Personal Energy Audit
SEBS Spring 2012 Honors Seminar
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In this exercise, you'll be our evaluating at your personal energy consumption. Please collect data over **two weekdays and the weekend**; from this data, you'll extrapolate to your average weekly and annual energy consumption. Please bring your complete data and calculations to class the week of Feb. 29.

You'll be collecting or estimating data regarding your energy consumption in seven areas:

- Transportation
- Heating and cooling
- Lighting
- Electronics and appliances
- Food
- Manufactured goods
- Services

You are *strongly* encouraged to keep track of your data and perform your calculations in a spreadsheet program such as Excel.

Please read through this entire exercise before you start collection data, so that you have an understanding of how the data will be used. It may be helpful to refer to the American Physical Society's reference page on energy units (http://www.aps.org/policy/reports/popa-reports/energy/units.cfm).

Data Collection

1. Transportation

For the four-day data collection period, record the number of commuting miles driven or ridden in a car, bus, train, or airplane. Record each trip separately. For trips in cars, record the type of car and the number of passengers in the vehicle. Also record the miles per gallon for each car; if you do not know this, you can find typical values at fueleconomy.gov

Example

Sat.	New Brunswick to Wegman's and back	Car (Civic), solo	24 miles
	Train to New York and back	Train	75 miles
Sun.	To friend's house and back	Car (Civic), solo	5 miles
Mon.	Cook Campus to Busch Campus and back	Car (Civic), 2 people	11 miles
Tue.	Cook Campus to Busch Campus and back	Car (Civic), solo	11 miles

Honda Civic: 34 miles per gallon

Separately, estimate the number of long-distance miles you've travelled in the last year by each mode of transportation for reasons other than commuting (in order to capture annual transportation use that occurs on a less than weekly basis).

Example

Road trip	Car (Civic), 2 people	3,000 miles
Amtrak (NE Corridor)	Train	1,000 miles
Airplane	Airplane	15,000 miles

2. Heating and Cooling

Hot Water

Record the amount of hot water you use in any of the following ways.

	Weekend		Weekday		
	Sat.	Sun.	Day 1	Day 2	Rest of Week
Hot shower (length in minutes)					-
Baths (each)					-
Dishwasher (number of loads)					-
Sink (time in minutes)					-
Laundry, hot (num. of loads)					
Laundry, warm (num. of loads)					
Other (describe)					-

Since you probably do laundry on a weekly basis, for laundry estimate the number of loads for the remainder of the week outside the data collection window. (If you do laundry less than weekly, estimate an average weekly rate; e.g., if you do two loads every two weeks, indicate 1 load under "rest of week.") Do likewise for other activities not captured (e.g., if you run the dishwasher once a week.)

Air Heating and Cooling

If you used heating or air-conditioning at home, for each day, record the outside high and low temperature and the temperature set on the thermostat. If you don't have a thermostat, inquire of facilities, measure the indoor air temperature, or assume the temperature is 65°F when the heat is on and 75°F when the A/C is on. Also record the size of your space; e.g., if you live in a 1000 ft^2 apartment with 4 people, note that you have a space of 250 ft^2.

Example

	Sat	Sun	Mon	Tue

High temperature	48 F	46 F	43 F	45 F
Low temperature	28 F	32 F	27 F	25 F
Thermostat temperature	68 F	68 F	68 F	68 F

Personal space: 750 ft^2

3. Lighting

For lighting, record the number of lights on times the amount of time in hours that they are operating. For example, if you had three bulbs on for two hours, record that as "6 bulb hours."

	Weekend		Weekday	
	Sat.	Sun.	Day 3	Day 4
Incandescent lights				
CFLs				
Fluorescent tube lights				
Other (Describe)				

4. Electronics and Appliances

Record the amount of time in hours that any of the following appliances are operating. For a desktop computer or a television, please note the nature (CRT/Fluorescent-backlit LCD/LED-backlit LCD/plasma) and size of the display.

	Weekend		Weekday		
	Sat.	Sun.	Day 3	Day 4	Rest of Week
Refrigerator (large)					-
Refrigerator (medium dorm size)					-
Refrigerator (small dorm size)					-
Washing machine					
Clothes dryer (hot)					
Clothes dryer (warm)					
Hair dryer					-
Microwave oven					-
Fan					-
Computer (desktop, not incl. display)					-
Computer (laptop)					-
Phone/camera/e-reader charger					-
Clock					-
Television/Computer Monitor					-
TV Set-Top Box (DVR, DVD, etc.)					-

Stereo					-
Other (Describe)					-

Since you probably do laundry on a weekly basis, for laundry estimate the number of hours for the remainder of the week outside the collection window. (If you do laundry less than weekly, estimate an average weekly rate.)

Note that refrigerators typically have a duty cycle of about 50%, which means that 50% of the time they're on, they are actively drawing a significant amount energy. You should adjust you estimate of the time the refrigerator is on accordingly (so a full day for a refrigerator should be 12 hours).

4. Food

For 2 days, record everything you eat and drink, except for water. If you happen to know the number of food Calories in an item, record that as well. (Otherwise, you'll have to look it up later.)

Example

Mon.	Breakfast	Cereal with milk, banana
	Break	Orange
	Lunch	Salad, hummus sandwich
	Break	Apple
	Dinner	Chicken with pasta
	Break	Ice cream

5. Manufactured Goods

Estimate the amount of money you've spent during the past year buying non-food "stuff." Break it down into the following categories:

- Electronics, appliances, and apparel
- Other products

6. Services

Estimate the amount of money you've spent during the past year buying services (e.g., education, entertainment, health care, phone service, charitable and political contributions, etc. – everything except transportation, energy, food, and manufactured goods). If somebody bought a service for you (e.g., the state or your parents paying your tuition), count that too. Rutgers' full-cost tuition is about $23 thousand/year.

Energy Calculations
In the following, we will do a number of calculations based on your data to estimate your annual energy consumption and associated CO_2 emissions.

In parts 1-4, we will extrapolate from your energy consumption over two weekdays and your energy consumption per weekend. We will then estimate your weekly energy consumption by multiplying your 2-weekday consumption by 5/2 and adding it to your weekend consumption. We will finally multiply this by 52 weeks/year to estimate your annual consumptions.

1. Transportation

a) Automobile Travel

For each car trip, calculate the gallons of gasoline used per passenger mile.[1] For example, for an 11 mile trip with two people (i.e., a 22 passenger mile trip) in a Honda Civic getting an average of 34 vehicle miles per gallon:

> 22 passenger miles / (34 vehicle miles/gallon) = 0.32 gallons passenger/vehicle
> 0.32 passenger gallons/vehicle × 1 vehicle/2 passengers = 0.16 gallons

Add up all your weekday travel and your weekend travel to get your gasoline consumption per two weekdays and your gasoline consumption per weekend. Transform this total into a weekly estimate of gasoline consumption, and then into an annual estimate. Include any road trips or other infrequent travel in the annual estimate.

Gasoline has an energy content of about 40 kWh/gallon. Multiply your annual gasoline consumption by this energy content to estimate your annual energy consumption from automobile transport.

Gasoline has a density of about 2.7 kg/gallon. It is composed largely of octane, which has a molecular composition of C_8H_{18}. The atomic mass of C is 12 g/mol and that of H is 1 g/mol; octane is therefore 84% carbon by mass. Gasoline therefore has a carbon content of about 2.3 kg C/gallon. CO_2 has a molecular mass of 44 g/mol (3.7 times greater than the isolated C atom). Combusting gasoline therefore yields emissions of about 8.4 kg CO_2/gallon. Estimate your CO_2 emissions from automobile transportation during the year.

For example:

> 200 gallons × 40 kWh/gallon = 8,000 kWh
> 200 gallons × 8.4 kg CO_2/gallon = 1,680 kg CO_2

b) Bus travel

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[1] A passanger mile is the product of the distance and the number of people conveyed; for example, two people moved going ten miles is twenty passenger miles.

Bus have a typical fuel efficiency of 6 miles/gallon. Assuming the average Rutgers bus has thirty passengers, this amounts to about 180 passenger miles/gallon. Extrapolate from your bus travel during the data collection period to estimate your associated fuel consumption, energy consumption and carbon emissions during the past year.

c) Train travel

A fully loaded Amtrak train averages about 190 passenger miles/gallon; assume trains generally run at half capacity. Amtrak and NJ Transit use diesel fuel, which has a similar energy and carbon content to gasoline. Extrapolate from your train travel during the data collection period to estimate your associated fuel consumption, energy consumption and carbon emissions during the past year. Remember to include any infrequent train travel in the annual estimate.

d) Air Travel

The efficiency of an aircraft depends upon how full an aircraft is; we'll simply use a typical efficiency of 50 passenger miles/gallon. Use this efficiency to calculate how many gallons of jet fuel were used in your air travel in the last year.

Jet fuel has a similar energy and carbon content to gasoline. Calculate your energy consumption and CO_2 emissions from air travel in the last year.

e) Total Liquid Fuels Consumption for Transportation

Add up the liquid fuels (gasoline, diesel, jet fuel) you consumed in all your transportation for the past year, along with its energy content and CO_2 emissions.

2. Heating and Cooling

a) Hot Water

Typical flow rates for different uses of hot water are:

- Hot shower: 11 liters/minute
- Baths: 110 liters each
- Dishwasher: 45 liters/load
- Sink: 8 liters/minute
- Laundry, hot: 90 liters/load
- Laundy, warm: 40 liters/load

Calculate your use of hot water during the data collection period. Extrapolate to calculate your hot water consumption for the past year, remembering to adjust your weekly and annual estimates to correctly count laundry use.

The heat capacity of water is 4.2 kJ/liter/°C (equivalently, and by definition, 1 kcal/liter/°C). That is to say, it takes 4.2 kJ of energy to heat 1 liter of water 1°C. Since we're using units of kWh in this exercise, we'll convert to Wh and call the heat capacity 1.2 Wh/liter/°C. Assume water comes into Rutgers at 10°C (50°F) and is heated using a gas boiler to 60°C (140°F). This is a warming of 50°C. Under ideal conditions it would take

$$50°\text{C} \times (1.2\ \text{Wh/liter/°C}) = 0.06\ \text{kWh/liter}$$

to heat hot water. Assume the boiler is 90% efficient and that 20% of heat is wasted in distributing hot water around campus. Then in practice it will take

$$0.06\ \text{kWh/liter} \times (1/0.9) \times (1/(1-0.2)) = 0.08\ \text{kWh/liter}$$

to heat hot water. Calculate your energy consumption for hot water during the past year.

Natural gas has an energy content of about 14 kWh/kg and is composed of methane (CH_4). Methane has a molecular mass of 16 g/mol, of which 12 g/mol is due to C. Calculate the mass of methane consumed during the past year and the associated CO_2 emissions released when methane is combusted to produced CO_2 and H_2O. (Recall CO_2 has a molecular mass of 44 g/mol.)

b) **Hot air**

Buildings lose heat by two methods: (1) conduction through a wall, ceiling, floor, or window, and (2) ventilation (i.e., exchange of inside and outside air). Leakiness can be reduced through better insulation (which reduces conduction) and reduced ventilation. For this exercise, we'll assume a typical leakiness per unit area of 2.0 W/m^2/°C.

Your energy consumption from heating is given by:

$$(\text{Inside Temperature} - \text{Outside Temperature}) \times \text{Leakiness} \times \text{Duration} / \text{Efficiency}$$

For example, if I have a 700 square foot (65 m^2) apartment, I keep my thermostat set at 68°F (20°C), the average temperature for a day is 5°C (41°F), and my furnace is 90% efficient, by energy consumption will be:

$$(20°\text{C} - 5°\text{C}) \times (2.0\ \text{W/m}^2/°\text{C}) \times 65\ \text{m}^2 \times 24\ \text{hours} / 0.9 = 39\ \text{kWh}$$

(For your reference, natural gas consumption is typically measured in therms; 1 therm is equal to 29.3 kWh).

Use your recorded high and low temperatures to calculate the average daily temperature, then calculate your heating energy consumption for the sampling period.

For longer periods of times, heating demands are usually related to something called a "heating degree day." A heating degree day is the number of degrees the average daily temperature is below a reference temperature (e.g., 65°F). So four days during which the temperature is 45°F would be 80 heating degree days. Note that the energy consumption per heating degree day is given by

1°F × Leakiness × 24 h / Efficiency

and that our standard value for leakiness per unit area is equal to 1.1 $W/m^2/°F$. In the same apartment described above, my heating energy consumption per degree day will be 1.9 kWh/heating degree day.

According to http://climate.rutgers.edu/stateclim_v1/norms/monthly/hdd.htm, there are typically about 5300 heating degree days (in °F below 65°F) in New Brunswick per year. So in the same apartment described above, if I keep my thermostat set at 65°F, I will consume about 25,000 kWh/year for heating. If I instead keep my thermostat at 70°F, then for every day the heat is on and temperature outside is below 70°F, I will consume an additional

5°F × Leakiness × 24 h / Efficiency = 9.5 kWh.

Conversely, if I keep my thermostat at 60°F, I will consume 9.5 kWh less.

Assume that the heat is on for 180 days/year. What is your annual energy consumption for hot air? Assuming your furnace is powered by natural gas, what are the associated carbon emissions?

c) **Cold Air**

Since it's still winter, we'll assume you didn't have air conditioning on during the data collection period and just do an annual calculation.

First, we'll calculate the cooling power used to cool your space; then, we'll calculate how long this power is employed during the course of the year.

Cooling power in the United States is measured in British Thermal Units (BTU)/hour. One British Thermal Unit/hour is equal to about 0.28 W of cooling power.

If you're in a centrally cooled building, we'll employ a contractor's rule of thumb: 12,000 BTU/h is sufficient power for 400 square feet. So calculate the air conditioning capacity needed for your living space; for example, for a 700 sq ft. apartment, this would be 21,000 BTU/h (6,150 W) cooling power.

Alternatively, if you use window air conditioning units, a typical unit has a capacity of 5000 BTU/h (1500 W cooling power), so calculate cooling power by multiplying 5000 BTU/h by the number of units. Since I have two units in my apartment, this gives me 10,000 BTU/h cooling power.

The energy efficiency of air conditioners is measured using a metric of unit of cooling energy per unit of electrical energy. In the U.S., we use Seasonal Energy Efficiency Ratios (SEER) with units of BTU cooling energy/Wh electrical energy. In Europe, they use units of Wh cooling energy/Wh electrical energy (makes more sense, right?).

A typical window air conditioner has a U.S. SEER of 9 BTU/Wh. A typical room air conditioner has a SEER of 13 BTU/Wh. So the electrical energy used to run my 10,000 BTU/h of room air conditioning (SEER of 9) for one hour is

10,000 BTU/h × 1 hour × (1 Wh/9 BTU) = 1.1 kWh

Calculate the electrical energy used to cool your space for one hour.

Cooling demand is proportional to cooling degree days, which are like heating degree days but measure degrees about 65°F.

Air conditioning isn't usually on twenty-four hours a day, though; it's usually running during the hottest hours of the day. Since the typical spread between high and low temperatures is about 20°F. So we'll assume a day with an average temperature of 65°F has a high of 75°F and a low of 55°F, and a day with an average temperature of 85°F has a high of 95°F and a low of 75°F. If your thermostat is set a 75°F, it won't quite turn out for the day with an average temperature of 65°F, and it'll be running 24 hours for the day with an average temperature of 85°F. The latter corresponds to 20 cooling degree days, so we'll assume 24 hours of A/C operation per 20 cooling degree days. Calculate your cooling energy demand per cooling degree day.

In the example above:

10,000 BTU/h × 24 hours/20 CDD × (1 Wh/9 BTU) = 1.3 kWh/CDD

According to http://climate.rutgers.edu/stateclim_v1/norms/monthly/cdd.htm, there are typically ~950 cooling degree days per year in New Brunswick. So my annual electricity consumption for cooling is about 1,235 kWh.

If the A/C is assumed to be used for 100 days/year, then if I keep the thermostat at 80°F instead of 75°F, I save about:

5°F × 100 days × 1.3 kWh/CDD = 650 kWh

Assume that the A/C is on for 100 days/year. What is your annual electricity consumption for A/C?

3. Lighting

A 100 W traditional incandescent bulb emits about 1,750 lumens of light, at an efficiency of 17.5 lm/W. A comparable compact fluorescent bulb uses about 25 W, for an efficiency of about 70 lm/W. Fluorescent tube lamps can have efficiencies as high as about 100 lm/W, as can advanced LED lamps.

So if I have 5 CFLs with a luminosity of 1,750 lumens (100 W incandescent equivalent) that I use for 6 hours, my electrical energy consumption is

$$5 \times 25 \text{ W} \times 6 \text{ hours} = 750 \text{ Wh}$$

Calculate your electricity consumption for lighting during the sampling period, and extrapolate to the past year.

4A. Electronics and Appliances

Calculate your electricity consumption from appliances and equipment during the sampling period, and extrapolate to the typical week and the year. Typical wattages are listed below.

You can use these wattages, or identify the wattages for the actual equipment your using. There are two ways to do this: for some products, you could look up power on the Internet; for Energy Star labeled products, the Energy Star website (energystar.gov) is a helpful resource; for products that meet California minimum standards, you can also look at the California Energy Commission database (http://www.appliances.energy.ca.gov/).

Alternatively, look on the back or bottom of the item, and it usually is written there. If it does not indicate the wattage, then look for the amperage (A). The number of amps multiplied by 120 (volts) is equal to the wattage.

	Watts
Refrigerator (large)	750
Refrigerator (medium dorm size)	330
Refrigerator (small dorm size)	300
Washing machine	375
Clothes dryer (hot)	5,000
Clothes dryer (warm)	2,500
Hair dryer	1,875
Microwave oven	1,450
Fan	50
Computer (desktop, not incl. display)	100
Computer (laptop)	85
Phone/camera/e-reader charger	7
Clock	4
LCD Television/Display (19”)	30

LCD Television/Display (27”)	60
LCD Television (40”)	100
LCD Television (55”)	150
Plasma Television (65”)	250
Set-Top Box (DVR, DVD, etc.)	15
Stereo	100

4B. Total Electricity Consumption

Add up your estimated annual electricity consumption from air conditioning, lighting, electronics, and appliances.

The electric transmission and distribution system in the United States is about 95% efficient. Accordingly, increase your total to account for transmission and distribution losses.

In 2009, power plants in New Jersey generated 62 TWh (62×10^9 kWh) of electricity. The state also had net imports of 14 TWh from neighboring states.

In 2011, grid-based electricity generation (not including distributed solar) in New Jersey came from:

Nuclear	52%
Natural gas	38%
Coal	9%
Renewables	1%

While average grid-based generation in neighboring states (the PJM Interconnect) came from:

Coal	56%
Nuclear	34%
Natural Gas	8%
Oil	1%
Renewables	1%

Thus average grid-based electricity consumed in New Jersey (~82% from in state and ~18% from out-of-state) comes from:

Nuclear	49%
Natural Gas	33%
Coal	17%
Renewables	1%

This compares to the national grid:

Coal	47%
Nuclear	21%
Natural Gas	20%
Hydro	7%
Wind	3%
Other Renewables	1%
Oil	1%

According to Meier (2002), life cycle CO2-equivalent emissions of greenhouse gases (i.e., including the energy used in manufacturing plants and extracting resources as well as the combustion process) are:

Coal	1.03 kg/kWh (of which, 1.02 kg/kWh from combustion)
Natural Gas	0.62 kg/kWh (of which, 0.51 kg/kWh from combustion)
Nuclear	0.02 kg/kWh
Renewables	0.02 kg/kWh

So the average lifecycle CO_2 intensity of electricity consumed in New Jersey is about 0.4 kg/kWh. (This compares to a national average of 0.7 kg/kWh).

Calculate your annual CO_2 emissions from electricity.

The electric energy consumption figure calculated just now cannot be directly compared to those calculated for transportation (liquid fuels) or heating (natural gas), because it refers to consumption of electrical energy rather than energy in primary fuels. About 67% of the primary energy in fossil fuels is lost as heat in the generation of electricity; only about 33% makes it to the grid. Calculate the primary energy consumption associated with your electrical energy use. For example, 400 kWh electricity consumption corresponds to 400 kWh/0.33 = 1,210 kWh primary energy consumption.

5. Food

Eshel & Martin (2006) estimate the following efficiencies for different foods, in terms of kcal food output/kcal fossil energy input. (Note that a kcal is a food Calorie = 4.184 kJ = 1.2 kWh). The fossil energy inputs are primarily for fertilizers, farm machinery, fuel, irrigation, and pesticides.

Chicken	18.1%
Milk	20.6%
Eggs	11.2%
Beef	6.4%
Pork	3.7%
Lamb	1.2%

Herring	110%
Tuna	5.8%
Salmon	5.7%
Shrimp	0.9%
Corn	250%
Soy	415%
Apple	110%
Potatoes	123%

Using these and an online calorie calculator (e.g., http://www.webmd.com/diet/healthtool-food-calorie-counter) estimate your caloric intake from these different sources. For foods not listed, classify them as a kindred food type: for herbivorous fish, use herring; for carnivorous fish, use salmon; for shellfish, use shrimp; for grains, use corn; for fruits and vegetables, use potatoes; for legumes, use soy.

Use the Eshel & Martin efficiency estimates to estimate the amount of fossil energy underlying your diet in the two days your recorded. (Remember that 1,000 food Calorie = 4.184 MJ = 1.2 kWh). For example, 200 food Calories from chicken (efficiency of 18.1%) require input of 1,100 kcal (1,320 kWh) of fossil energy.

Extrapolate to your annual fossil energy consumption in food.

About 40% of food in the United States is lost as food waste, so increase your consumption accordingly to account for this 60% efficiency. Increase your totals by another 10% to account for energy used for transportation and packaging.

Assuming a carbon intensity of~0.2 kg CO_2/kWh, estimate your associated CO_2 emissions.

6. Manufactured goods

It is quite involved to calculate the energy and carbon embodied in material consumption, so we will do a very crude approximation. Multiply your expenditures over the past year by the energy intensities indicated below, which are averages of manufacturing energy per gross output in US dollars.

- Electronics, appliances, and apparel (0.1 kWh/dollar)
- Other products (1.0 kWh/dollar)

Sum up the energy embodied in products you purchased during the past year.

Increase your estimates by 10% to account for energy used for transportation and packaging.

Assume manufacturing emissions have a carbon intensity of 0.2 kg CO_2/kWh. What are the associated CO_2 emissions?

7. Services

We will crudely estimate your energy consumption and CO_2 emissions associated with your consumption of services (e.g., education, entertainment, health care, phone service, charitable and political contributions, etc. – everything except transportation, energy, food, and manufactured goods).

In 2011, the commercial sector in the U.S. consumed about 5.4 trillion kWh of primary energy, had CO_2 emissions of about 1,000 Mt, and had gross output of about $18 trillion. Therefore, assume each dollar you spent on services was associated with about 0.3 kWh of primary energy and 0.06 kg of CO_2.

What is the energy consumption and CO_2 emissions associated with your consumption of services over the last year?

8. Summary

Create a summary table tabulating your annual primary energy consumption and associated CO_2 emissions from:

- Transportation
- Heating
- Electricity
- Food
- Material consumption
- Services

Estimate your total annual primary energy consumption.

How do your primary energy consumption and associated CO_2 emissions compare to the world average (21,000 kWh/person/year and 4.9 tonnes CO_2/person/year)? How do they compare to the US average (about 94,000 kWh/person/year and 17.6 tonnes CO_2/person/year)?

(Note that U.S. average is not corrected for the energy and carbon embodied in imports, which is roughly included in your totals; with this correction, the U.S. average is about 100,000 kWh/person/year and 19 tonnes CO_2/person/year).

Identify some weaknesses in our methodology. How might they affect your results?

Reducing Your Footprint

Consider some personal and societal measures that would affect your energy and carbon budget. What would be the consequences of:

1) Replacing all your incandescent bulbs with CFLs? Replacing all your bulbs with advanced LED lamps that produce 100 lm/W?

2) Removing red meat from your diet? Switching to a vegan diet?

3) Replacing your refrigerator with one that is twice as efficient?

4) Reducing the leakiness of your home/apartment by 80%?

5) Replacing your furnace with an electric heat pump (essentially, an air conditioner running in reverse) with a SEER rating of 14? (Remember to take into account the difference between final electrical energy and primary energy.) How about replacing your furnace after reducing the leakiness of your home by 80%?

6) Also using the heat pump to provide hot water? (Assume the ratio between energy demand for the heat pump and energy demand for the boiler is the same as between the heat pump and the furnace.)

6) Increasing the efficiency of manufacturing by 30%?

7) Using buses or trains instead of driving? (Assume the societal investments that make this possible take place.)

8) Replacing half of air travel with trains running at full capacity (190 passenger miles/gallon)?

9) If the energy intensity of services declines proportional to the reductions in the energy intensity of heating + electricity resulting from the above?

Considering both the situation with none of the above measures implemented and all of the above measures implemented:

10) Replacing all the coal on the NJ and PJM grids with natural gas? With renewables? Replacing all the coal with renewables, and also replacing natural gas with a 50/50 mix of nuclear and renewables?