[2]	0.799 (1.760)
LPG[3]	0.229 (0.501)
Fuel oil (residual)[3]	0.265 (0.584)
Fuel oil (distillate)[3]	0.254 (0.560)
Coal (bituminous)[3]	0.398 (0.878)
Coal (lignite)[3]	0.553 (1.215)
Natural gas[3]	0.184 (0.406)
Natural gas[4]	0.205 (0.452)
Fuel oil (distillate)[4]	0.254 (0.560)
Gasoline[4]	0.272 (0.600)
Natural gas[3]	0.188 (0.415)
Fuel oil (distillate)[3]	0.255 (0.562)
Natural gas[4]	0.181 (0.400)

SPC 189 CO_2e Calculation for Benchmarking

For Electricity

9.518 kWh/sf/yr x 1.76 lbs/kWh = 16.75 lbs/sf/yr

For Natural Gas

1.926 kBtu/sf/yr / 3.414 kBtu/kWh = 0.564 kWh/sf/yr x 0.406 lbs/kWh = 0.23 lbs/sf/yr

16.98 lbs/sf/yr

16.98 lbs/sf/yr x 100,000 sf = 1,698,000 lbs of CO_2

or 849 tons of CO_2

eQUEST Modeling for Proposed Building

Annual Energy Consumption by Enduse

	Electricity kWh (x000)	Natural Gas MBtu	Steam Btu	Chilled Water Btu
Space Cool	207.89	-	-	-
Heat Reject.	6.02	-	-	-
Refrigeration	-	-	-	-
Space Heat	-	65.13	-	-
HP Supp.	-	-	-	-
Hot Water	-	123.39	-	-
Vent. Fans	109.46	-	-	-
Pumps & Aux.	67.22	-	-	-
Ext. Usage	-	-	-	-
Misc. Equip.	367.51	-	-	-
Task Lights	-	-	-	-
Area Lights	175.82	-	-	-
Total	933.92	188.52	-	-

SPC 189 CO_2e Calculation for Proposed

For Electricity

9.339 kWh/sf/yr x 1.76 lbs/kWh = 16.44 lbs/sf/yr

For Natural Gas

1.885 kBtu/sf/yr / 3.414 kBtu/kWh = 0.552 kWh/sf/yr x 0.406 lbs/kWh = 0.22 lbs/sf/yr

16.66 lbs/sf/yr

16.66 lbs/sf/yr x 100,000 sf = 1,666,000 lbs of CO_2

or 833 tons of CO_2

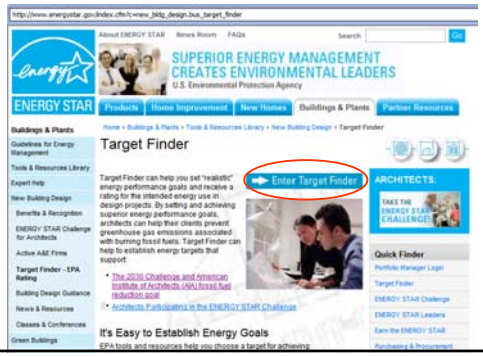
SPC 189 CO_2e – Final Test

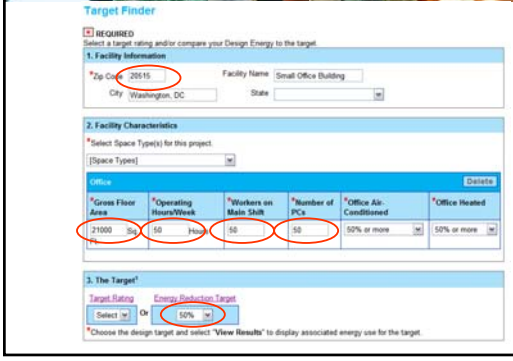
Proposed Building less then Benchmark Building

16.44 lbs-CO_2/sf/yr less then 16.98 lbs-CO_2/sf/yr **Building Passes**

Example Building

21,000 square foot office building
Located in Washington D.C. (ASHRAE Climate Zone 4A)
50 person occupancy
50 hours per week operation
Envelope performance, internal loads and HVAC efficiency are dependent on the version of the code used





Target Energy Performance Results

The design **must** achieve a rating of 75 or higher to be eligible for "Designed to Earn the ENERGY STAR". **View Statement of Energy Design Intent** for project summary.

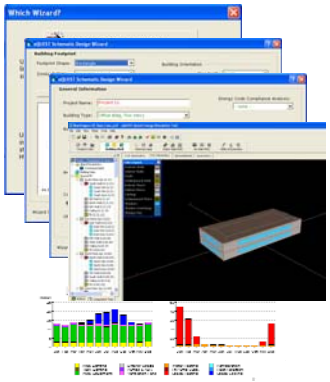
View

NOTE: Assumptions are 79% electricity and 21% Natural Gas. The Target & Top 10% energy use for this facility are calculated based on the typical fuel mix in the zip code specified.

Target Energy Performance Results (estimated)

Energy	Design	Target	Top 10%
Energy Performance Rating (1-100)	N/A	93	90
Energy Reduction (%)	N/A	50	45
Source Energy Use Intensity (kBtu/Sq. Ft./yr)	N/A	97.9	107.5
Site Energy Use Intensity (kBtu/Sq. Ft./yr)	N/A	33.3	36.6
Total Annual Source Energy (kBtu)	N/A	2,055,078.9	2,256,625.5
Total Annual Site Energy (kBtu)	N/A	700,402.7	769,092.9
Total Annual Energy Cost ($)	N/A	$ 13,830	$ 15,186

Energy Modeling



eQUEST

Building Creation Wizard

Energy Efficiency Measure Wizard

Graphical Results Display

EUI for Small Office Building - Climate Zone 4A

Scenario	Gas	Electric	Renewables	Total
Ave. CBECS	13.98	52.62	0	66.60
BEPS-1980	21.84	26.68	0	48.52
50% CBECS	6.99	26.31	0	33.30
90.1-2007	4.46	36.62	0	41.08
189.1	6.40	27.76	-0.33	33.83

Units : EUI (kBtu/ft²-yr)

CUI for Small Office Building - Climate Zone 4A

Scenario	Gas	Electric	Renewables	Total
Ave. CBECS	1.63	24.20	0	25.83
BEPS-1980	2.56	12.28	0	14.84
50% CBECS	0.82	12.10	0	12.92
90.1-2007	0.52	16.84	0	17.36
189.1	0.75	12.77	-0.15	13.37

Units: CUI (lbs-CO_2/ft²-yr)

Building Improvement Strategies

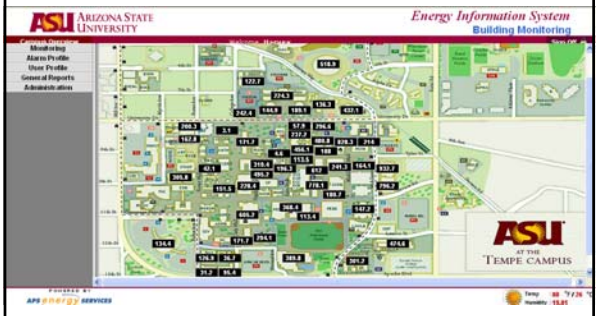
- 25% of the electricity usage can be supplied by solar
- Solar thermal can supply all space and DHW needs
- Advanced daylighting strategies
- Advanced lighting and control strategies
- Advanced HVAC equipment
- Radiant heating and cooling
- On-site generation of all electricity
- Combined the best of the above scenarios (the red strategies)

CUI for Small Office Building - Climate Zone 4A

Scenario	Gas	Electric	Renewables	Total
Ave. CBECS	1.63	24.20	0	25.83
BEPS-1980	2.56	12.28	0	14.84
50% CBECS	0.82	12.10	0	12.92
90.1-2007	0.52	16.84	0	17.36
189.1	0.75	12.77	-0.15E	13.37
25% Solar Electric[1]	**0.75**	**12.77**	**-3.33E**	**10.19**
Solar Thermal Heating[2]	**0.75**	**12.77**	**-0.15E -0.41T**	**12.96**
Daylighting[3]	**0.79**	**12.08**	**-2.94T**	**9.93**
LED lighting & Controls	**0.79**	**10.93**	**-0.15E**	**11.57**
Advanced HVAC	**0.71**	**12.48**	**-0.15E**	**13.04**
Radiant Heating & Cooling[4]	**0.38**	**11.04**	**-0.15E**	**11.27**
On-site Generation	**6.60**	**0**	**0**	**6.60**
Combination Scenarios[1,2,3,4]	**0.79**	**10.35**	**-3.33E -3.35T**	**4.46**

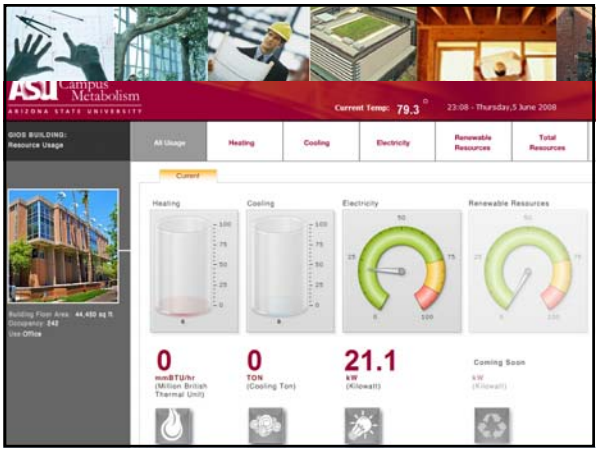
Units: CUI (lbs-CO_2/ft²-yr)
E = Solar Electric
T = Solar Thermal

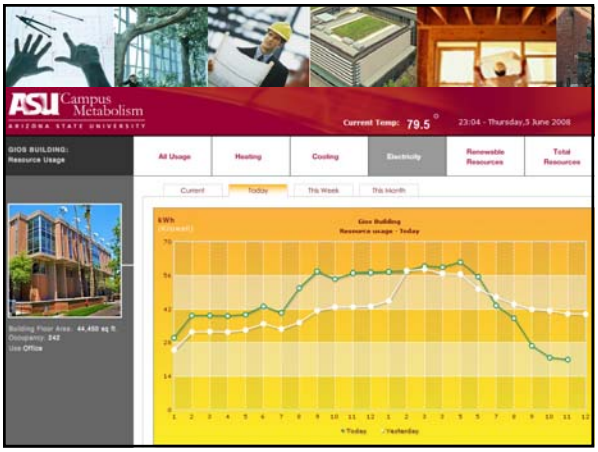
ASU's Current Campus Energy Information System

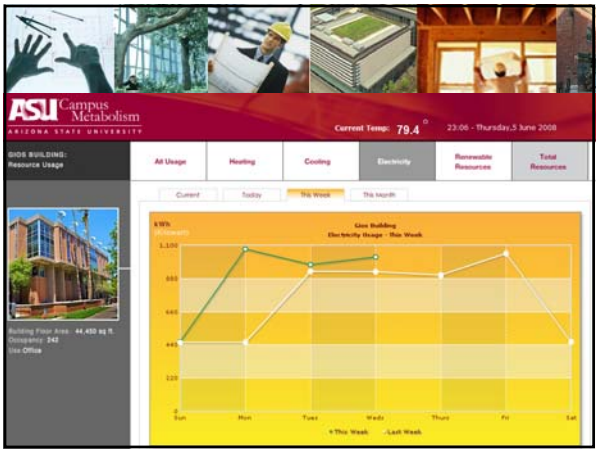


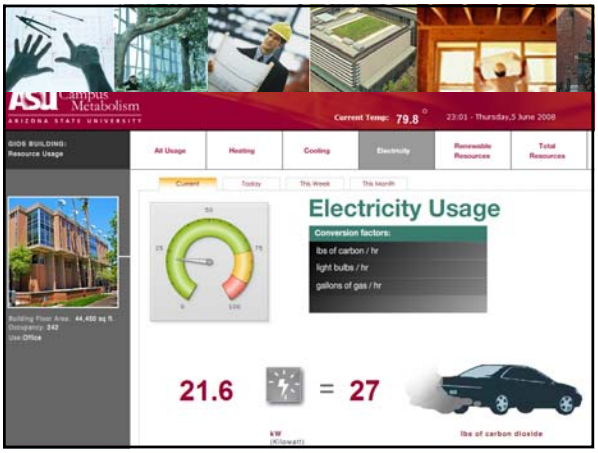
Typical Campus Building Profile

http://eis.asu.edu/campusmetabolism







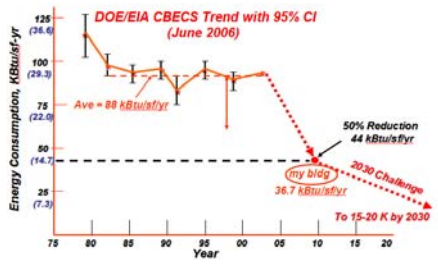


Where We Want To Go – Campus Dashboard

Conclusion

- Numerous similarities between the European work, GBI/ANSI and ASHRAE 189P (use very similar emission factors).
- GBI/ANSI tracks Architecture 2030 very well.
- Renewables will play an important role in moving a building toward carbon neutrality.
- The CO_2 calculation eliminate the site vs. source problem, by being site energy converting to source CO_2.
- Unlike ASHRAE 189P, GBI/ANSI does not use Appendix G but rather CBEC's for benchmarking which makes it an easier calculation.
- Because it is a pass/fail test, ASHRAE 189P does not allow for fuel switching.
- Both of these procedures will get designers thinking about carbon and prepare them for some type of Carbon Cap and Trade System.

Carbon Neutral Buildings can be Accomplished



After: James Woods

Thank You

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