

## Economics of Electricity

J2\$

kW versus kWh; marginalism &amp; market structures

Much of the material in the following slides comes from Principles of Economics by N. Gregory Mankiw

## Watts up? kW versus kWh<sup>†</sup>

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- A kWh is a measure of *energy* - how much fuel is used by something over a period of time
- Similarly, BTUs, Calories, therms, and Joules are measures of energy
- Electricity supplies energy in a form that can be used to run appliances, machines, etc.
- However, expressing energy in terms of kWh doesn't mean much unless we know the time period over which it was measured
- And to comparisons of kWh consumption requires standardization on the time periods involved

<sup>†</sup> See <http://www.energylens.com/articles/kw-and-kwh>

## Power



James Watt

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- A kW is a measure of *power* - the rate at which energy is converted from one form into another
- Loosely speaking it's the rate at which energy is being used or generated
- Joules per second and Watts are the same thing:  $1 \text{ W} = 1 \text{ J/sec}$
- A kilowatt is 1000 watts [ $\text{W} = 0.001 \text{ kW}$ ]
- A 3 kW wind turbine is capable of generating 3 kW of power: the rate at which it can generate energy; *not* the amount of energy it can generate
- A 60 W light bulb "uses" 60 W of power when it is turned on
- It doesn't matter how long it's turned on; when it's on it's using 60 W of power, when it's off it's using 0 W

## From Joules [Watts] to \$\$\$

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- To put an economic value on power we need to know how long it is being generated/consumed
- "Energy consumption" = average power [a.k.a. "load" or "demand"]  

$$\text{Energy [kWh]} = \text{Power [kW]} \times \text{Time [h]}$$
- 1 kW over a 30 minute period =  $1 * 0.5 = 0.5 \text{ kWh}$
- Check your understanding of the difference between kW and kWh:  

$$1 \text{ kWh over a 30 minute period} = 1 \text{ kWh}$$
- Calculate \$\$ by multiplying kWh consumption by price per kWh

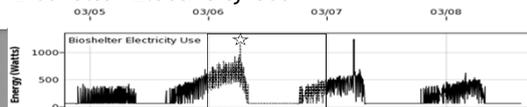
## Electricity Pricing Schemes

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- Prices can change over time (PUC approved rate changes; monthly in some situations)
- Prices can change by time of day
- Prices can vary by maximum ('peak') demand
- Block pricing
- Taxes
- Incentive programs to reduce consumption; 'nudges'
- 'Green' power [See <https://megreenpower.com/overview>]
  - 1.5 cents more per kWh; purchased in 'blocks'; Maine-based renewable energy

## Bioshelter Electricity Use

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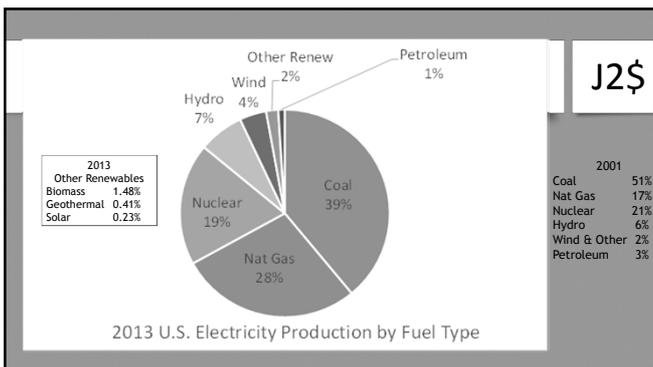
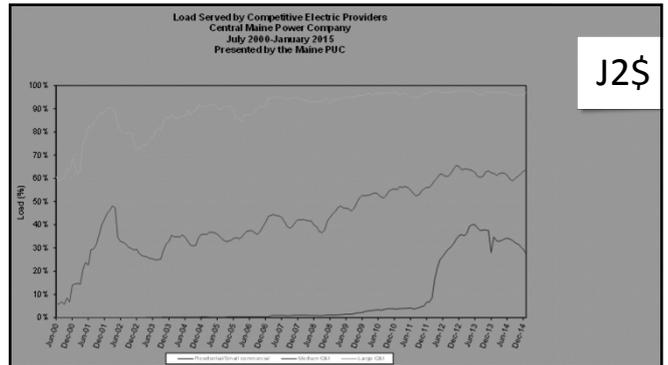
- Pick a 24-hr period: March 6, 2015
- At 0:05am I recorded 28.52 Wh [(342.24 W) × (1/12 h)]
- ...
- At 6:25am I recorded 1,163.89 W or 96.99 Wh
- Total Wh for March 6<sup>th</sup>: 6,884.447 Wh or 6.884447 kWh
- Average price of electricity: \$0.158
- March 6<sup>th</sup> cost me \$1.09 (about \$33 per month × 5 months = \$165/yr)

### A 'typical' residential electric bill J2\$

- Information on the bill
- 'Standard offer'
- Green Power options
- 75 "Competitive Electricity Providers" for CMP residential customers

Maine Green Power allows you to select the participation level that best suits your home or business:

- Half block – 250 kWh per month - \$3.75 (Available to residential customers only)
- 1 block – 500 kWh per month - \$7.50 (Roughly equivalent to the average households usage)
- 2 blocks – 1000 kWh per month - \$15
- 3+ blocks – Residential customers are limited to 4 blocks (at \$7.50 each), but businesses can set their desired level.



### Marginalism J2\$

- Thinking like an economist means evaluating behavior "... at the margin"
- Your decision to prepare now for your midterm next week isn't about whether or not to study at all ...
- ...it's about whether to devote an extra hour to working on this course versus an hour at the gym, or playing a video game, or spending time with your friends
- Your answer to this dilemma will likely be different this week than, say, next Thursday evening as the opportunity cost of not studying increases

### Production J2\$

Assume diminishing marginal products for at least some factors of production

Marginal product of labor

- Amount of additional output you get from employing one additional worker for a fixed stock of capital
- Slope of the production function
- Marginal product of the first worker is greater than the 100<sup>th</sup> worker

### Costs of production J2\$

**Fixed costs (FC)**

- Do not vary with the quantity of output produced
- Incurred even if the firm produces nothing at all
- Examples: rent on office space; insurance premiums; generators; flue gas scrubbers (a.k.a. 'sunk' costs)

**Variable costs (VC)**

- A function of the level of output
- Examples: unit labor costs; fuel costs

**Implicit costs**

- Require no outlay of money from the firm
- Examples: opportunity cost; reputation effects; brand loyalty

## Average &amp; Marginal Costs

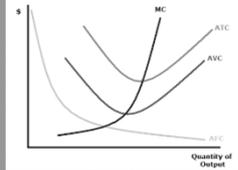
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## Average total cost

- Average fixed cost + average variable cost
- $ATC = TC / Q$
- Cost of producing a typical unit of output

## Marginal cost

- Change in total cost / Change in output
- $MC = \Delta TC / \Delta Q$
- Cost of increasing production by one additional unit
- MC equals ATC at the minimum point on the ATC curve



## Competitive Markets

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- Three key characteristics
  1. Many buyers and sellers
  2. Homogenous goods and services
  3. No barriers to entry/exit
- Result: the actions of a single buyer or seller will not impact the equilibrium market price

## Monopoly

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- Barriers to entry cause monopolies
- Only one seller/producer
- Other firms cannot enter the market because they can't compete with it

## Three main reasons why monopolies arise:

1. A key resource is owned by a single firm
2. Government gives exclusive rights to produce a good or service
3. Costs of production make a single producer more efficient than a large number of producers

## Other market structures

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## Oligopoly

- Only a few sellers, each offering a similar product
- Examples: athletic equipment; crude oil (OPEC)

## Monopolistic competition

- Many firms selling similar, but not identical products
- Examples: e-book sellers; digital music; computer games; movies

## Firm revenue

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## All firms:

- Total revenue:  $TR = P \times Q$
- Average revenue:  $AR = TR / Q$
- Marginal revenue:  $MR = \Delta TR / \Delta Q$
- Profit = total revenue - total cost

## Firms operating in competitive markets:

- P is determined by the market and does not vary with Q
- A 1 unit increase in Q increases total revenue by \$P
- Therefore,  $MR = P$

## Profit maximization

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- Economic profit: total revenue minus all of the opportunity costs (implicit and explicit) of producing the goods and services it sells
- Accounting profit: total revenue minus total cost
- Profit maximization occurs when  $MR = MC = P$
- Proof by contradiction ['suppose not']:
  - Suppose  $MR < MC$ : firm will reduce output since each additional unit costs more than it earns in revenue; marginal cost falls; profit increases
  - Suppose  $MR > MC$ : firm will increase output since each additional unit earns more than it costs; marginal cost increases; profit increases
  - When  $MR = MC$  the competitive firm will no longer have an incentive to change output

### Geometry of profit maximization J2\$

- MR equals the market price
- $AR = (P \times Q) / Q = P = MR$
- $MR > MC_1$  @  $Q_1$  so the firm can increase profit by increasing output
- $MR < MC_2$  @  $Q_2$  so the firm can increase profit by decreasing output
- Profit is maximized when  $MC = MR$  at  $Q_{max}$

### Competitive Firm's Supply Curve J2\$

- The marginal cost curve illustrates the quantity supplied by the firm at any give price
- Therefore, the MC curve is the competitive firm's supply curve
- For the competitive firm, the price of its output is pre-determined
- Therefore,  $MR = \$P$
- An increase in price (say, due to an increase in demand) causes  $MR > MC$  and the firm will respond by increasing  $Q$  to increase profit

### Shut-down decision J2\$

- The competitive firm ignores fixed costs in the decision whether or not to shut down
- As long as the firm can cover its variable costs it will remain in business
- Algebra:  
 Shut down if  $TR < VC$  or if  $TR/Q < VC/Q$   
 Since  $TR/Q = AR = P$  and  $VC/Q = AVC$   
 Shut down if  $P < AVC$

### Monopolies J2\$

Government created in the public interest

- Patent and copyright laws encourage investment, innovation, and creativity

Natural monopolies

- One firm can supply a good or service to an entire market at a lower cost than could two or more firms
- Economics of scale exist; ATC declines over the entire relevant range of production

### Monopolies J2\$

- Monopolies can control the price of its output by adjusting the quantity it supplies to its market
- Competitive firms have no control over price because they are small relative to the market
- The competitive firm's demand curve is equal to the market price (perfectly elastic)
- The monopolist's demand curve is the market demand curve
- Thus, market demand constrains the monopolist's production possibilities
- A monopolist can choose to produce at any point on the market demand curve

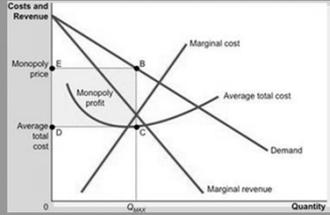
### Marginal Revenue for the Monopolist J2\$

- The monopolist's marginal revenue is always less than the price of its output because it faces a downward sloping demand curve
- To increase output, the monopolist must lower its price
- Thus, the monopolist's marginal revenue will always be less than its price
- $MR = \Delta TR / \Delta Q$
- When the monopolist increases output, there are two effects on  $\Delta TR$ :
  - TR increases due to the increase in  $Q$ , but
  - TR decreases due to the decrease in  $P$
- If  $Q$  gets large enough, the negative price effect can outweigh the positive output effect causing  $MR$  to become negative

Profit maximization for the monopolist

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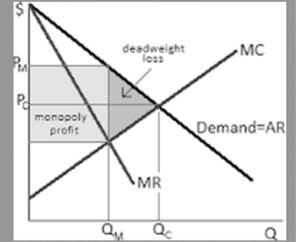
- Profit maximization once again occurs at the point where  $MR = MC$
- But for the monopolist,  $P > MR$



Problems with monopolies

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- Inefficient allocation of resources
- Socially efficient level of output occurs where the demand curve intersects the marginal cost curve
- The value to consumers (willingness to pay) equals the cost to the monopolist
- But the monopolist produces less than the socially efficient quantity of output
- Result is a deadweight loss to society



Government responses

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1. Antitrust Laws designed to increase competition
2. Regulation of prices
  - Unique challenge with natural monopolies
  - Setting  $P=MC$  means the monopolist loses money
  - Subsidies must be offset through higher taxes
  - Setting  $P=ATC$  means zero economic profit and no incentive for the monopolist to reduce costs through innovation or investments that increase productivity
3. Turn the private monopoly into a public corporation (e.g., the U.S. Postal Service)
4. Do nothing

