

Econ 366 – Energy Economics

Fall 2012

Topic 2a:

Residential Energy Demand

Household Demand for Energy

- “Energy” is demanded by households for its ability to produce heat / work
 - for example: space heating, operating appliances and home electronics (including charging phones, ipads, etc)
 - use of cars / public transit, although based on household decisions, usually included under ‘transportation’

Levels of Aggregation

- Disaggregated:
 - *demand for energy by an individual household for a particular energy type (e.g., electricity) or for energy in general (requires conversion to a common unit of measurement)*
- Aggregated
 - demand of entire residential 'sector'
 - Usually by region / country

Microeconomic Analysis of Energy Demand

- “derived demand”
- Households purchase energy to provide thermal comfort, lighting, run household appliances and home electronics.
- Multi-stage process whereby each individual decides:
 - (i) whether to purchase energy commercially
 - (ii) what type of equipment to use
 - (iii) how intensely / often to use the equipment (household capital stock)

OVERVIEW Figure 3.1 from Textbook

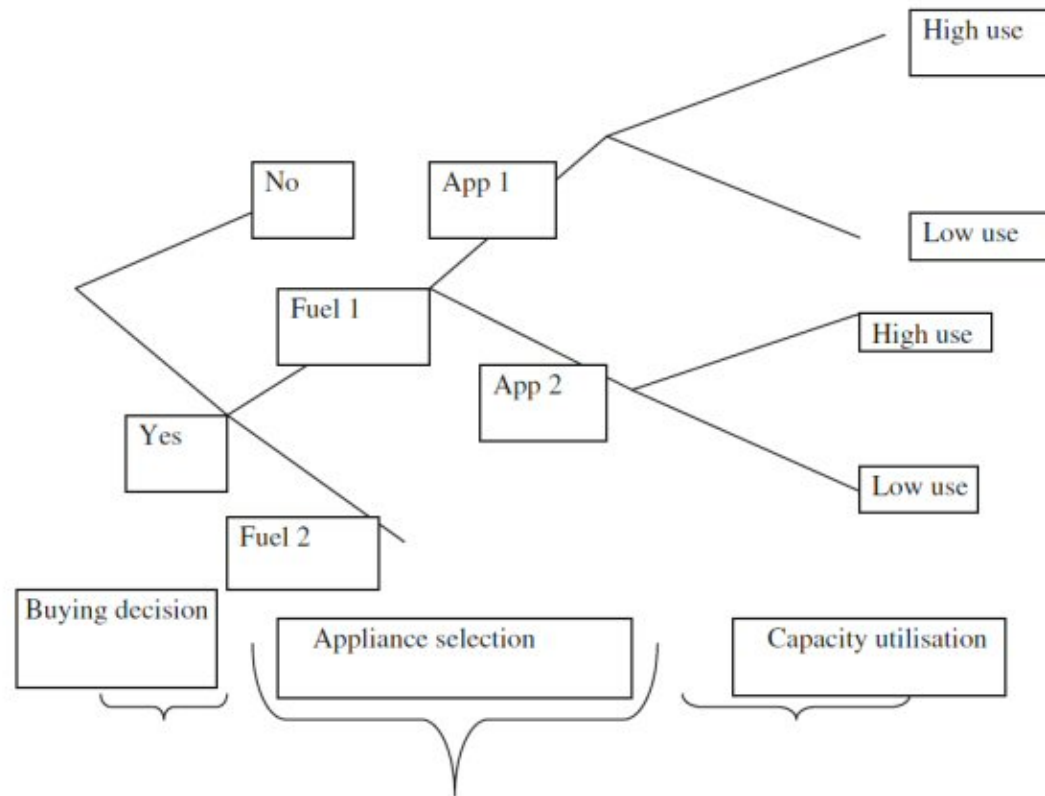


Fig. 3.1 Three-stage decision-making. Source Author

Microeconomic Analysis of Energy Demand

- (ii) what type of equipment to use
- Energy is often consumed on a daily basis, but equipment is only replaced periodically
- As a result, the demand for energy is sometimes said to be 'path dependent'.
- Long-term responses to prices (can adjust both the equipment used and how intensely it is used) are therefore different than short-term responses (can only adjust how intensely current equipment is used)
- These price responses are of interest to, among others, policy makers

Microeconomic Analysis of Energy Demand

- (iii) how intensely / often to use equipment
- This can be translated into how much energy must be purchased ([derived] quantity demanded)
- As with other purchased commodities, the amount demanded will depend on prices, income, and a variety of other factors.
- Residential demand for an individual household over a period of time (month, for example):
 - $Q^d = f(\text{own-price, income, other prices,})$

Microeconomic Analysis of Residential Energy Demand

Basic Consumer Theory of Demand

- Each household is assumed to choose the amount of energy that maximizes their utility (satisfaction, well-being, happiness)
- (Total) Utility is a function of the 'bundle' of goods consumed by the household (energy, food, clothing, etc.)
- $U = g(Q_E, Q_F, Q_C, \dots)$
→ $u(Q_E, Q_{\text{OtherGoods}})$

Marginal Utility

- Marginal utility = the increase in utility from a one unit increase in the quantity of a good that is consumed
- $MU = \Delta \text{utility} / \Delta \text{quantity}$
- Positive, but diminishing marginal utility is generally assumed, up to a point of 'satiation'
- Each increase in utility from consuming more energy, for example, comes at a cost: P_E dollars that could have been used to purchase something else

Budget Constraint

- Can't afford to keep increasing consumption of all goods until all MUs are zero: Budget constraint
- $\text{Income} = P_E Q_E + P_F Q_F + P_C Q_C + \dots$
- $\text{Income} = P_E Q_E + P_{\text{Other}} Q_{\text{Other}}$
- $\text{Max } u(Q_E, Q_{\text{Other}})$
subject to $\text{Income} = P_E Q_E + P_{\text{Other}} Q_{\text{Other}}$

Solution to this problem:

Mathematical Result

$$\frac{MU_E}{P_E} = \frac{MU_{Other}}{P_{Other}}$$

Interpretation

- marginal utilities per dollar spent on each commodity must be equalized
- otherwise, the household can increase utility by re-allocating their budget

Suppose that MUs are not equalized:

Utility NOT maximized

$$\frac{MU_E}{P_E} > \frac{MU_{Other}}{P_{Other}}$$

for example,

$$10 > 5$$

Interpretation

- additional utility per dollar spent on energy exceeds the additional utility per dollar spent on other goods
- should purchase more energy and fewer other goods
- leads to an increase in utility

Tracing out a demand relationship:

Deriving a Demand Schedule

$$\frac{MU_E}{P_{E0}} = \frac{MU_{Other}}{P_{Other}}$$

decrease price of energy

from P_{E0} to P_{E1} →

$$\frac{MU_{E1}}{P_{E1}} > \frac{MU_{Other}}{P_{Other}}$$

(at original quantities)

Method

- start in equilibrium and decrease (or increase) the price of energy (or income or the price of other goods)
- results in a new situation where the household is no longer maximizing utility
- figure out how quantities should be re-adjusted

Another Approach to Demand Analysis: Indifference Curves

- consumers make comparisons across bundles of goods (such as bundle A and bundle B)
- three possibilities for any 2 given bundles for a given household:

$u(A) < u(B) \rightarrow$ prefers B to A

$u(A) = u(B) \rightarrow$ indifferent between A and B

$u(A) > u(B) \rightarrow$ prefers A to B

Properties of Indifference Curves

- Downward sloping: to maintain the same overall utility, a decrease in one good must be compensated for by an increase in the other good.
- Slope = marginal rate of substitution = rate at which one good must be substituted for another in order to yield the same level of satisfaction
- Formula for slope 'derived' on board in class
- Indifference curves are convex due to diminishing marginal utility

Deriving a Demand Curve

- Each indifference curve represents a different level of utility
- Given the budget constraint, which is the 'highest' indifference curve that can be reached?
 - The budget constraint must be tangent to the indifference curve → utility-maximizing value of E
 - Holding the price of other goods constant, alter the price of E and trace out the utility maximizing quantities of energy (E)

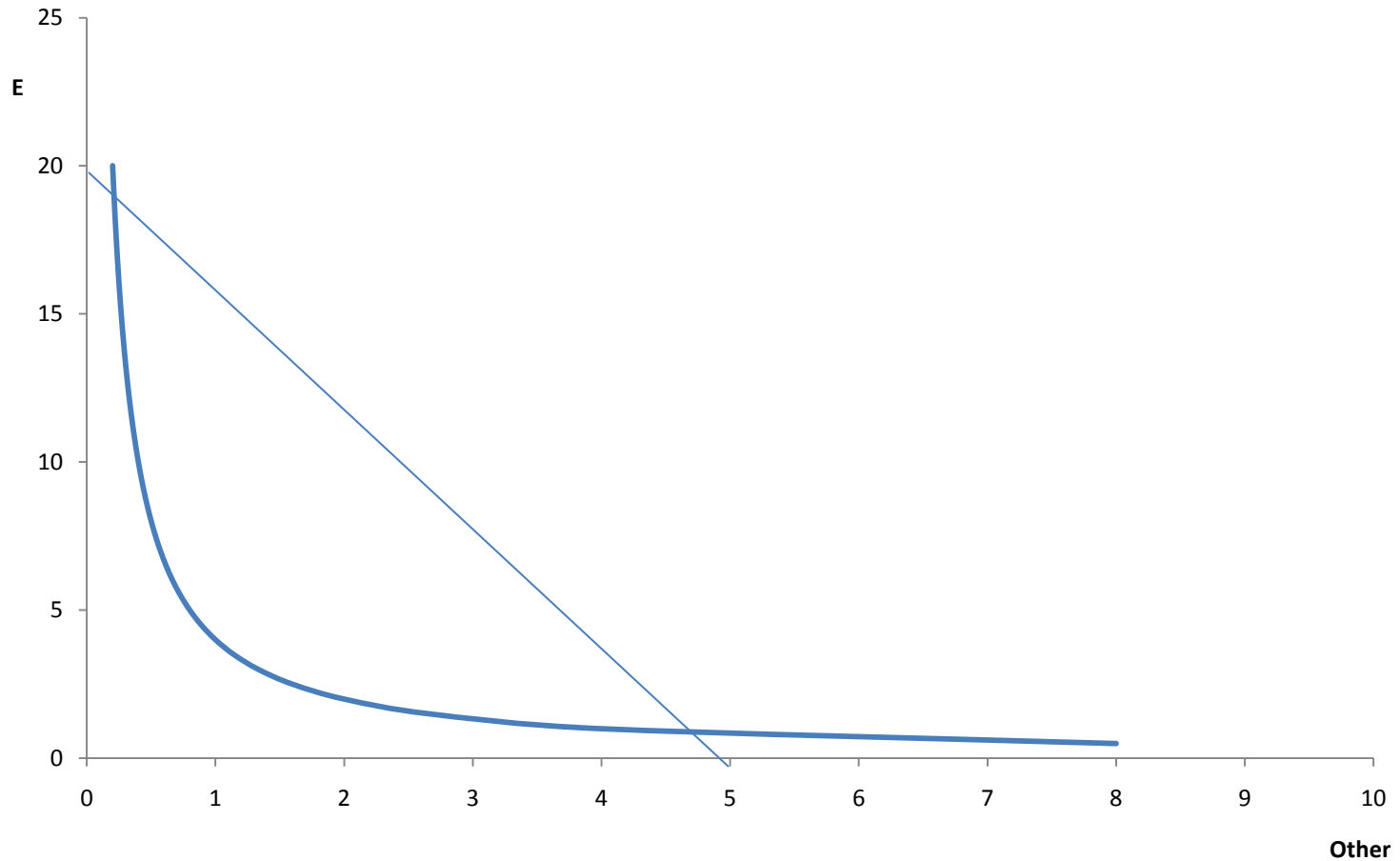
Deriving a Demand Curve: Textbook Example

- Budget Constraint: $100 = 5 \times Q_E + 20 \times Q_{Other}$
– i.e., start with $P_E = 5$ and $P_{Other} = 20$
- Utility Function: $U = \sqrt{Q_E \times Q_{Other}}$
- First, find the utility-maximizing Q_E for this initial price of energy

Indifference Curves and Cost of Purchasing Bundles: Utility = 2

Energy	Other	Utility	Cost
1	4	2	85
2	2	2	50
3	1.3333333	2	41.666667
4	1	2	40
5	0.8	2	41
6	0.6666667	2	43.333333
7	0.5714289	2	46.42857
8	0.5	2	50
9	0.4444444	2	53.888889
10	0.4	2	58
11	0.363636	2	62.27273

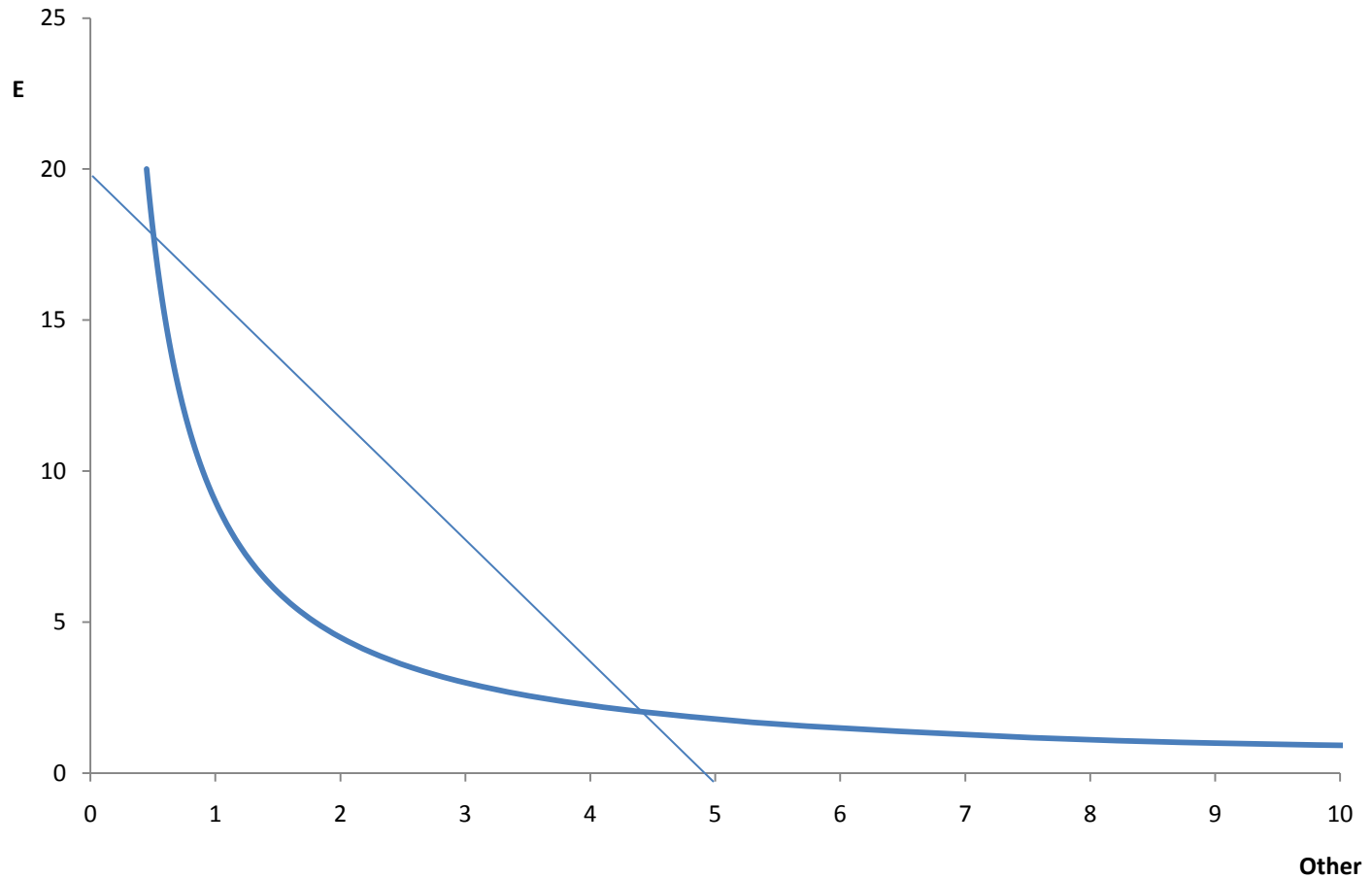
Budget Constraint and IC2 ($U = 2; E \times \text{Other} = 4$)



Indifference Curves and Cost of Purchasing Bundles: Utility = 3

Energy	Other	Utility	Cost
1	9	3	185
2	4.5	3	100
3	3	3	75
4	2.25	3	65
5	1.8	3	61
6	1.5	3	60
7	1.285714	3	60.71429
8	1.125	3	62.5
9	1	3	65
19	0.473684	3	104.4737
11	0.818182	3	71.36364

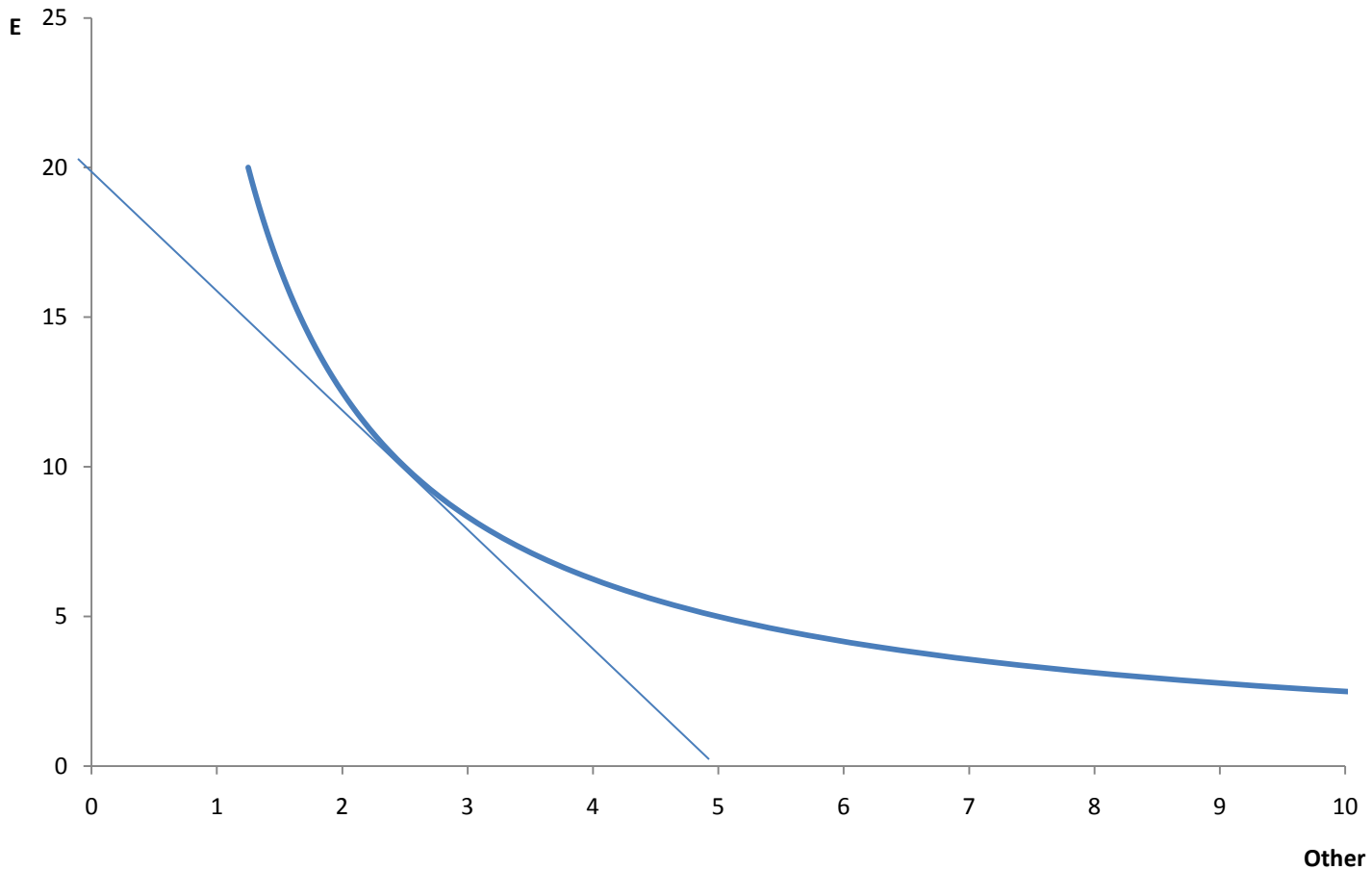
Budget Constraint and IC3 ($U = 3; E \times \text{Other} = 9$)



Indifference Curves and Cost of Purchasing Bundles: Utility = 5

Energy	Other	Utility	Cost
1	25	5	505
2	12.5	5	260
3	8.3333333	5	181.6667
4	6.25	5	145
5	5	5	125
6	4.1666667	5	113.33333
7	3.5714289	5	106.4286
8	3.125	5	102.5
9	2.7777778	5	100.5556
10	2.5	5	100
11	2.272727	5	100.4545

Budget Constraint and IC5 ($U = 5; E \times \text{Other} = 25$)



Deriving the Demand Curve (continued)

- We have found the utility maximizing value of Q_E for $P_E = 5$
- We now must repeat the process for other values of P_E
- When $P_E = 10$, the budget constraint changes (can no longer afford to buy 10 units of energy and 2.5 of other goods)
- The utility maximizing value of energy becomes $Q_E = 5$

Deriving the Demand Curve (continued)

- Once we have done this for several values of P_E , we can trace out the demand curve for one particular household
- To 'aggregate' up to the demand curve for energy in the entire residential sector, we need to add up over all households.
- To see what happens to demand when income changes, we would adjust the budget constraint changing this factor, holding P_E and P_{Other} constant
- To see what happens to demand when prices of other goods change, we would adjust the budget constraint changing this factor, holding P_E and Income constant

Other Factors that Affect Household Energy Demand

- Socio-economics and demographic factors: household size, whether or not somebody home during the day,
- Environmental factors: climate, hours of sunlight
- Building characteristics and technologies: thermal envelope, HVAC system, appliances and their energy efficiency characteristics

How is Energy Demand Different from that for “Ordinary” Goods?

- Residential Energy prices aren't observed as easily as those for other goods. Not bought in a store with a visible price tag. (CBEEEDAC study)
- Amounts purchased and costs observed with a lag (monthly electricity and natural gas bills; less frequent in some countries)
- Not all households pay directly for energy (CBEEEDAC study)
- Amount used today depends on previously purchased equipment (whose selection depended on previous prices and previous expected prices), and can lead to asymmetric reactions to price changes.

Long-term demand and improved technologies: rebound effects

- purchase of more energy efficient equipment means that the same 'output' (amount of heat, quantity of cooked meals) can be produced using less energy.
- If a technological improvement results in being able to heat your house with 15% less energy, will you use 15% less energy for heating?
- More on this later in the context of transportation

Residential Demand and Policy

- How can we use what we know about demand to help us to design policy?