Ethyl Lactate

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Presentation Outline

- Solvent
  - What is a solvent?
  - Characteristics of a good solvent
- Process considerations
  - Plant layout and process specifications
  - Equipment costs
  - Economic analysis
- Business Plan (Mathematical model)
  - Optimization
  - Business strategy

What is a Solvent?

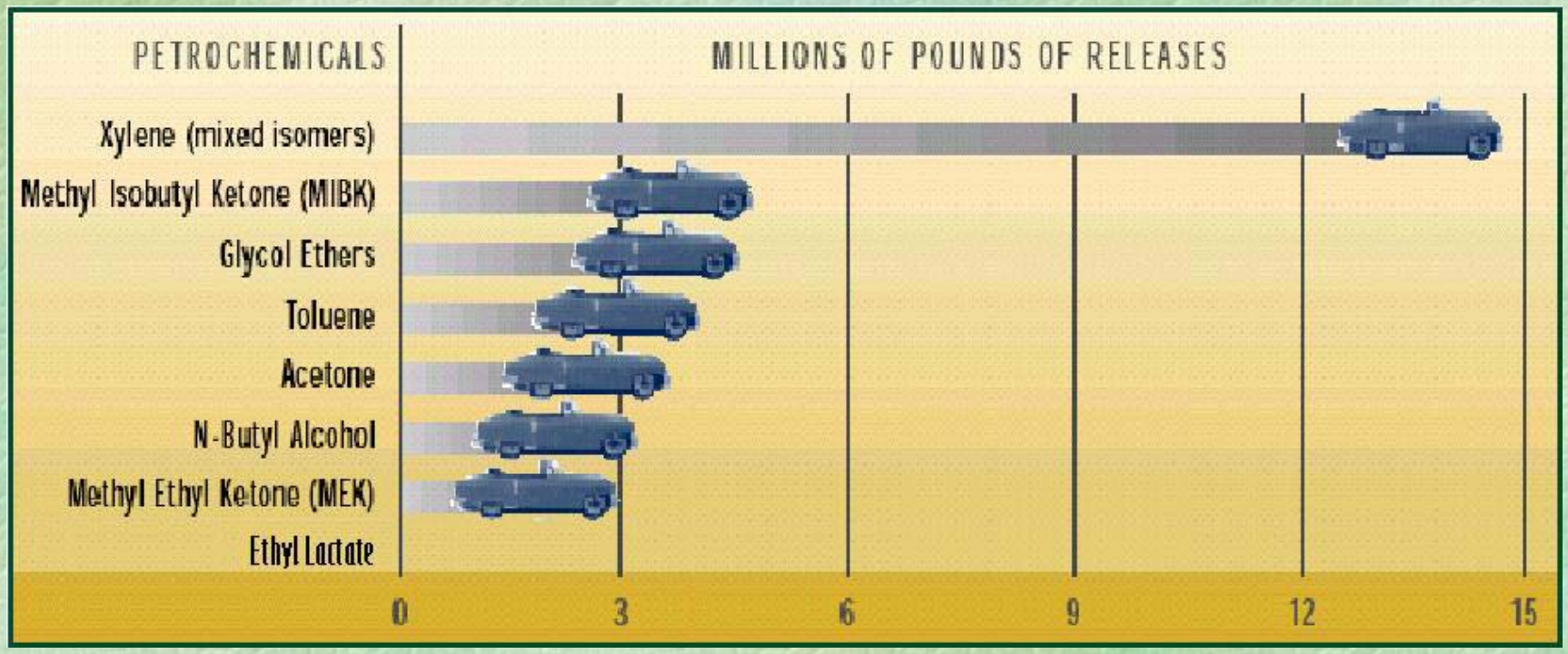
- Industrial uses
  - Removes grease
  - Cleaning purposes
- Dissolves hydrocarbons
- Volatility
  - High volatility – fast evaporation home use
  - Low volatility - safety, reuse, emissions

Conventional Solvents

Petroleum Based Organic Compounds

Toxic, EPA standards limit use

Added cost of disposal



http://www.p2pays.org/ref/07/06851.pdf

Green Solvents

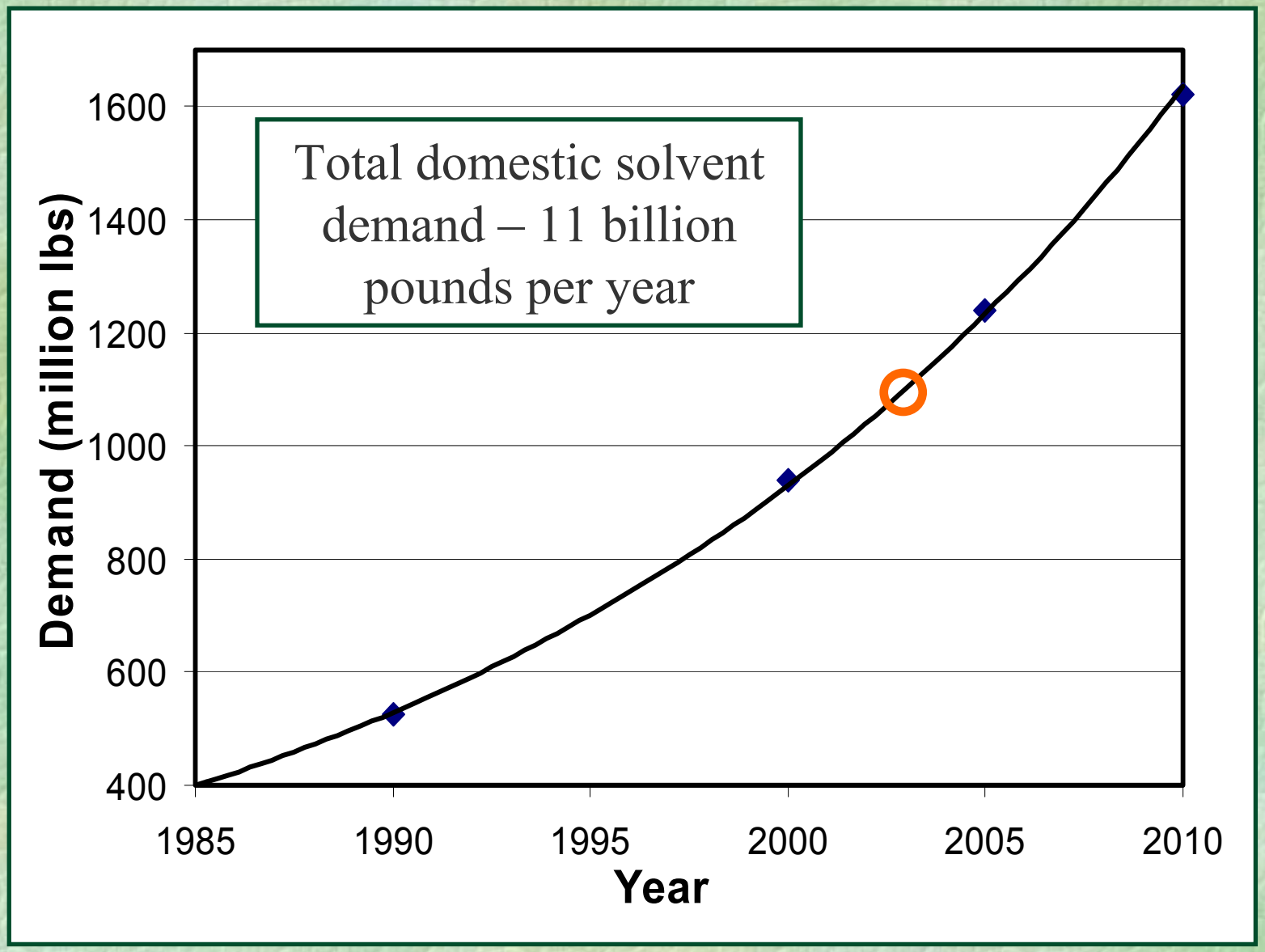
- Organic raw materials

  Renewable resources
- Non-toxic

  No disposal costs
- Non-volatile

  Safe and recyclable

Green Solvent Demand



Solvent Comparison

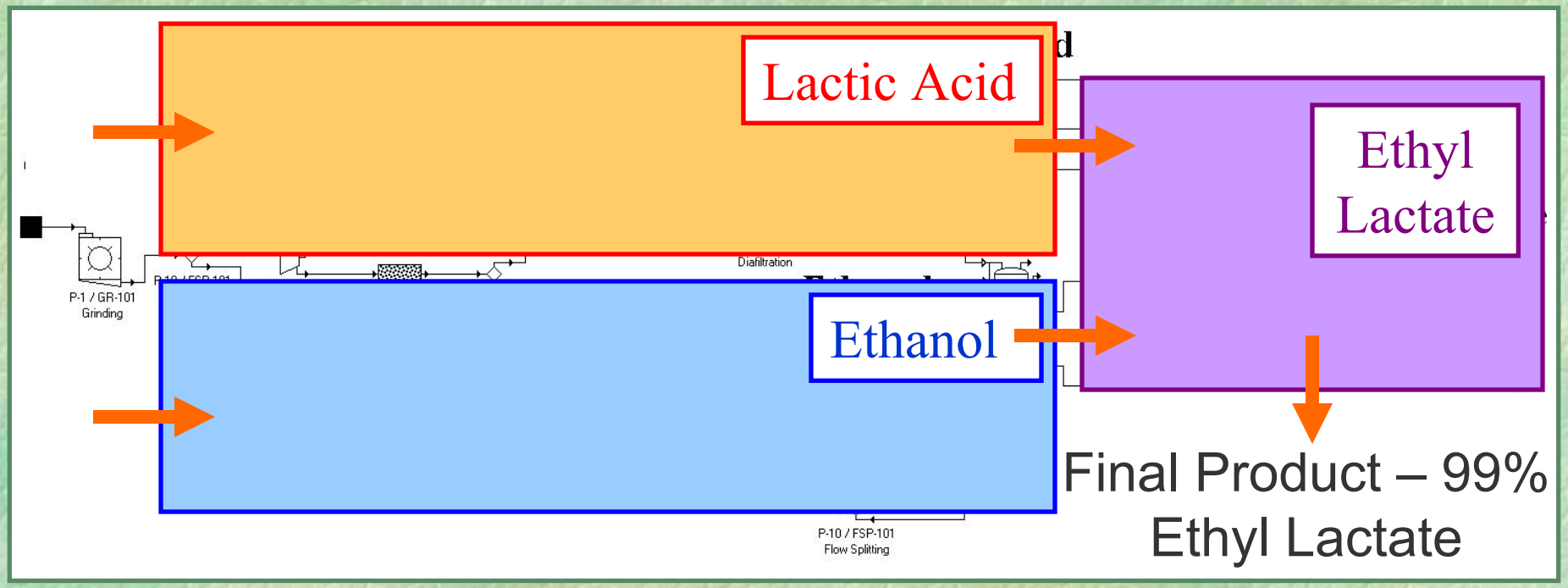
- EPA regulations
  - Toxic Release Inventory (TRI)
- Evaporation rate
  - Reusability in industrial applications
- Price ($/lb)
- Effectiveness
  - Ability for a solvent to maintain its characteristics when reused
  - Characterizes the strength of the solvent

Why Ethyl Lactate?

Solvents	Toxic Release Inventory (TRI)	Evaporation rate	Price($/lb)	Effectiveness (KB xylene =1)	Effective price ($/lb.eff)
Xylene	Yes	0.86	1.03	1	1.03
Toluene	Yes	2.4	1.05	1.025	1.02
Acetone	Yes	7.7	0.37	1.375	0.27
N-methyl 2-pyrolidone (NMP)	Yes	0.03	1.50	3.5	0.43
Methyl ethyl ketone (MEK)	Yes	6	0.46	1.275	0.36
Ethyl lactate	No	0.22	1.00	10	0.1

Ethyl lactate – effective, economic, non-toxic

Process Flow Diagram



$$C_2H_5OH + C_3H_6O_3 \rightarrow C_5H_{10}O_3 + H_2O$$

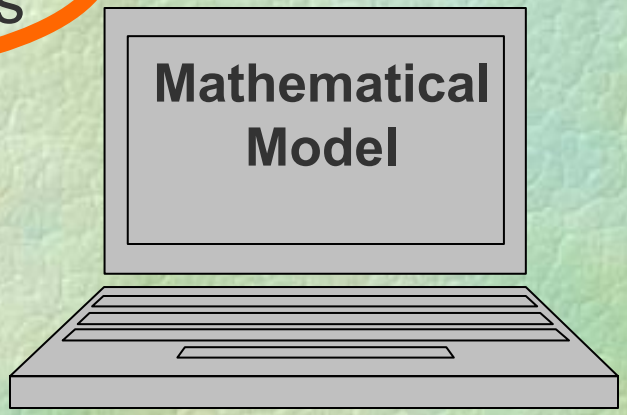
Innovations

- Electrodialysis
  - Traditionally useful for decreasing salt concentration in solution
  - Lactic acid purification
- Pervaporation
  - Traditionally useful for alcohol dehydration
  - Organic removal from water

Business Plan

Input

- FCI vs. Capacity
- Operating Costs
- Raw Materials
- Locations
- Distances
- Freight costs
- Taxes
- Demand
- Product Prices



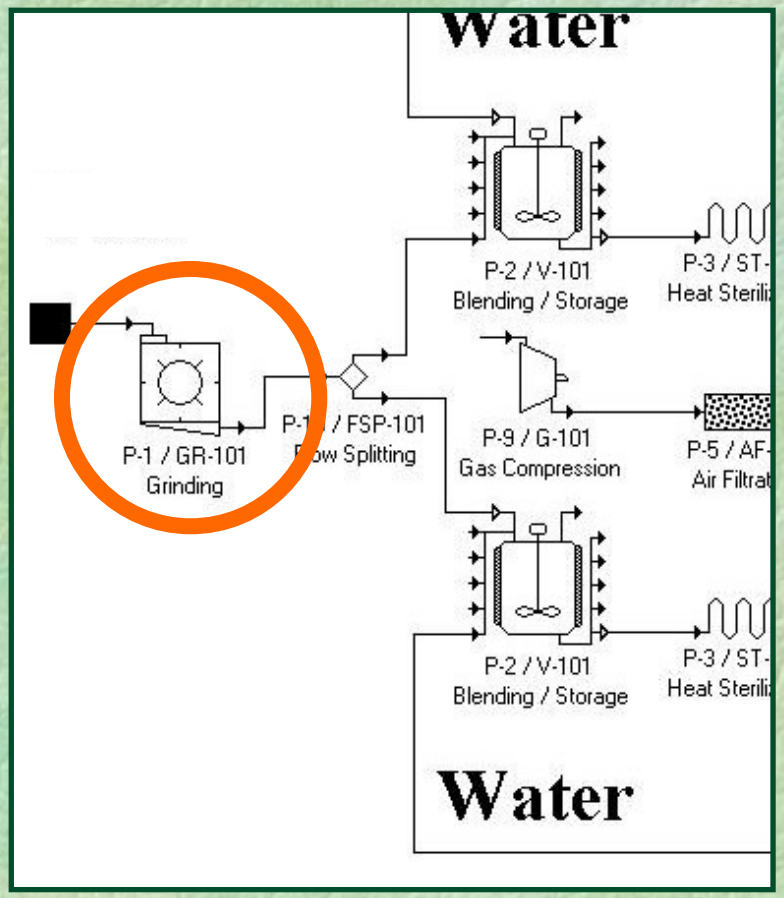
Output

- Number of plants
- Plant location(s)
- Product market(s)
- Raw material(s)
- Raw material market(s)

Base Equipment Costs

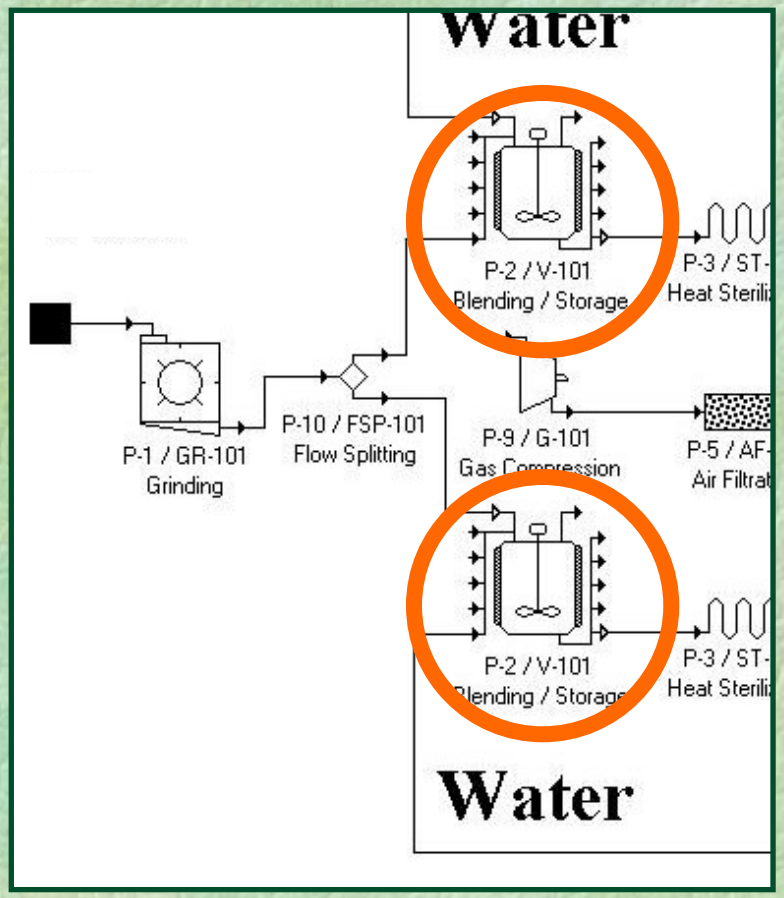
- Equipment costs are based on 63 million pounds of annual ethyl lactate production
  - Base equipment costs include no capital improvements
- Effects on capacity
  - Equipment based on maximum possible capacity, then set to lower operating conditions
  - Equipment can be added later

Raw Material Milling



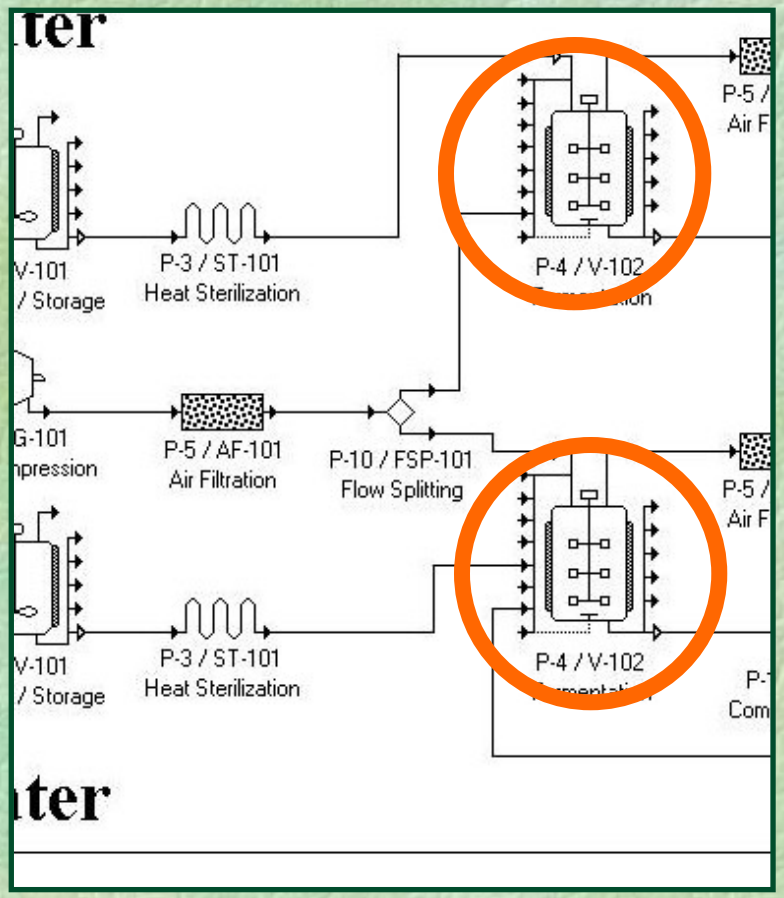
- Quantity – 3 units
- Total equipment cost $480,000
- Rated throughput – 41,000 lb h^{-1}
  - 327,000 lb per batch;
  - 72.7 million pounds annually
- Process time – 8 h

Blending Tanks



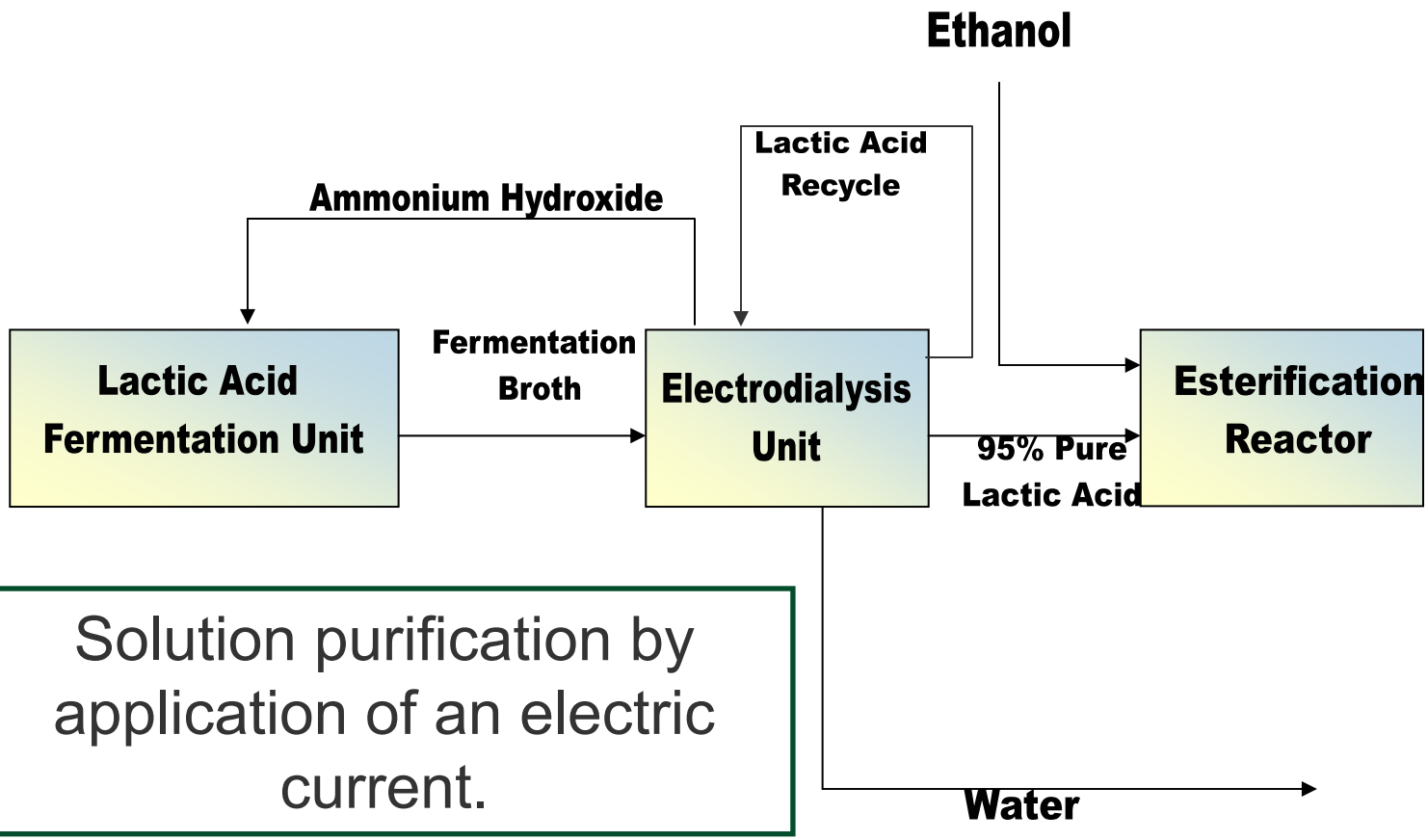
- Quantity – 10 units
- Total equipment cost $3,140,000
- Volume – 80,000 L
  - Blends water and sugars; 90-10 weight %
- Process time – 5.3 h

Fermentation



- Quantity – 14 units
  - 7 Ethanol-specific;
    7 lactic acid-specific
- Total equipment cost – $29,358,000
- Volume – 350,000 L
- Process time – 27 h

Electrodialysis Process

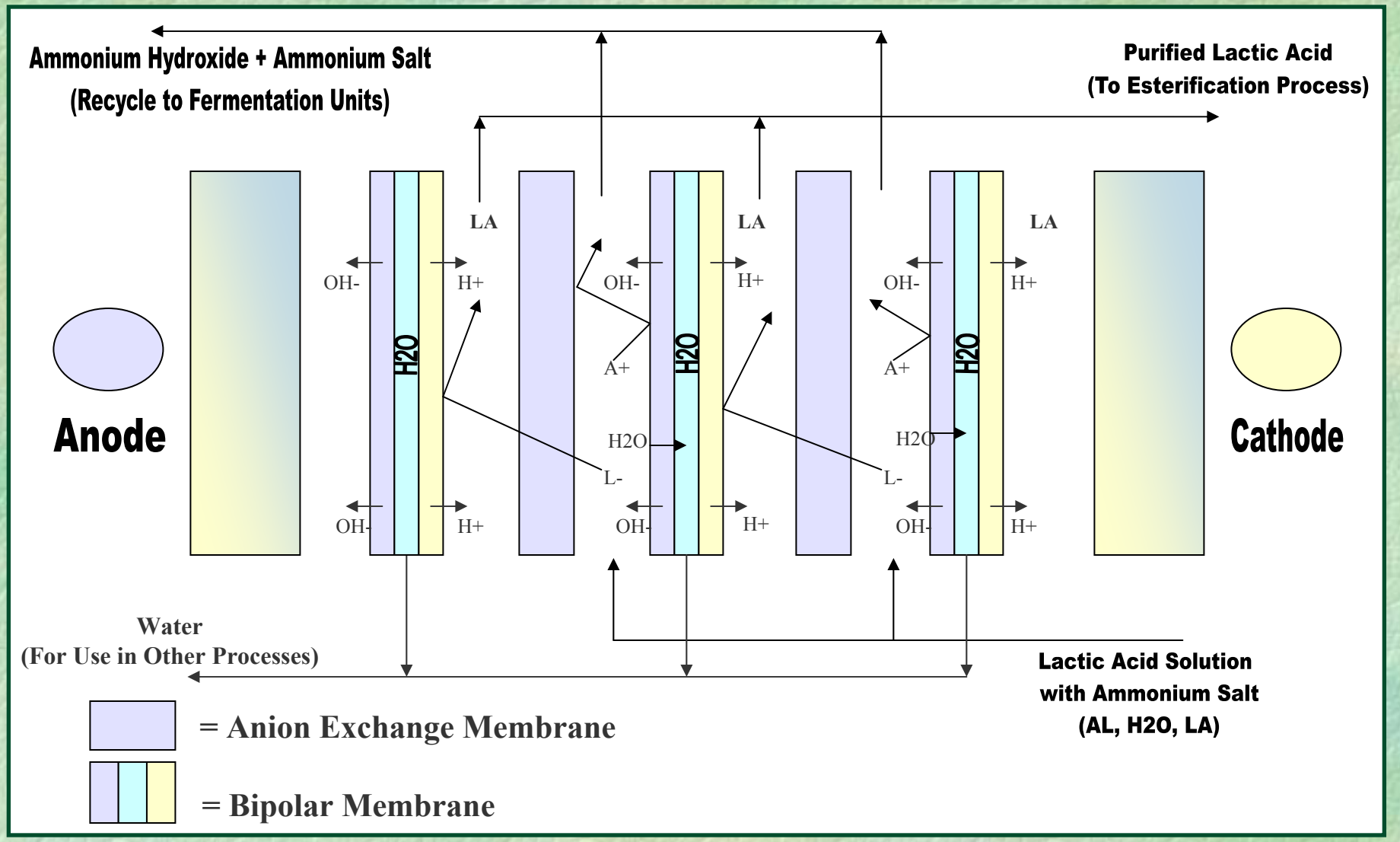


Solution purification by application of an electric current.

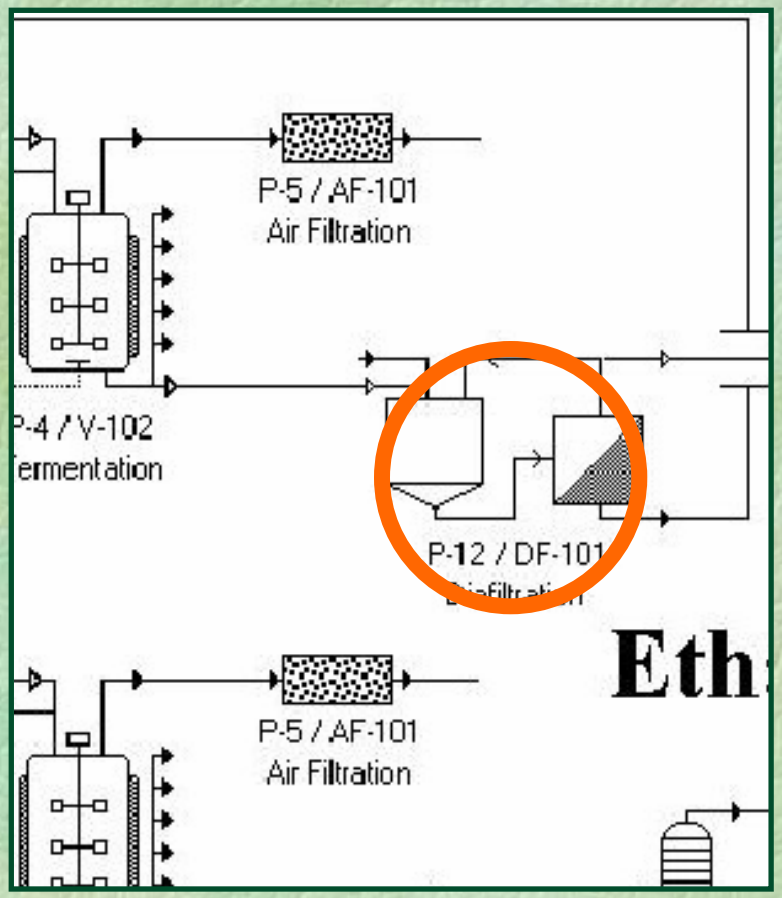
Lactic Acid Separation by Electrodialysis

- Why Electrodialysis (ED)?
  - Uses 90% less energy than traditional methods
  - Low operating cost
  - Pure Product
- Electrodialysis Equipment
  - Power Source
  - Anode/Cathode with rinse container
  - “Stacks”

Bipolar With Anion-Exchange Membranes ED

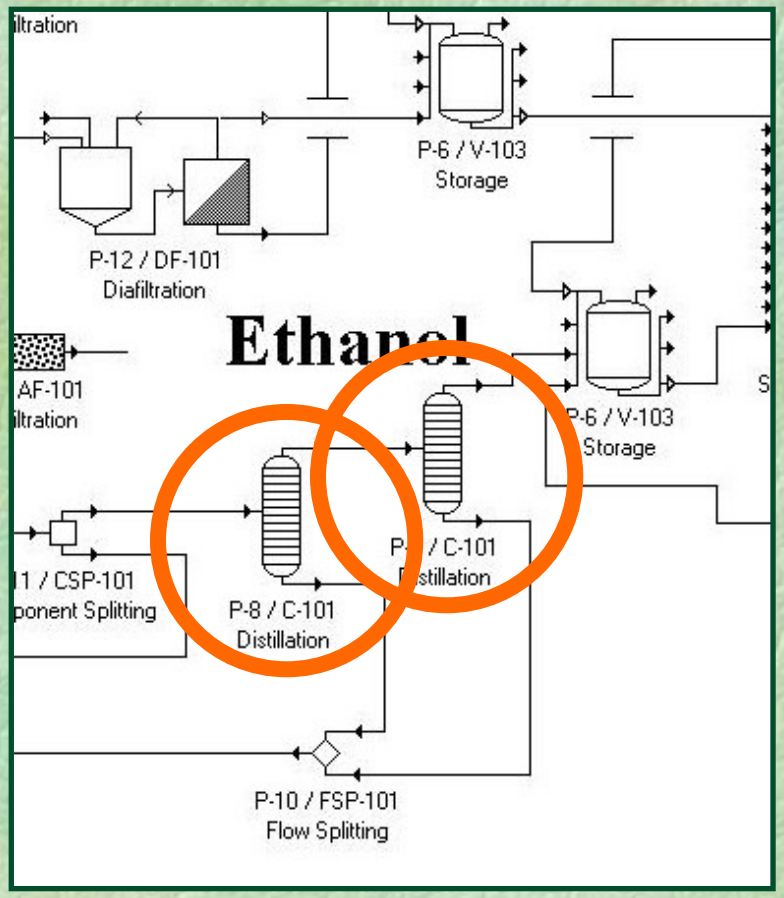


Electrodialysis Specifications



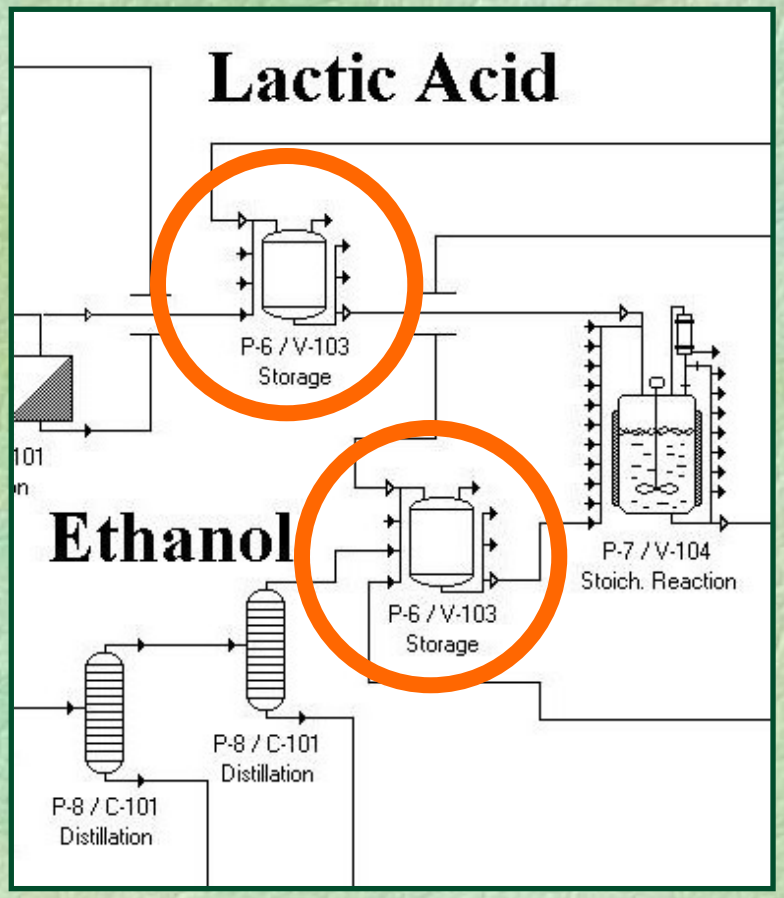
- Quantity – 1 unit
- Total equipment cost – $122,000
- Throughput – 105 gpm

Ethanol Distillation



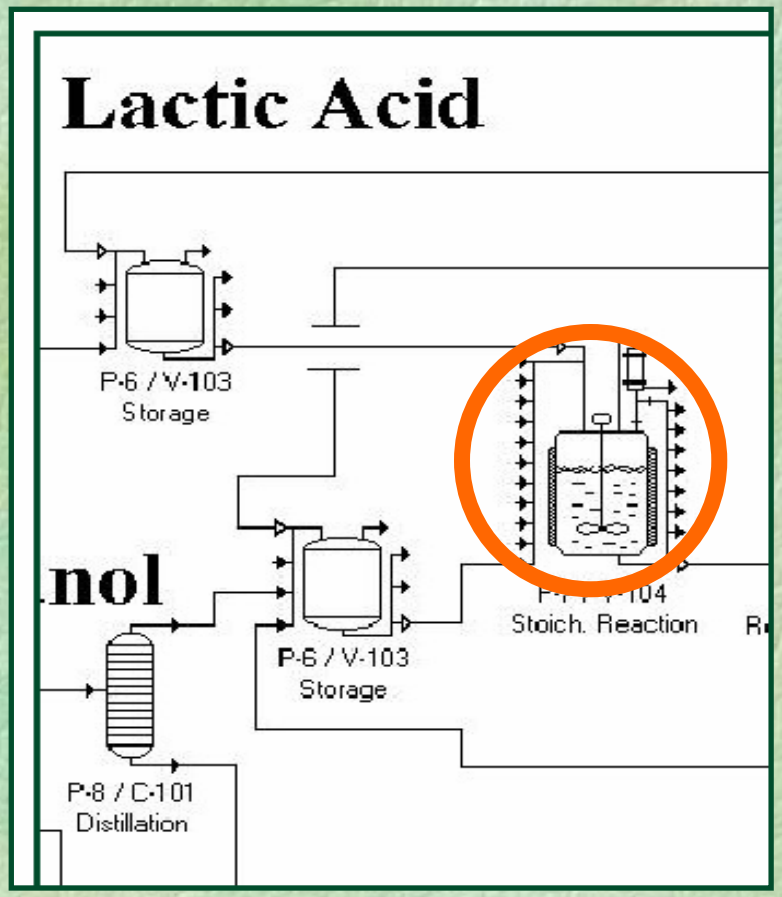
- Quantity – 2 units
- First column - $44,000
- Second column - $80,000
- Final purity – 95 wt%

Storage Tanks



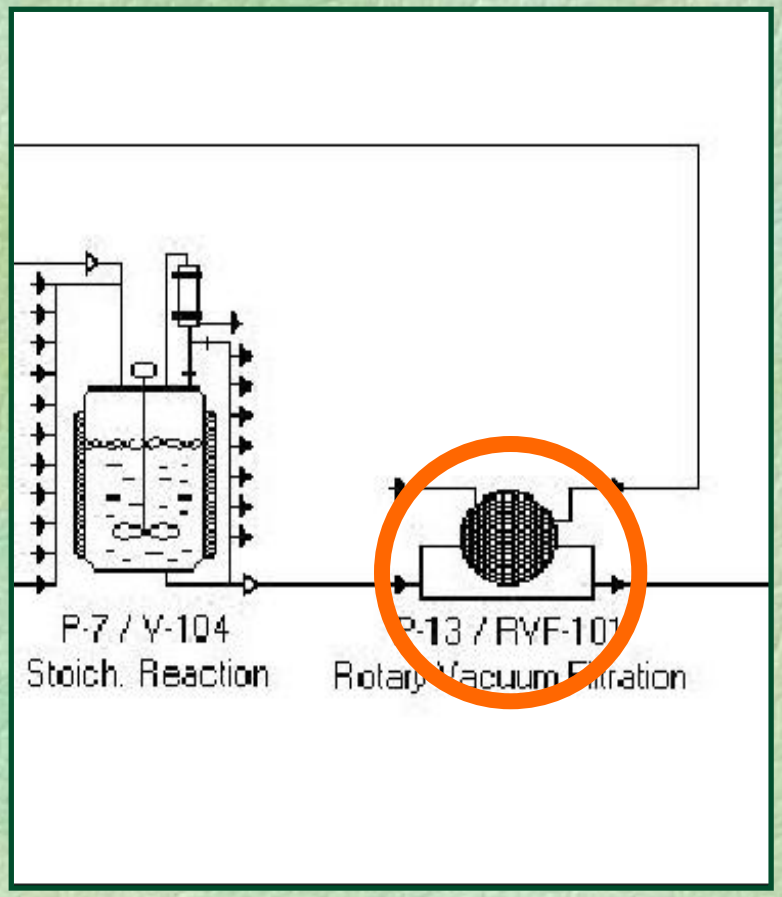
- Quantity – 24 units
- Total equipment costs – $7,512,000
- Volume – 80,000 L
- Ethanol, lactic acid, raw materials

Esterification Reaction



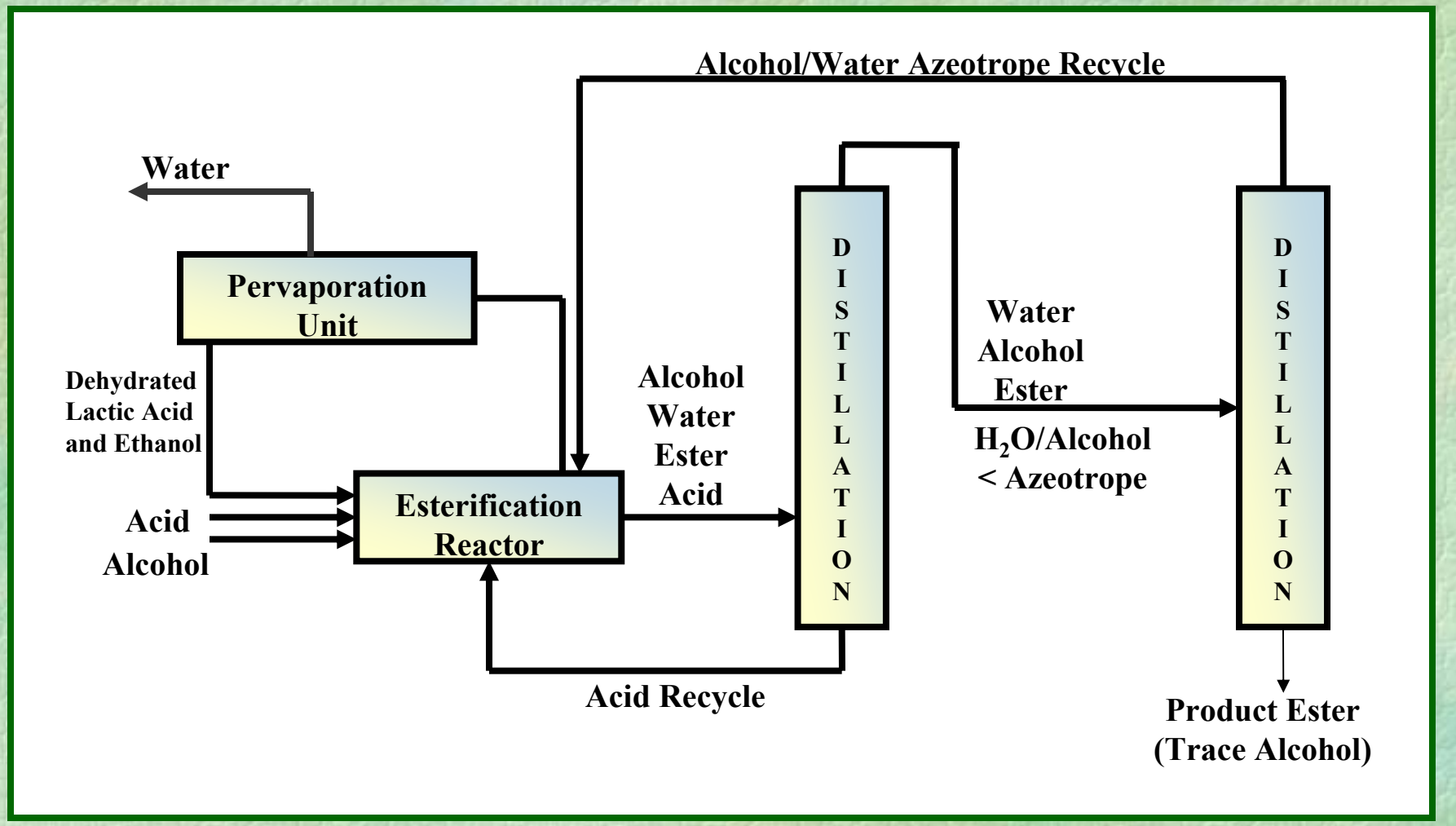
- Quantity – 9 units
- Total Equipment Cost
  - $3,730,000
- Volume – 32,000 L
  - produces 289,000 lbs of ethyl lactate per batch

Pervaporation

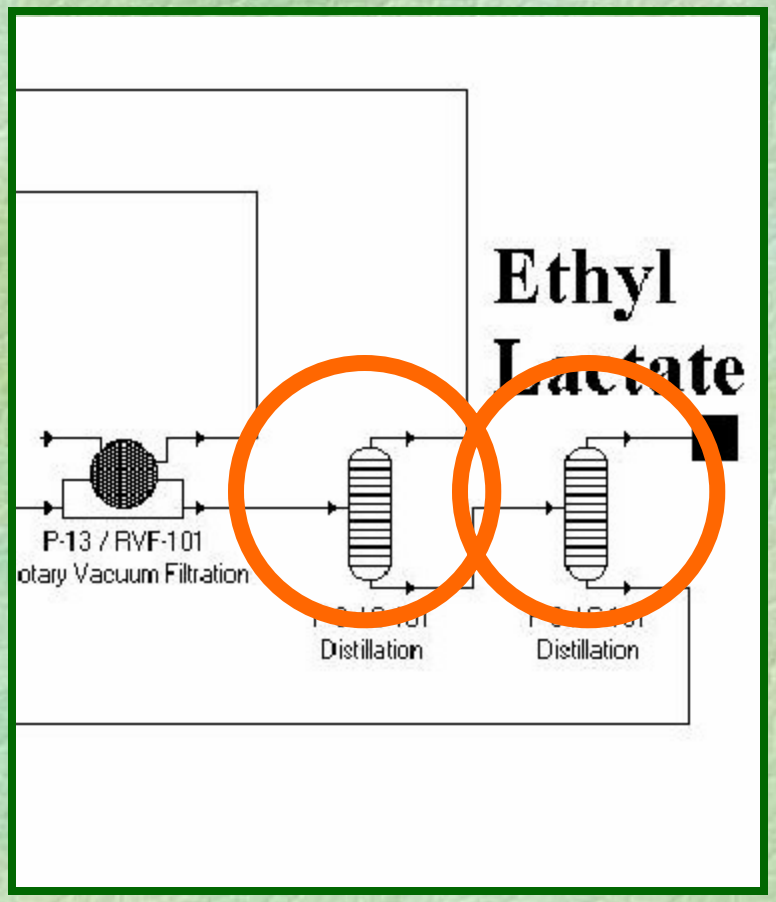


- Quantity - 4 units
- Total Equipment Cost
  - $620,000
- Throughput:
  - Total = 43 gpm
  - Unit = 11 gpm

Ethyl Lactate Production



Ethyl Lactate Purification



- Quantity – 2 units
- Total Equipment Cost
  - Column 1: $ 44,000
  - Column 2: $ 60,000
- Throughput
  - Column 1
    - 8450 lbmol/hr
  - Column 2
    - 5090 lbmol/hr

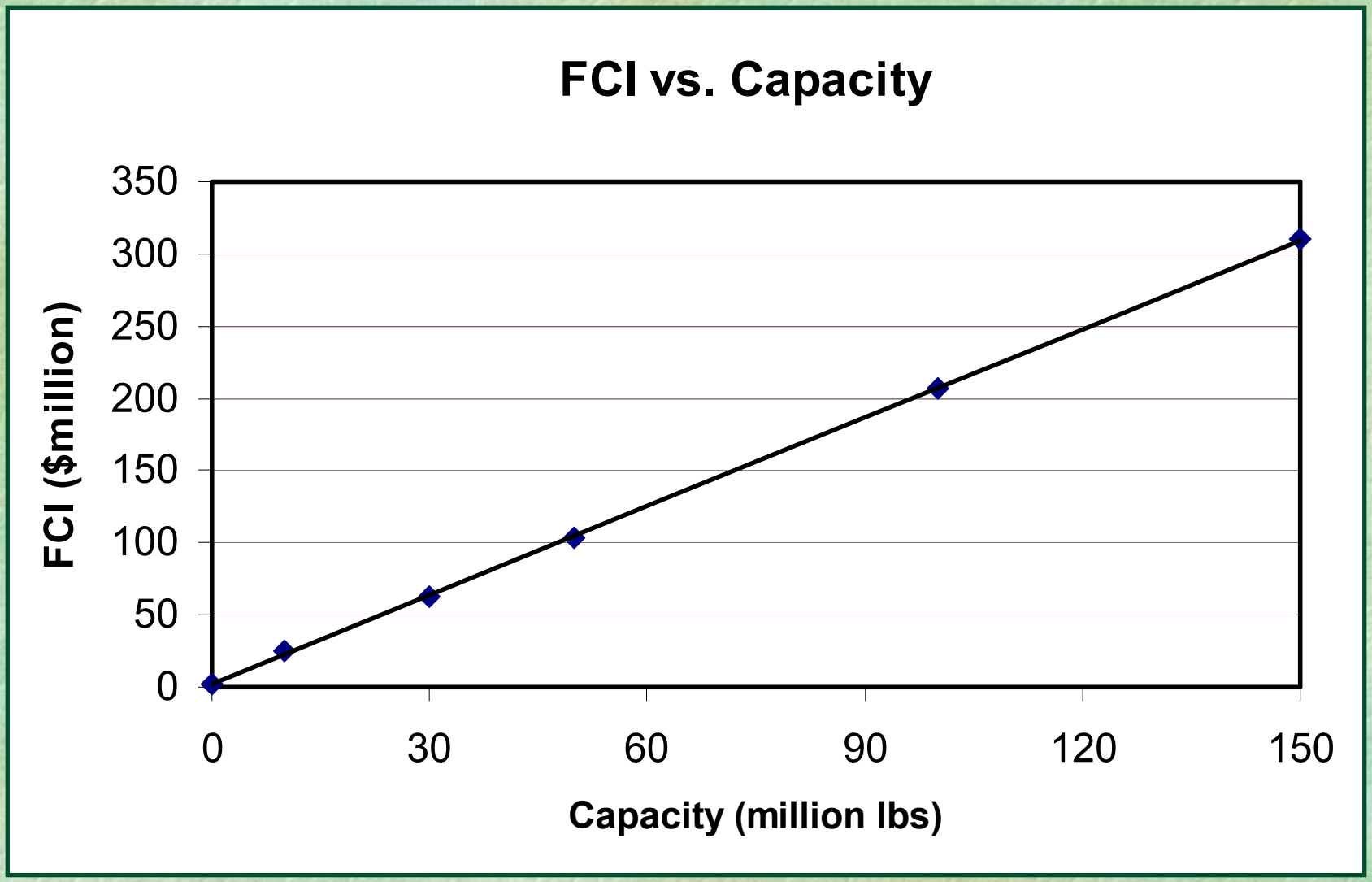
Ethyl Lactate Purification

- Column 1 - excess lactic acid removal
- Column 2
  - Distillate: Ethanol/Water Azeotrope
  - Bottoms: Ethyl Lactate (with trace alcohol)

Total Capital Investment

Item	48 mil lb	117 mil lb	175 mil lb	292 mil lb
1. Equipment Purchase Cost	43,000,000	105,000,000	150,000,000	261,000,000
2. Installation	8,210,000	18,000,000	26,200,000	44,100,000
3. Process Piping	2,700,000	6,050,000	8,880,000	14,900,000
4. Instrumentation	308,000	691,000	1,020,000	1,710,000
5. Insulation	2,310,000	5,190,000	7,610,000	12,800,000
6. Electricals	3,850,000	8,640,000	12,700,000	21,300,000
7. Buildings	3,470,000	7,780,000	11,400,000	19,200,000
Total Plant Direct Costs	63,900,000	151,000,000	217,000,000	375,000,000
8. Engineering	16,400,000	38,400,000	55,100,000	94,800,000
9. Construction	23,000,000	53,700,000	77,100,000	133,000,000
Total Plant Costs	103,000,000	243,000,000	350,000,000	603,000,000
10. Contractor's fee	5,220,000	12,200,000	17,600,000	30,300,000
11. Contingency	10,400,000	24,500,000	35,200,000	60,600,000
Direct Fixed Capital	119,000,000	280,000,000	402,000,000	694,000,000
Working capital	21,000,000	49,400,000	71,000,000	122,000,000
Total capital investment	**140,000,000**	**329,000,000**	**473,000,000**	**816,000,000**

FCI Versus Capacity



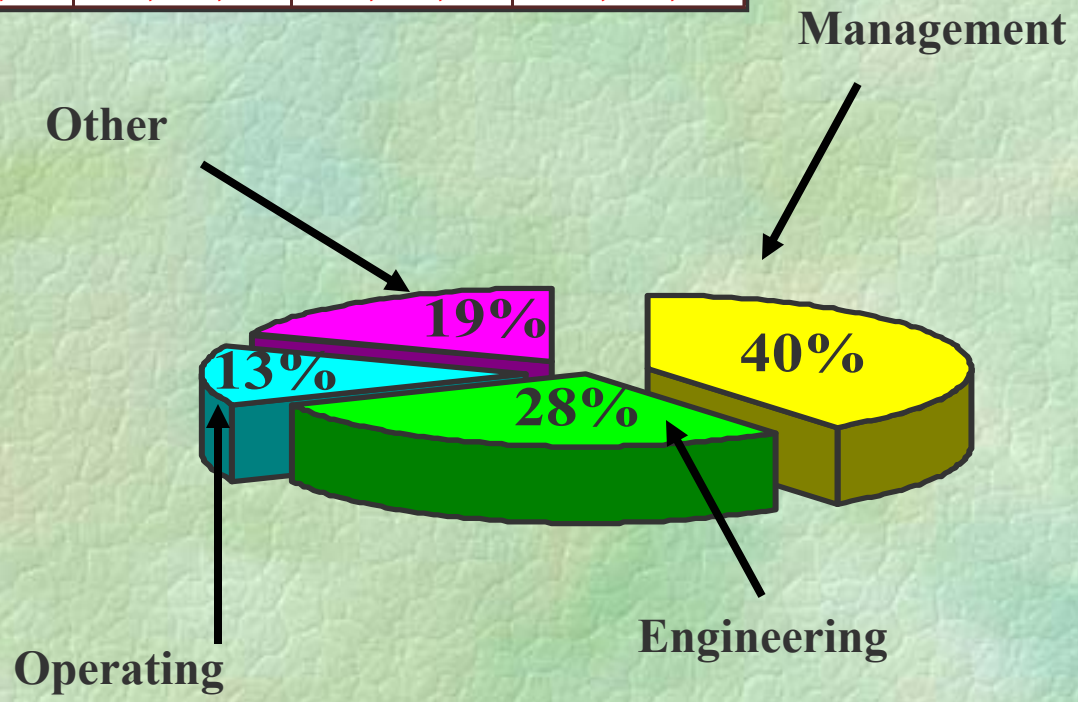
Total Product Cost

Total product cost		
I. Manufacturing cost = direct production costs + fixed charges + plant overhead costs		
A. Direct production costs		
1. Raw materials	at 64 million capacity $0.03/lb	$5,980,000
2. Labor cost	calculated from national wage data	$3,020,000
3. Utilities	simulated by SuperPro and Proll	$3,190,000
4. Maintenance and repairs	1% fixed capital investment	$1,560,000
5. Operating supplies	15% maintenance and repairs	$234,000
6. Laboratory charges	calculated based on operating labor	$83,000
7. Patents and royalties	Set aside portion for patents purchasing	$200,000
	subtotal	$14,300,000
B. Fixed charges		
1. Depreciation	sinking fund method applied on 8% interest	$3,410,000
2. Local taxes	1.5% local rate at Dayton, Ohio	$2,340,000
3. Insurance	1% of fixed capital investment	$1,560,000
4. Rent	calculated on land and buildings value	$411,000
C. Plant-overhead costs		$442,000
	subtotal	$22,400,000
II. General expenses =distribution and selling + financing		
A. Distribution and selling	2% of total capital investment	$628,000
B. Financing	borrowing charged on 5% TCI	$9,190,000
	subtotal	$9,820,000
III. Total product cost		**$32,300,000**

Annual Operating Cost

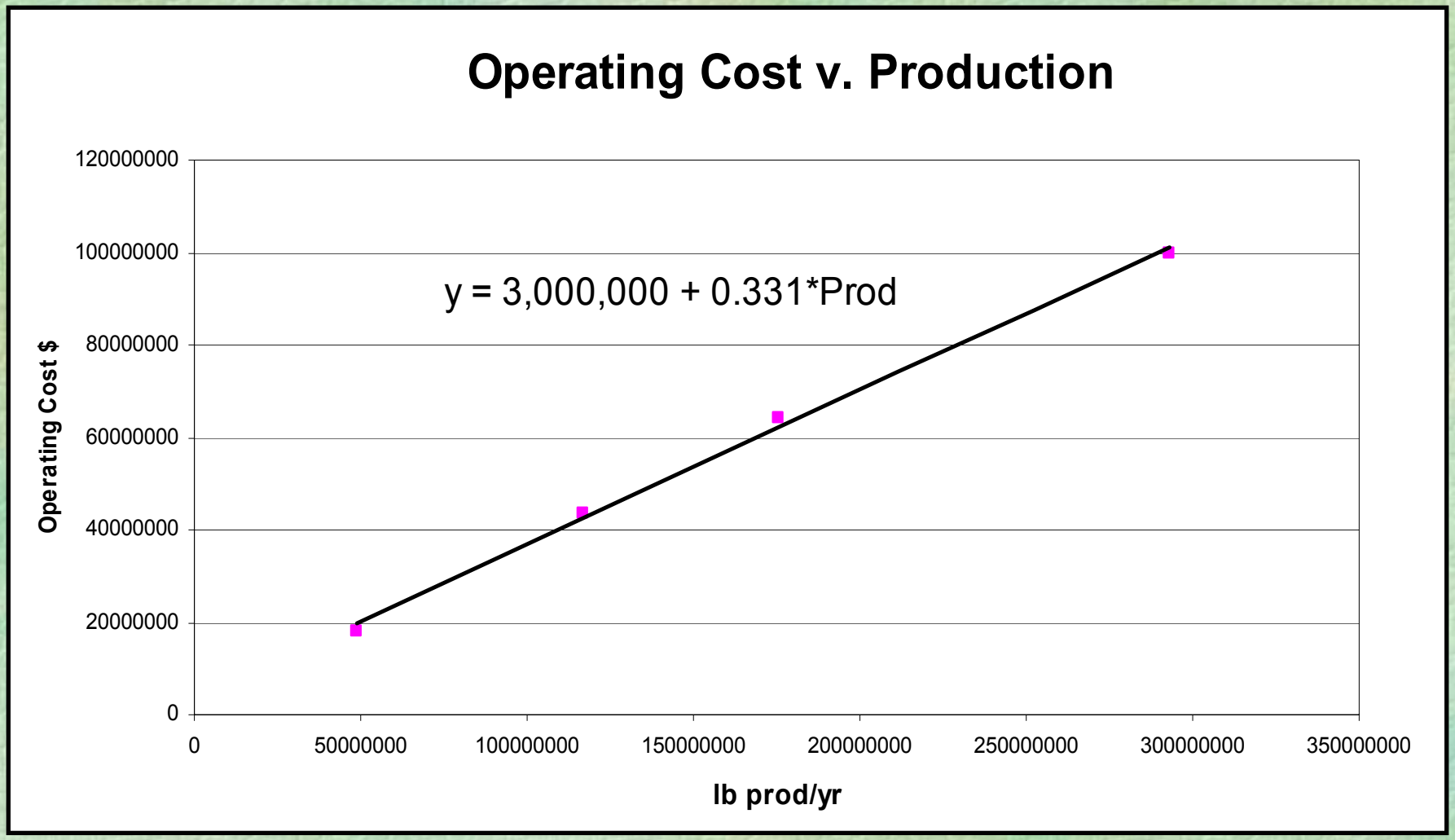
Capacity	48 mil	117 mil	175 mil	292 mil
Raw materials	2,680,000	8,620,000	12,900,000	21,500,000
Labor-Dependent	1,880,000	2,290,000	2,580,000	2,940,000
Equipment-Dependen	11,000,000	27,000,000	40,100,000	61,600,000
Laboratory/QC/QA	24,000	38,000	42,000	44,000
Utilities	2,450,000	5,650,000	8,390,000	13,900,000
Total	**18,100,000**	**43,600,000**	**64,000,000**	**100,000,000**

- Total staff: 55
- Total wage paid per year: $3,020,000
- Operating annual salary: $883,000



Labor Cost Breakdown

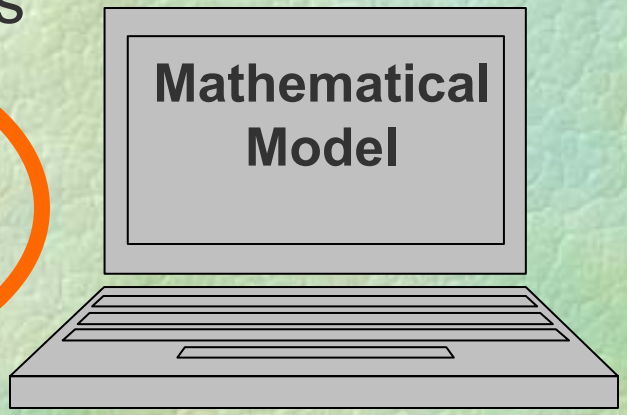
Operating Costs Versus Capacity



Business Plan

Input

- FCI vs. Capacity
- Operating Costs
- Raw Materials
- Locations
- Distances
- Freight costs
- Taxes
- Demand
- Product Prices



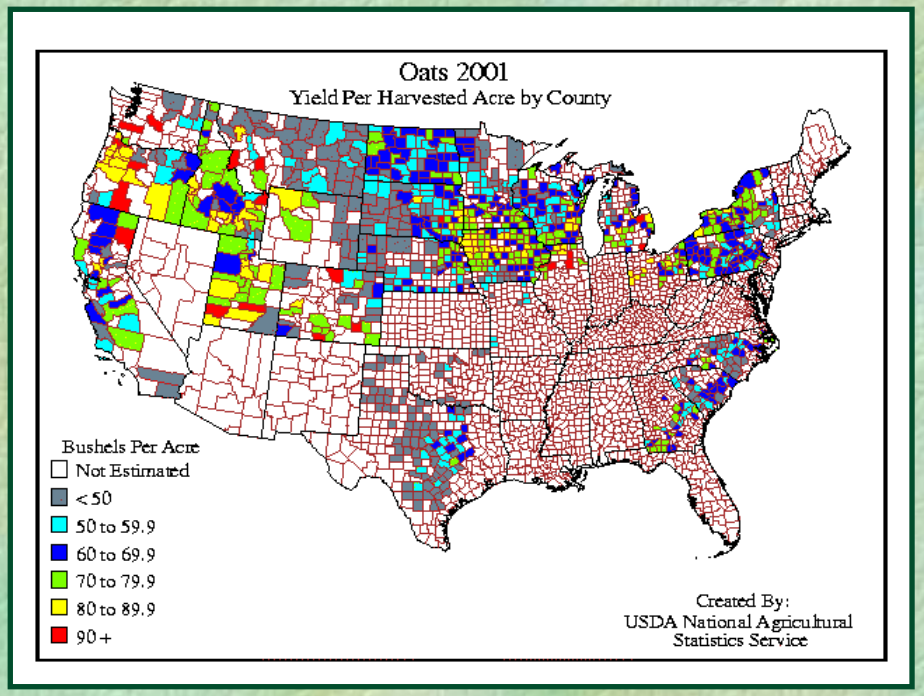
Output

- Number of plants
- Plant location(s)
- Product market(s)
- Raw material(s)
- Raw material market(s)

Specific Locations

- Most economic raw material
  - Oats, corn, rice, soybeans, wheat
- Possible market locations
  - Relative to industry and commercialization
- Potential plant locations
  - Nationwide basis

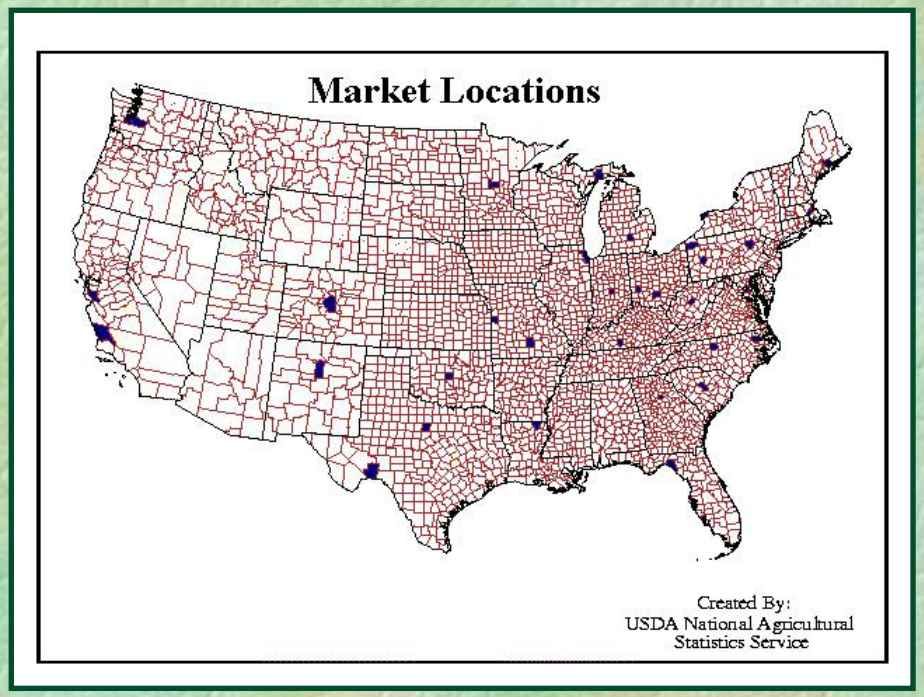
Raw Materials



Considered 21 possible raw materials

- USDA-NASS
  - Crop production by state for 2000-2001
  - U.S. crop yield by county for 2001
  - Sugar crops, starch crops, cellulosic
- NACo – National Association of Counties

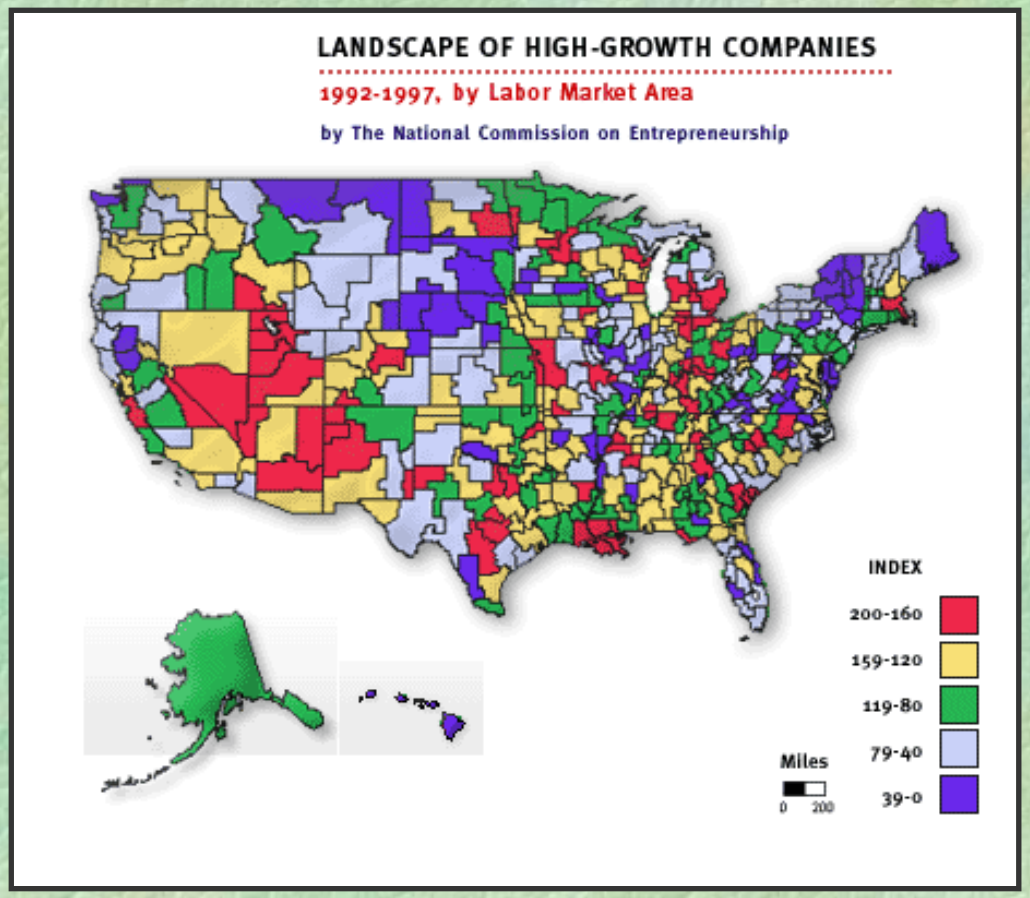
Possible Market Locations



Considered 50 possible market locations

- Industry Week U.S. 500
  - Current companies using degreasers
  - Motor vehicles and parts
  - Electronic and electrical equipment

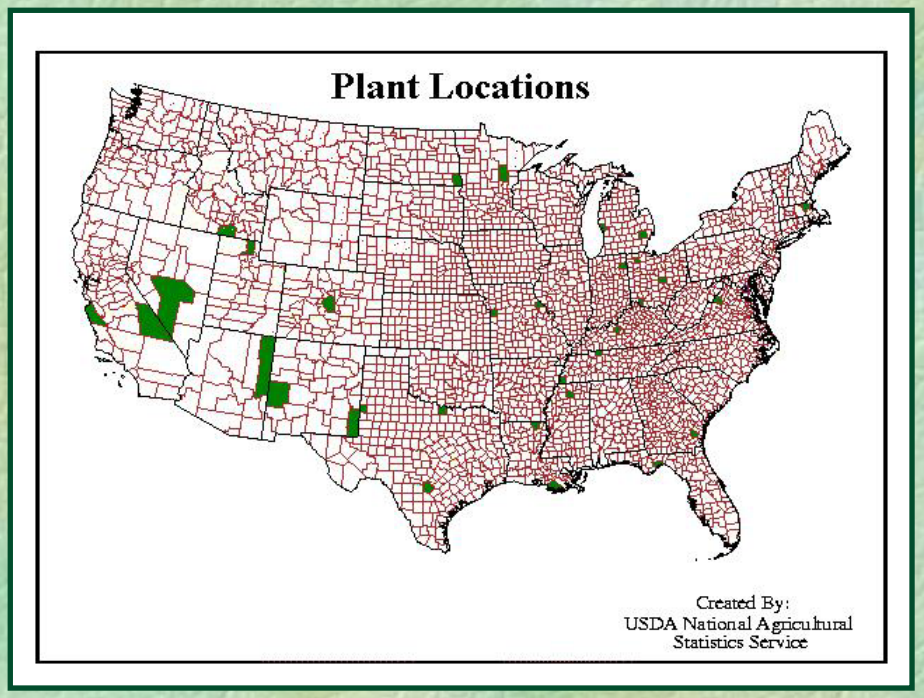
Possible Plant Locations



- NCOE
  - Population
  - Number or preexisting companies
  - Expected rate of city growth
  - Specialization in manufacturing businesses

http://www.ncoe.org/lma/lma.pdf

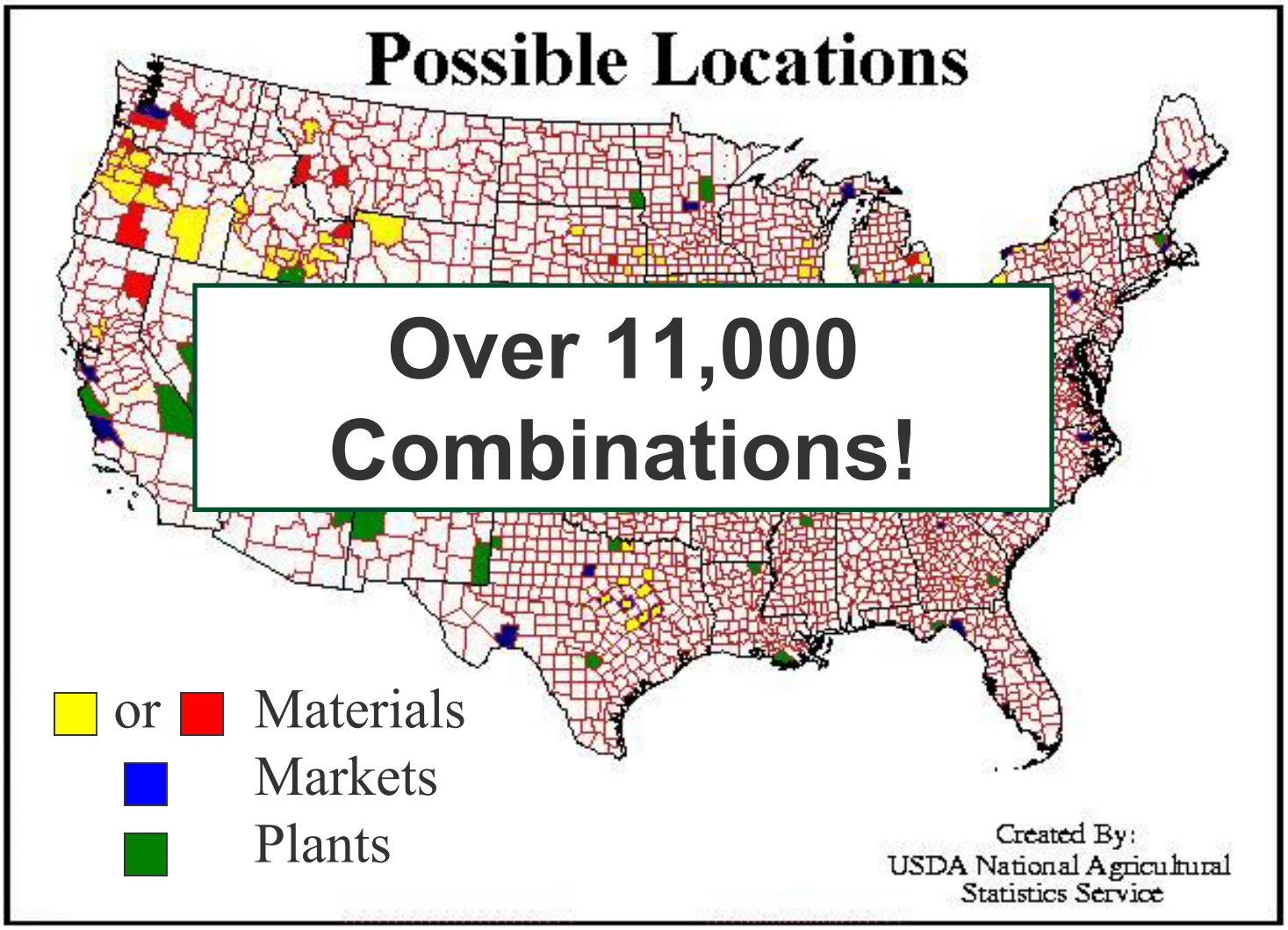
Possible Plant Locations



Considered 46 possible plant locations

- NCOE
  - National Commission on Entrepreneurship
  - Cities containing high-growth companies and high labor market areas
  - Specialization in manufacturing businesses

Possible Combinations



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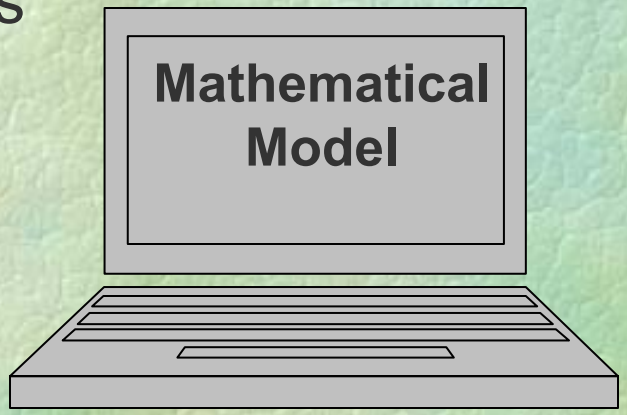

Output

- Number of plants
- Plant location(s)
- Product market(s)
- Raw material(s)
- Raw material market(s)

Freight Costs and Taxes

- Freight costs
  - $0.08 per pound per 1,000 miles
  - Raw materials and ethyl lactate
- Taxes
  - Local and state sales and property taxes

City	State	State Sales Tax	Local Sales Tax	Price after taxes $/lb
Chico	CA	7.25	0	0.0340
Binghamton	NY	4	2	0.0294
Olympia	WA	6.5	1.5	0.0300
Wenatche	WA	6.5	1.5	0.0300

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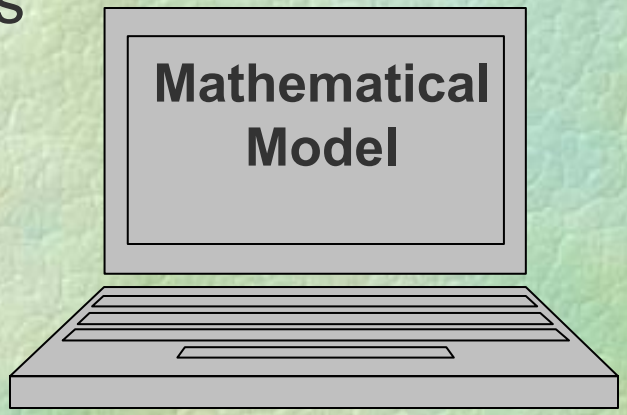

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- Raw material(s)
- Raw material market(s)

Product Demand and Prices

$$Demand_j = (GSP_{Manuf_j} * \frac{GDP}{\sum_j GSP_{Manuf}} * \frac{lbsolvents}{\$1000GDP} * P_{Green} * P_{EthylLacate} * PM$$

- P_{green} = (Tot Solv Dem)/(Green Solv Dem)
- $P_{ethyl\ lactate}$ = 9.7% + 0.1%/year

- Product Sell Price:
  $1.00, with 0.05% depreciation

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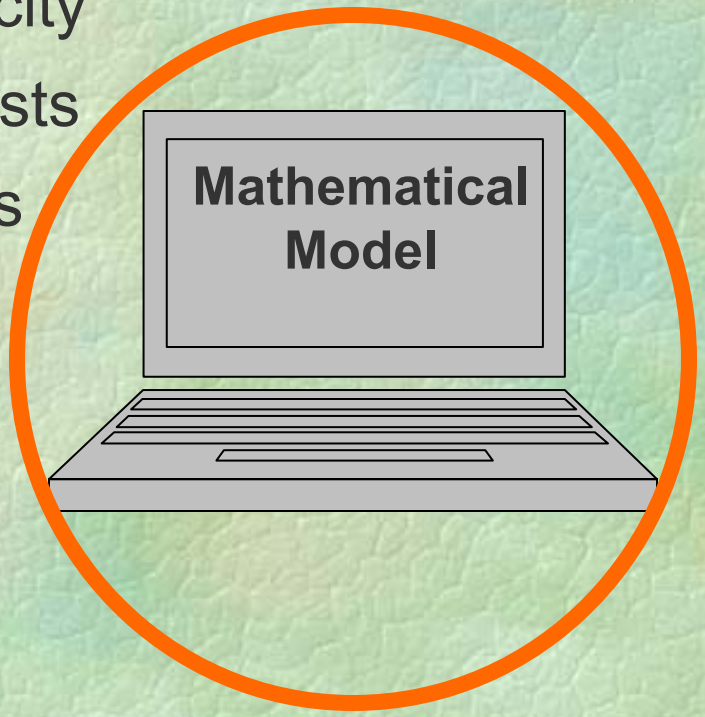

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Objective Function to Maximize

$$NPW = \sum_{plant}\left[\sum_{year}\left(\frac{CF_{plant,year}}{(1+irr)^{year}}\right)+\frac{(Vs_{plant}+Iw_{plant})*FCI_{plant}}{(1+i)^{year}}-TCI_{plant}\right]$$

CF = Cash Flow

Irr = Internal Rate of Return

Vs = Salvage Value, 10% of FCI

Iw = Working Capital, 15% of FCI

Project Lifetime – 20 years

Cash Flow Calculations

Cash Flow = Revenue – (Revenue – Depreciation)*Taxes

Revenue = Sales – Total Costs

Constraints

$$Demand_{market,year} <= \sum_{plant} product_{plant,market,year}$$

$product_{plant,\ year} = \Sigma_{rm}(rawmat_{plant,\ year} * conversion_{rm})$

$product_{\ year\ 1} = 0$

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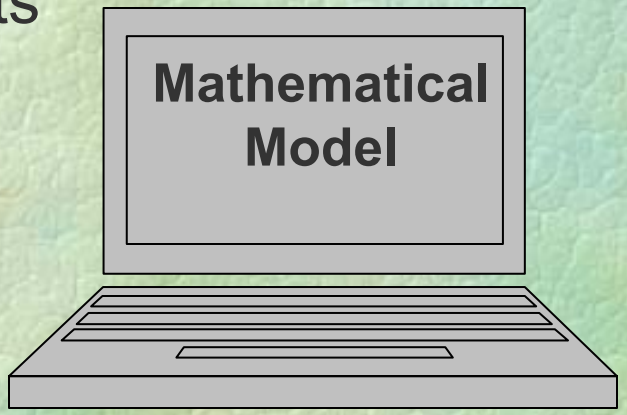
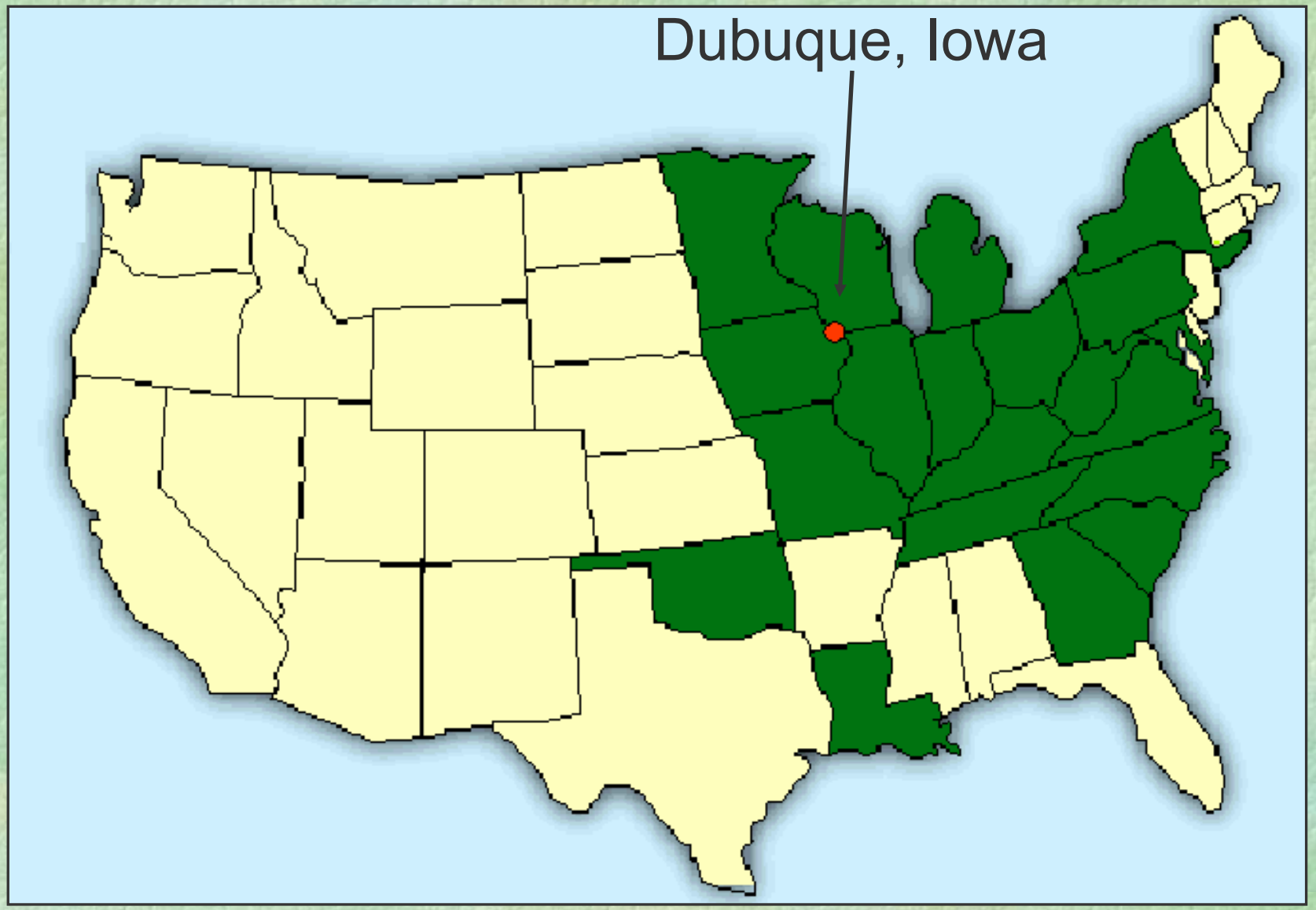


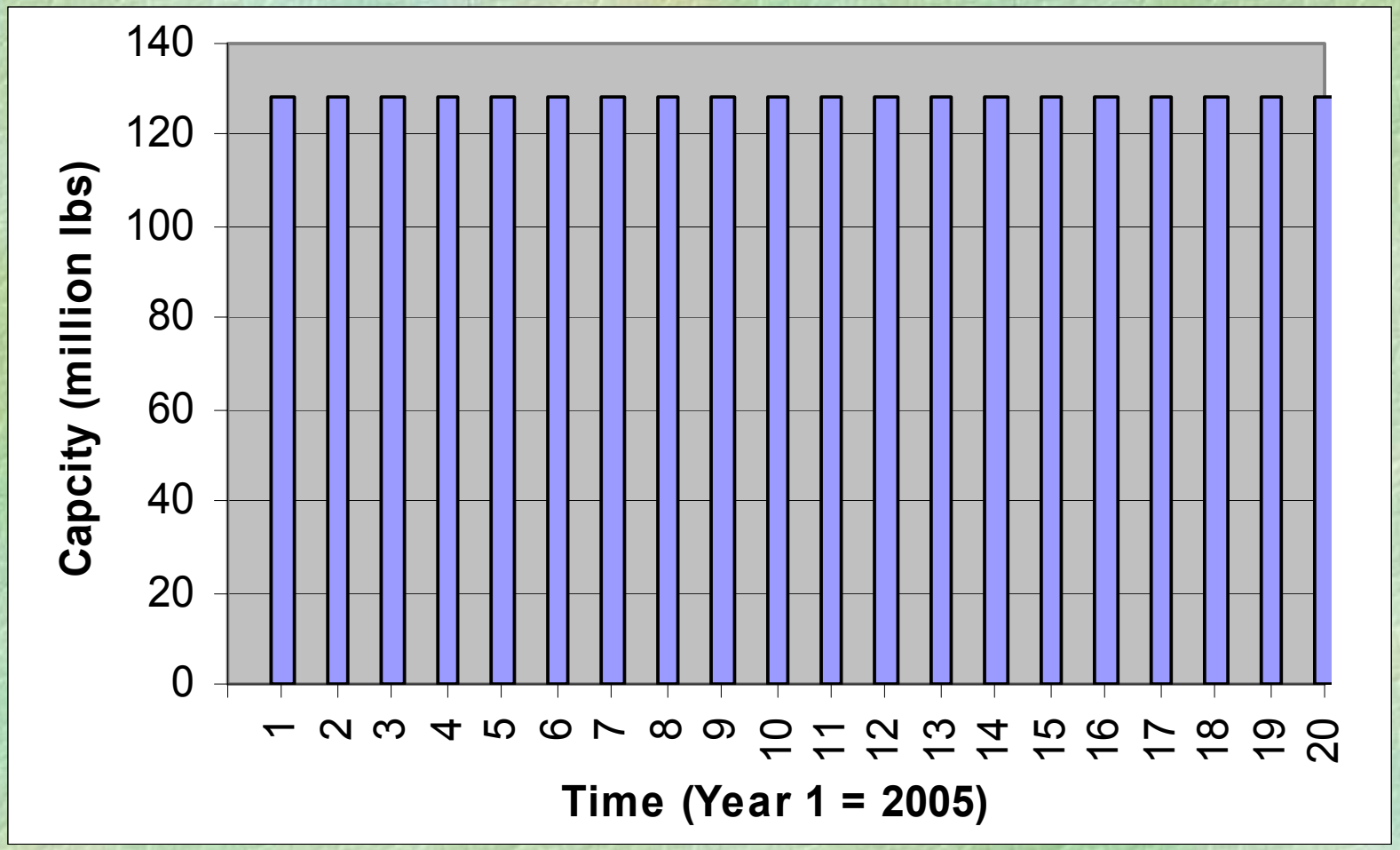
Output

- Number of plants
- Plant location(s)
- Product market(s)
- Raw material(s)
- Raw material market(s)
- Capacity addition
- Year of addition
- Loans and Repayment

Raw Material:Corn, Location Results

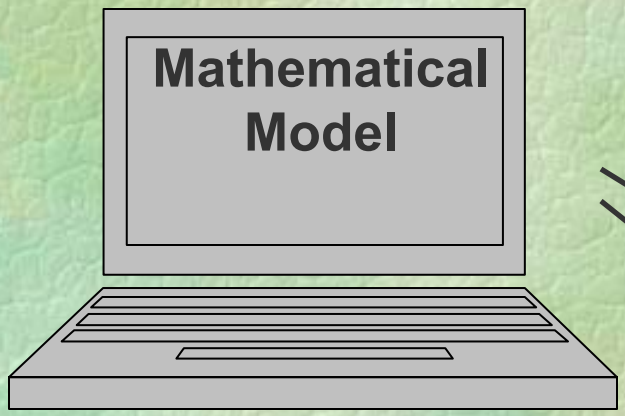


Plant Capacity and Production



Rate of Return = 8.6%

Capital Improvements



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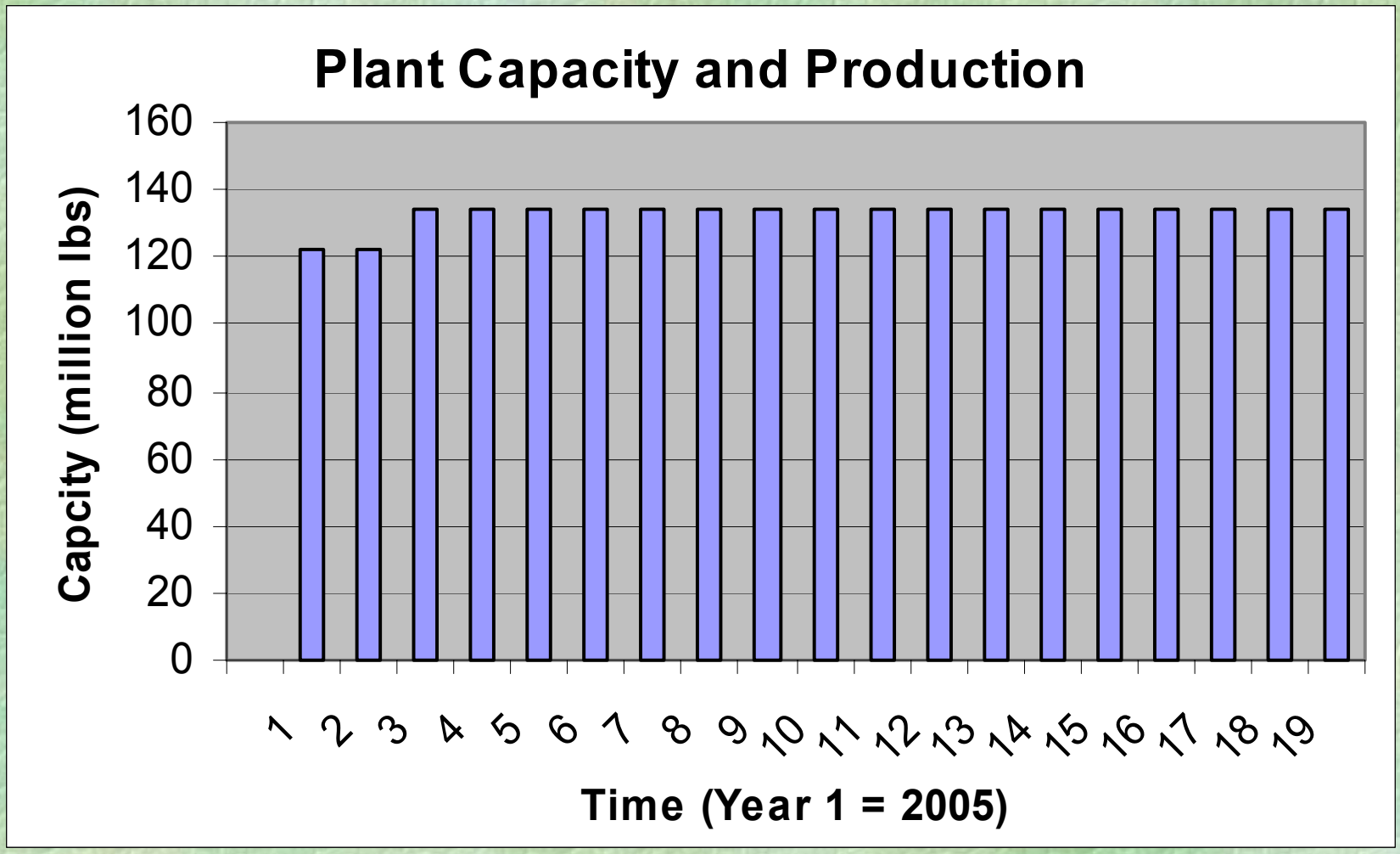
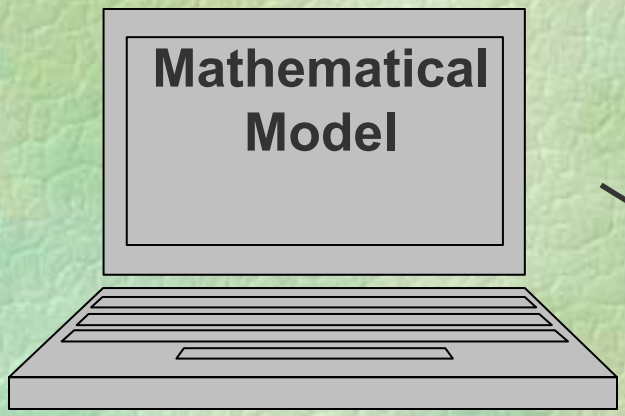
- Product market(s)
- Raw material(s)
- Raw material market(s)
- Capacity addition
- Year of addition

Plant Capacity and Production



Rate of Return = 8.6%

Budgeting



Output

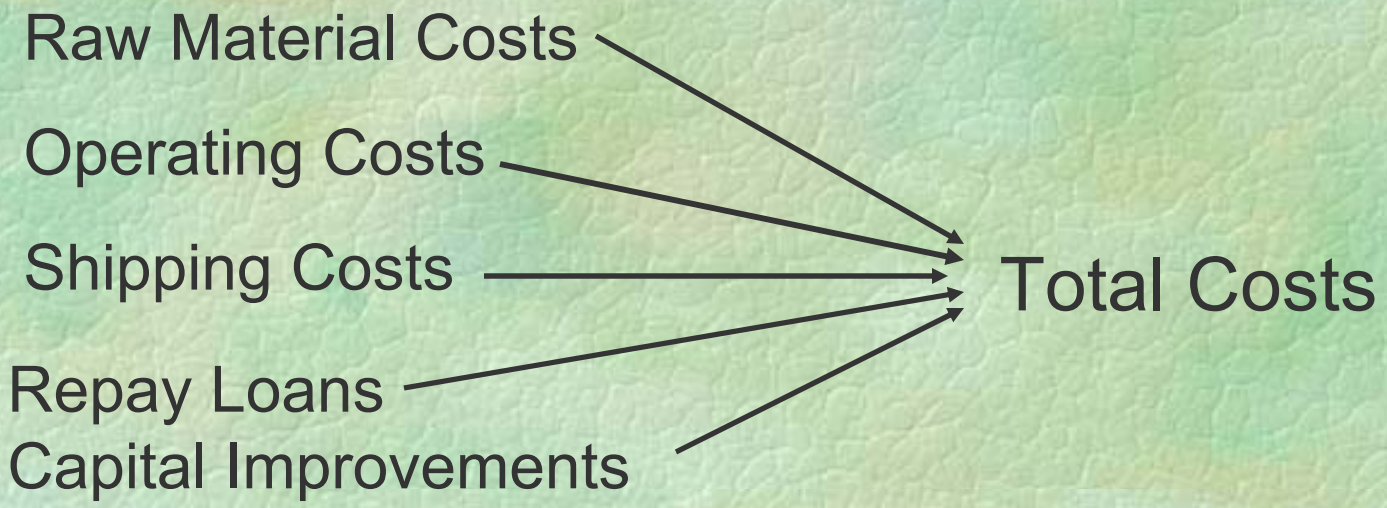
- Number of plants
- Plant location(s)
- Product market(s)
- Raw material(s)
- Raw material market(s)
- Capacity addition
- Year of addition
- Loans and Debt
- Revenues for Additions

Constraints for Budgeting

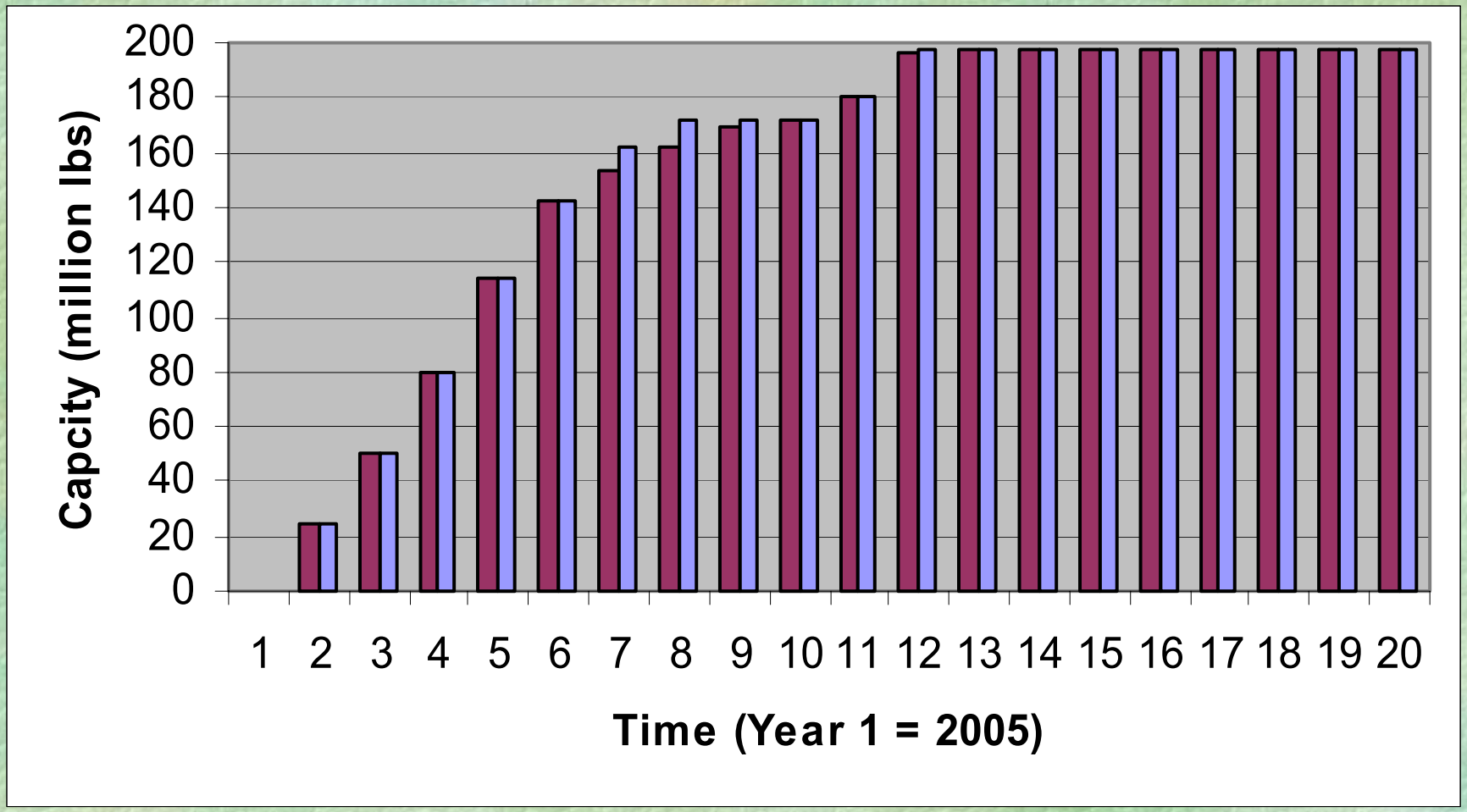
$Debt <= FCI_{year} + Pcf*Cash\ Flow$

Pcf = percent of annual cash flow

$FCI_{year\ 1} <= Initial\ Capital$



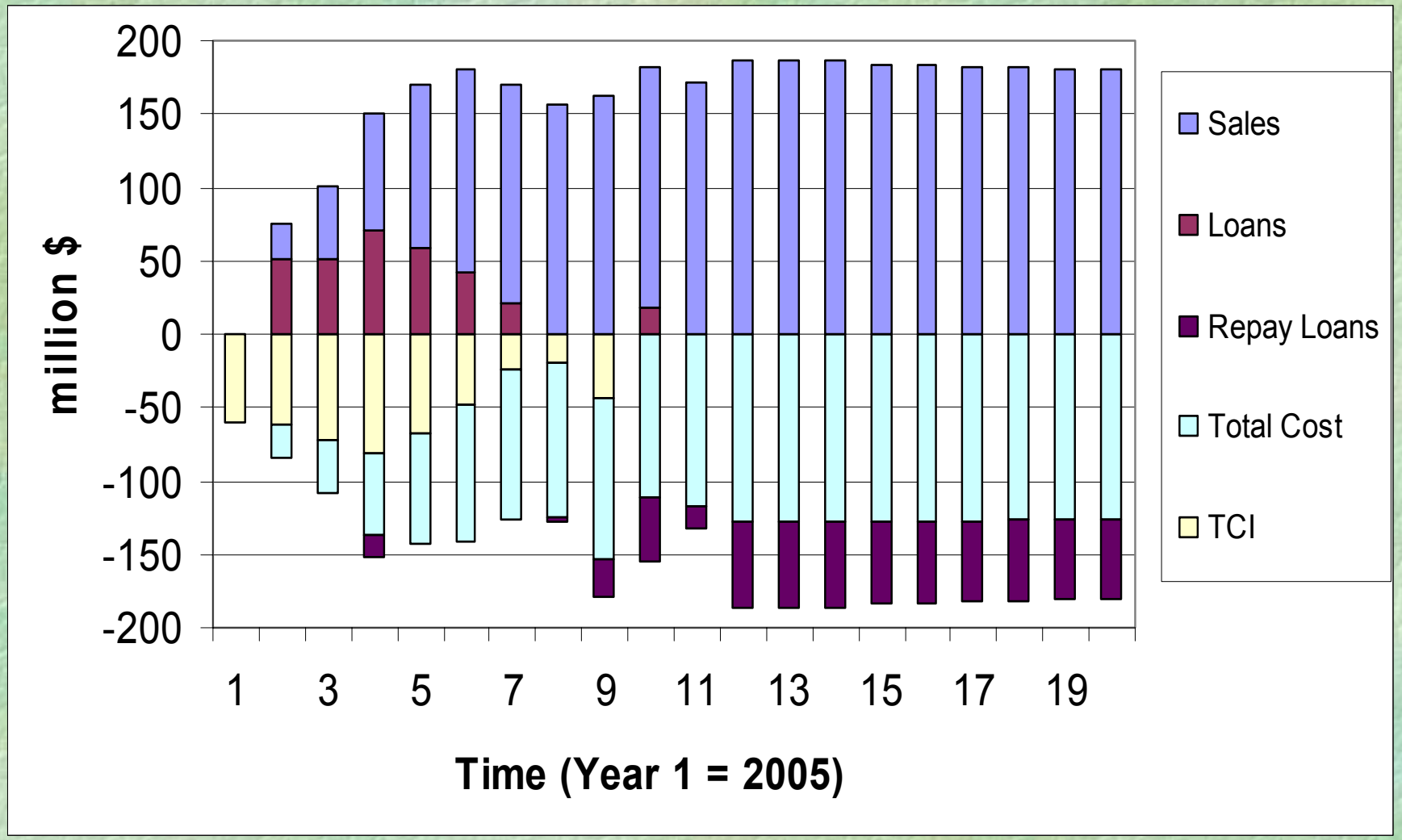
InitCap = $52 million, MaxDebt = FCI



ROR = 24 %

Max Cap = 198 million lbs

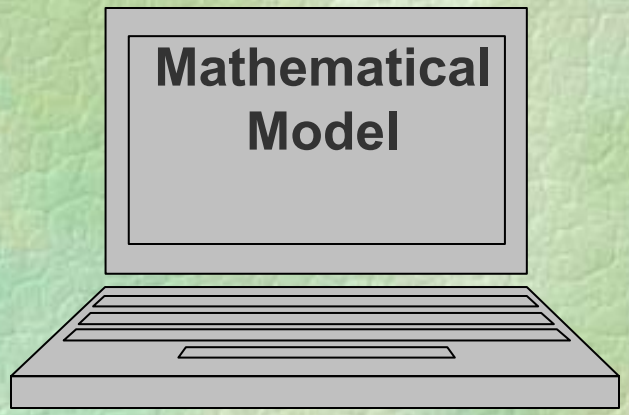
Annual Cash Flow



Vary Initial Capital and Max Debt by increasing percentage of cash flow

	NPW (million $ for ror = 15%)	
InitCap (million$)	**0%**	**20% CF**
68	42.2	42.7
52	41.6	42.1
40	34.8	35.4

Sensitivity Analysis



Vary until Change

- Freight Costs
- Operating Costs
- Raw material costs
- Raw material Conversion
- Product Costs

Percent market	100%	50%
NPW ($million)	41.6	1.5
Max Capacity (million lbs)	198	98

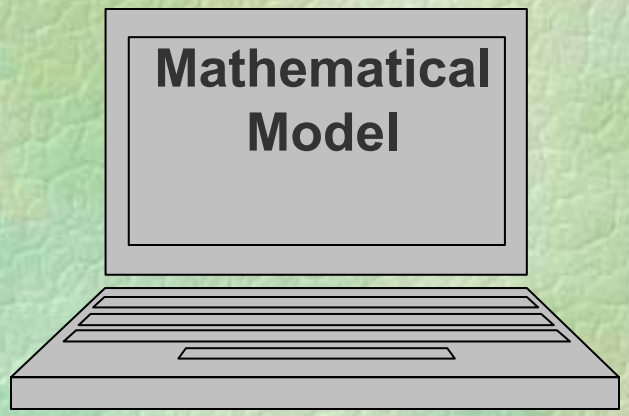
freight cost/1000 lbs	$0.04/2	$0.08/4
NPW ($million)	41.6	33.8
Max Capacity (million lbs)	198	194

Operating Costs as %prod	28%	33%
NPW ($million)	41.6	9.4
Max Capacity (million lbs)	198	188

raw mat costs	100%	110%
NPW ($million)	41.6	21.4
Max Capacity (million lbs)	198	188

Sale Price	100%	95%
NPW ($million)	41.6	11.3
Max Capacity (million lbs)	198	186

Risk Analysis



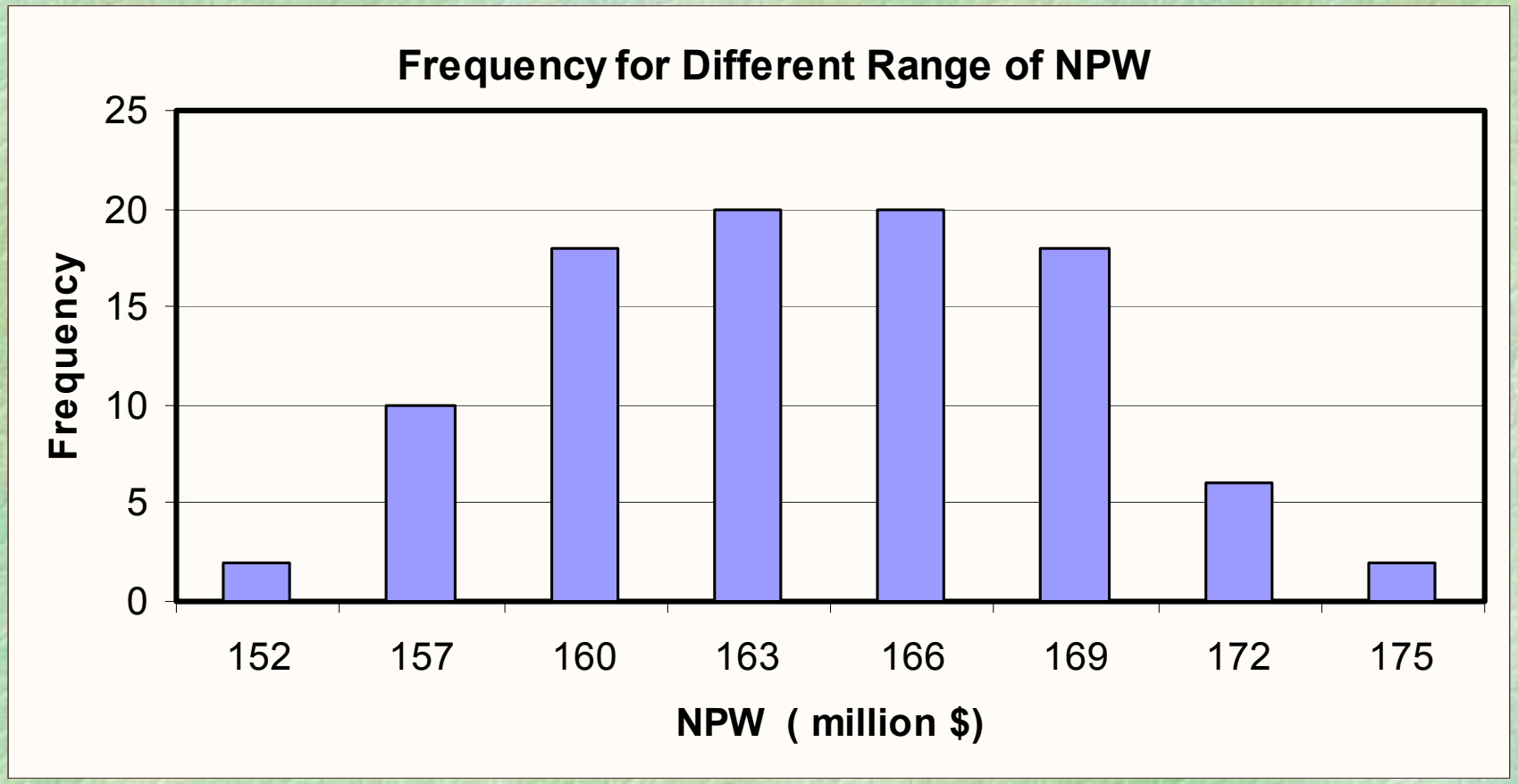
Uncertainty

- Price: 20% SD
- Demand: 20% SD

Create 100 scenarios

Similar to Monte Carlo Simulation

Risk Analysis : InitCap = $52 million, MaxDebt = FCI



NPW Average = $41.6 million

Conclusions

- Ethyl lactate is effective solvent
- Process is feasible and profitable
- Oats is an effective raw material
- Dayton, Ohio is an optimal location

Future Study

- Local demands and supplies in Dubuque, Iowa
- Equipment purchasing
- Budgeting analysis.
- CO_2 Sequestration:

Contingency Plan

- Lactic Acid Production
- Ethanol Production
- Polylactic Acid

Questions?

Cargill-Dow
PLA Plant.
Blair, Nebraska.

September 2001.