EngrD 2190 – Lecture 15

Concept: Process Analysis by Mathematical Modeling

Context: Process Economics of Selling Potable Water

Defining Question: How do capital costs differ from operating costs?

Read Chapter 3, pp. 152-156. Process Economics, cont'd
    Lecture 16 will cover the same concepts, but in a different context.

Professional Development – LinkedIn Pages

If you have not already done so, enroll in the Cornell Career Services "Career Development Toolkit" available via https://scl.cornell.edu/news-events/news/new-career-development-toolkit

Complete the LinkedIn module located within the "Networking" tab within the Toolkit.

Based on the guidance provided within the LinkedIn education module, create a LinkedIn account/page for yourself that is comprehensive, engaging, and effective.

Using the guidance provided in the education module, along with your own experience in creating your account, create a LinkedIn grading rubric and use it to assess the LinkedIn page of two of your class peers. Refer to the grading rubrics for homework as an example.

By Wednesday Oct 1, 5pm, email:

Last name beginning A-J Email to Professor Woltornist (AW499)

Last name beginning K-Z Email to Professor Bauer (btb42)

- A link to your LinkedIn page
- Completed grading rubrics for the LinkedIn pages of two peers.

Due Today

Prelim 1

- Prelim 1: Tuesday 10/7, 7:30-9:30 p.m. 245 and 128 Olin Hall

  Covers Chapter 2 and mass balances (formal and informal).

  Covers through Lecture 10, Homework 4, Calculation Session 5.

  Open notes and open exercise solutions.

  Bring a calculator. Graphing calculators are allowed.

  No laptops and no iPads.

Cornell ChemE Alumni in Corporate Positions

Joseph Coors (BChE 39) Chair (deceased), Coors Brewing
Ted Doan (BChE 49) Chairman (deceased), Dow Chemical
Dick Tucker (BChE 50) President (deceased), Mobil Oil Corporation
Marjorie Hart (BChE 51) Director, International Markets (retired), Exxon
Edward Callahan (BChE 53) Vice President of Health and Safety (retired), Allied Signal
Elliot Cattarulla (BChE 53) Vice President of Public Affairs (retired), Exxon
John Schmutz (BChE 55) Senior Vice President/Counsel (retired), duPont
Roger Fisher (BChE 57) Director of Chemical Analysis (retired), Amoco Corporation
Matthew Sagal (BChE 58) VP Business Develop
Larry Fuller (BS 61) President and CEO (retired
Ken Ackley (BChE 61) President (deceased), In
Sam Bodman (BChE 61) President (retired), Cabot Corporation; Secretary of Energy 2004-08
Greg Crowe (BChE 62) Founder (retired), International Envelope Co (Tyvek Envelopes)
Charles Lee (BChE 62) CEO (retired), GTE Corporation
J. Thomas Smith (BChE 62) Director of Ceramics (retired), GTE Laboratories
Peter Daley (BChE 63) VP of Technology (retired), Waste Management International
Sam Fleming (BChE 63) President (deceased), Decision Resources, Inc
John Carberry (BChE 64) Director of Environmental Technology (retired), DuPont
Phil Brodsky (BChE 65) Vice President for Research (retired), Monsanto
Edwin Dealy (BChE 65) Director of Worldwide Business (retired), Hercules Corporation
Leon Anziano (BChE 65) President and CEO (retired) Arch Chemicals
G. "Chip" Bettle (MEng 66) President (retired), CBC Research, Inc
Marty Schwartz (BChE 66) CEO (retired), Southwall Technologies, Inc
Charles Sherwood (BChE 70) Director, Research and Development, Johnson & Johnson

CEO of Fidelity Investments 1983-87.
2 trillion $ in assets.

Cornell ChemE Alumni in Corporate Positions

Stephen Matson (BChE 71) President, Arete Technologies
Charles Brown (BChE 72) Director of Manufacturing and Research, Kodak
Bill Welker (BChE 73) Vice President, Braun Corporation
Carol Nolan (BChE 73) Director of Technical Services, Immunex Corporation
Bruce Shutts (BChE 75) Director of Chemical Development, Schering-Plough
Catherine Jarett (BChE 77) Manager of Collaborations, Genentech
Carl Marharver (BChE 77) Chief Operating Officer, AviGenics, Inc.
Brian Swallow (BChE 78) Vice President of Engineering, Mearl Corporation
Rick Eno (BChE '82) President and CEO, Metabolix
Jeffrey Jensen (BChE 82) President and CEO, Eksigent Technologies
William Bentley (BChE 82) President and Founder, Chesapeake Perl
Ann L. Lee (BChE 83) Chief Technical Officer, Prime Medicine
Marlene Quijano (BChE '85) Vice President, Innovation, Kraft Foods
Eric Degenfelder (BChE '86) Director, Business Devel

Namesake for Cornell ChemE

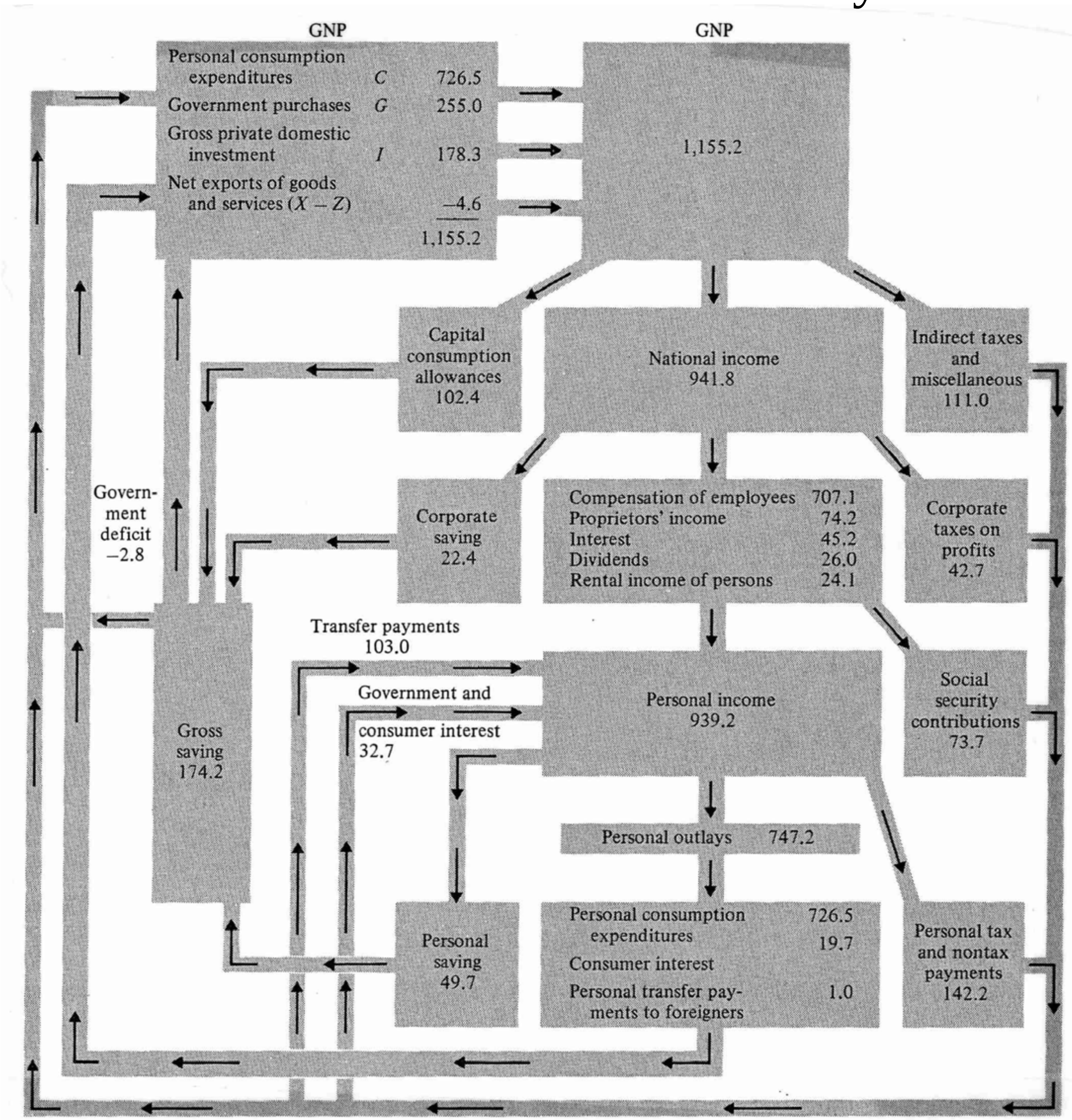
Eric Einset (BChE '86) Principal, Global Infrastructure Partners
Robert Frederick Smith (BChE '86) Founder, Vista Equity Partners
Brian Breidgan (BChE '88) Vice President and General M

Private equity company with $269,000,000,000 in assets.

Venkataraman Bringi (BChE '91) Vice President, Process
Ayanna Clunis (née Wilson) (BChE '95) Head of Operations, TPG Capital
Mary Carmen Gasco-Buisson (BChE '97) Chief Marketing Officer, Pandora
Todd Zion (BChE '97) Founder, SmartCells; Founder,

Sold SmartCells to Merck in 2010 for $500,000,000.

Flowsheet of the U.S. Economy

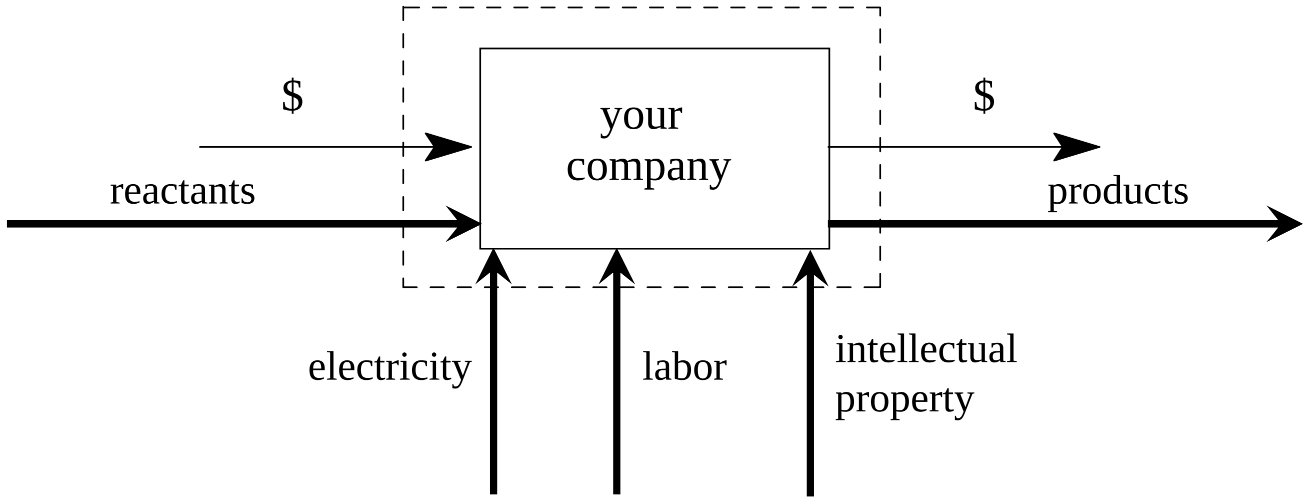


Process Economics

A formalism for calculating the finances of producing and selling a chemical product.

Analysis of asset flows:

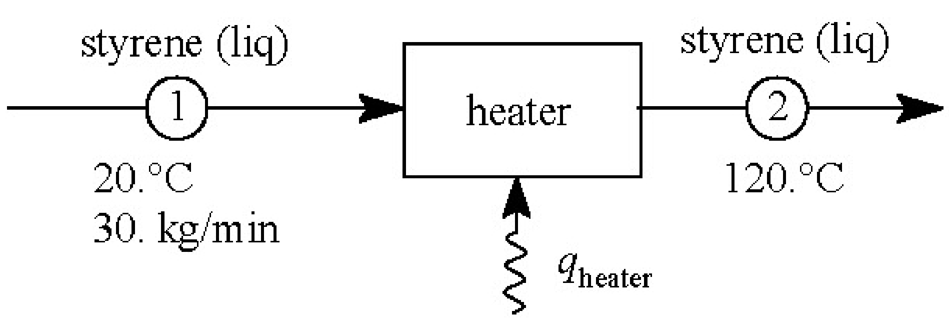
Asset Balances (Figure 3.58, p. 145)



Every stream has inherent assets.

Use economics to convert to conserved quantity: **assets** (in units of $).

Compare to Energy Balances



Every stream has inherent energy.

Use thermodynamics to convert to conserved quantity: **energy** (in units of Joules).

The Conservation of Assets

$$\frac{d(\text{assets})}{dt} = \text{rate of assets in} + \text{rate assets created} - (\text{rate of assets out} + \text{rate assets consumed})$$

Eqn 3.190, p. 145

$$\text{profit} = \text{revenue} - \text{operating costs}$$

Eqn 3.191, p. 146

Units of ‘assets’ are \$. Units of ‘rate of assets’ are \$/year.

Units of ‘profit,’ ‘revenue,’ and ‘operating costs’ are \$/year.

Not Steady State. We want $d(\text{assets})/dt = \text{profit} > 0$.

The Conservation of Assets

Are assets *truly* conserved, like mass and energy?

Mass and energy are defined by laws of nature. Assets are defined by economics.

The conservation of energy initially related two forms of energy:
potential (= mgh) and kinetic (= $\frac{1}{2}mv^2$). Leibnitz 1669

When experiments showed potential energy could be converted to thermal energy,
a new term was added: thermal energy (= $mC_P(\Delta T)$)

Each time conservation of energy appeared to be violated, a new term was added.

phase change energy (= $m(\Delta H_{phase})$)

pressure energy (= PV)

chemical reaction energy (= $m(\Delta H_{reaction})$)

nuclear energy (= mc^2)

~~orgone energy~~ Wilhem Reich 1930s

Example 1. You win a desalinator in a raffle.

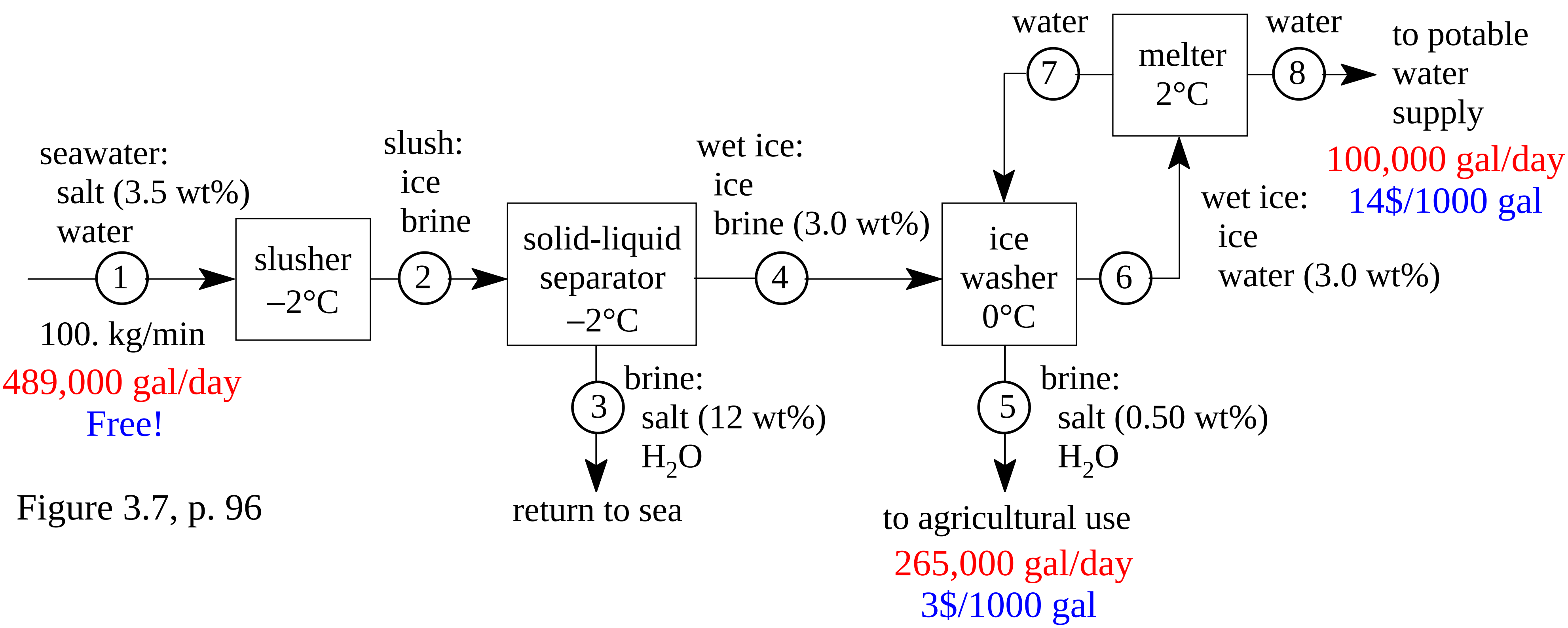


Figure 3.7, p. 96

Must convert gal/day to \$/year. Economics provides the conversion factors.

Desalinator operates 24 hours/day, 365 days/year.

Note!

$$\text{revenue} = \left(\frac{100{,}000 \text{ gal potable water}}{\text{production day}}\right)\left(\frac{14.\ \$}{1000 \text{ gal}}\right) + \left(\frac{265{,}000 \text{ gal agricultural water}}{\text{production day}}\right)\left(\frac{3.\ \$}{1000 \text{ gal}}\right)$$

$$= \left(\frac{1400\ \$}{\text{production day}} + \frac{795\ \$}{\text{production day}}\right)\left(\frac{365 \text{ production days}}{\text{year}}\right) = 801{,}175\ \$/\text{year}$$

Eqn 3.193, p. 146

Example 1, cont'd. You win a desalinator in a raffle.

$$\text{revenue} = \left(\frac{100{,}000 \text{ gal potable water}}{\text{production day}}\right)\left(\frac{14.\ \$}{1000 \text{ gal}}\right) + \left(\frac{265{,}000 \text{ gal agricultural water}}{\text{production day}}\right)\left(\frac{3.\ \$}{1000 \text{ gal}}\right)$$

$$= \left(\frac{1400\ \$}{\text{production day}} + \frac{795\ \$}{\text{production day}}\right)\left(\frac{365 \text{ production days}}{\text{year}}\right) = 801{,}175\ \$/\text{year}$$

Eqn 3.193, p. 146

$$\text{operating costs} = \text{electricity} + \text{rent} + \text{labor}$$

$$= \left(\frac{43{,}000\ \$}{\text{month}}\right)\left(\frac{12 \text{ months}}{\text{year}}\right) + \left(\frac{3{,}200\ \$}{\text{month}}\right)\left(\frac{12 \text{ months}}{\text{year}}\right)$$

$$+ \left(\frac{3 \text{ shifts}}{\text{day}}\right)\left(\frac{9 \text{ hours}}{\text{shift}}\right)\left(\frac{16.50\ \$}{\text{hour}}\right)\left(\frac{7 \text{ days}}{\text{week}}\right)\left(\frac{52 \text{ weeks}}{\text{year}}\right)$$

$$= 516{,}000\ \$/\text{year} + 38{,}400\ \$/\text{year} + 162{,}162\ \$/\text{year}$$

$$= 716{,}562\ \$/\text{year}$$

Eqns 3.194-7, p. 146

$$\text{profit} = \text{revenue} - \text{operating costs}$$

$$= 801{,}175 - 716{,}562$$

$$= 84{,}613\ \$/\text{year}$$

Nice!

Eqn 3.198, p. 147

Mid-Semester Survey

Example 2. Your friend purchases a desalinator ($340,000).

$$\text{revenue} = \left(\frac{100{,}000 \text{ gal potable water}}{\text{production day}}\right)\left(\frac{14.\ \$}{1000 \text{ gal}}\right) + \left(\frac{265{,}000 \text{ gal agricultural water}}{\text{production day}}\right)\left(\frac{3.\ \$}{1000 \text{ gal}}\right)$$

$$= \left(\frac{1400\ \$}{\text{production day}} + \frac{795\ \$}{\text{production day}}\right)\left(\frac{365 \text{ production days}}{\text{year}}\right) = 801{,}175\ \$/\text{year}$$

$$\text{operating costs} = \text{electricity} + \text{rent} + \text{labor}$$

$$= \left(\frac{43{,}000\ \$}{\text{month}}\right)\left(\frac{12 \text{ months}}{\text{year}}\right) + \left(\frac{3{,}200\ \$}{\text{month}}\right)\left(\frac{12 \text{ months}}{\text{year}}\right)$$

$$+ \left(\frac{3 \text{ shifts}}{\text{day}}\right)\left(\frac{9 \text{ hours}}{\text{shift}}\right)\left(\frac{16.50\ \$}{\text{hour}}\right)\left(\frac{7 \text{ days}}{\text{week}}\right)\left(\frac{52 \text{ weeks}}{\text{year}}\right)$$

$$= 516{,}000\ \$/\text{year} + 38{,}400\ \$/\text{year} + 162{,}162\ \$/\text{year}$$

$$= 716{,}562\ \$/\text{year}$$

$$\text{profit} = \text{revenue} - \text{operating costs}$$

$$= 801{,}175 - 716{,}562$$

$$= 84{,}613\ \$/\text{year}$$

Identical to your profit!? How can this be?

Your friend spent $340,000. Why is this not an operating cost?

Operating Costs vs. Capital Costs

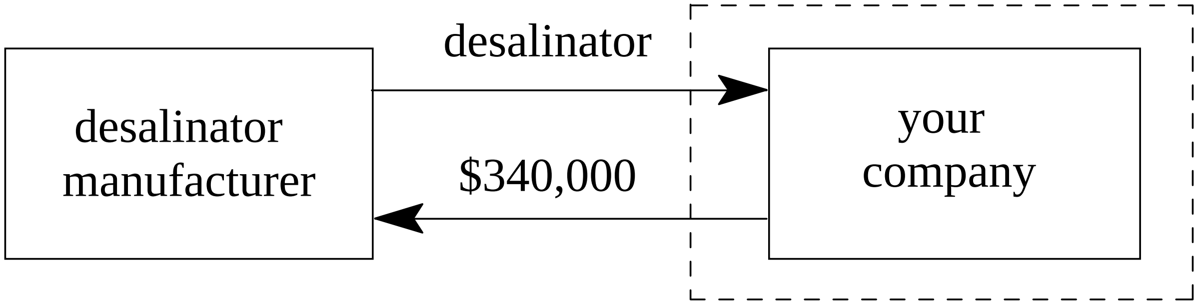


Figure 3.59. Asset flows during a desalinator purchase. (p. 147)

profit (or loss) = rate of assets in − rate of assets out Eqn 3.199, p. 147

= (revenue + equipment purchased) − (operating costs + capital costs)

equipment purchased (flow into company) = capital cost (cash flow out) Eqn 3.200, p. 147

∴ profit (or loss) = revenue − operating costs Eqn 3.191, p. 147

Equipment purchases are capital costs, not operating costs.

Operating Costs vs. Capital Costs, cont'd

Is any tangible purchase a capital cost?

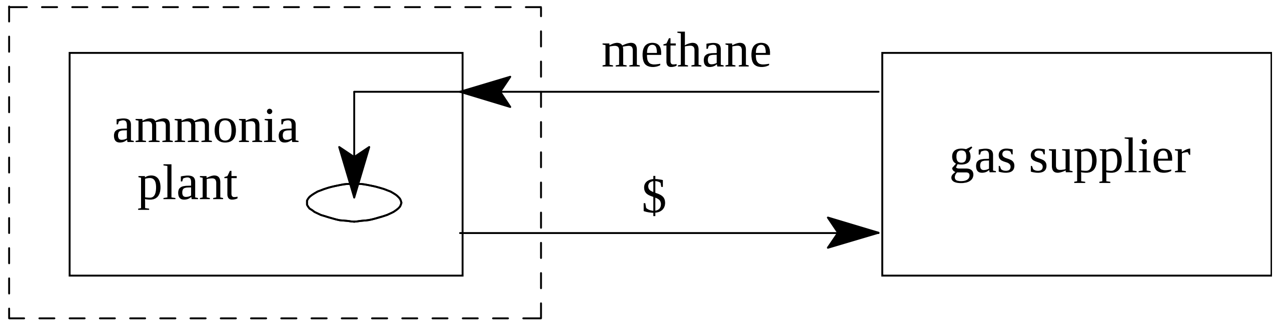


Figure 3.60. Asset flows during your reactant purchase. (p. 147)

$$\frac{d(\text{assets})}{dt} = \text{rate of assets in} - \text{rate of assets out} + \text{rate of formation} - \text{rate of consumption}$$

Eqn 3.200, p. 148

For reactants, rate of assets in $=$ $-$(rate of reactant consumption)

Because reactants are *consumed*, reactants do not increase the assets within a company.

If an item is consumed, the item is not capital.

Operating Costs vs. Capital Costs, cont'd

Capital Cost: Purchasing a Desalinator.

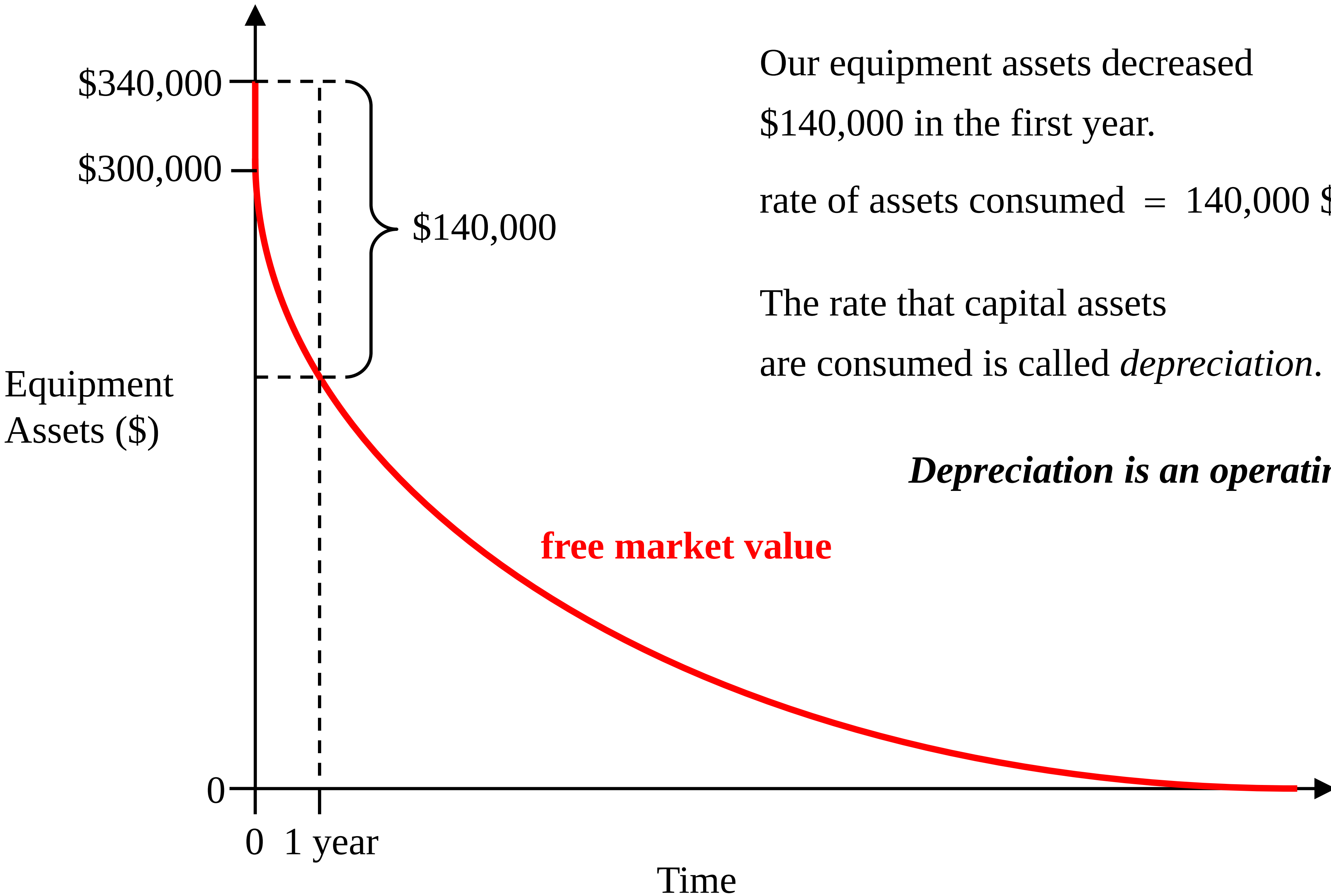
Before Purchase	After Purchase
your friend's company $340,000	your friend's company a desalinator
Assets = $340,000	Assets = $340,000 → 0 eventually

But capital items do not last forever.

Operating Cost: Purchasing Reactants.

Before Purchase	After Purchase
ammonia synthesis company $100,000	ammonia synthesis company (no reactants)
Assets = $100,000	Assets = $0

Capital equipment is also consumed
but slower than consumables.



Our equipment assets decreased $140,000 in the first year.

rate of assets consumed = 140,000 $/year

The rate that capital assets are consumed is called *depreciation*.

Depreciation is an operating cost.

Example 2. Your friend purchases a desalinator ($340,000).

$$\text{revenue} = \left(\frac{100{,}000\ \text{gal potable water}}{\text{production day}}\right)\left(\frac{14.\ \$}{1000\ \text{gal}}\right) + \left(\frac{265{,}000\ \text{gal agricultural water}}{\text{production day}}\right)\left(\frac{3.\ \$}{1000\ \text{gal}}\right)$$

$$= \left(\frac{1400\ \$}{\text{production day}} + \frac{795\ \$}{\text{production day}}\right)\left(\frac{365\ \text{production days}}{\text{year}}\right) = 801{,}175\ \$/\text{year}$$

$$\text{operating costs} = \text{electricity} + \text{rent} + \text{labor} + \text{depreciation}$$

$$= 516{,}000\ \$/\text{year} + 38{,}400\ \$/\text{year} + 162{,}162\ \$/\text{year} + 140{,}000\ \$/\text{year}$$

$$= 856{,}562\ \$/\text{year}$$

$$\text{profit} = \text{revenue} - \text{operating costs}$$

$$= 801{,}175 - 856{,}562 = -55{,}387\ \$/\text{year}$$

How much cash at the end of the year? $84,613 But the net value of the company is *decreasing*.

Profit is taxed. Consider two tax exhortations:

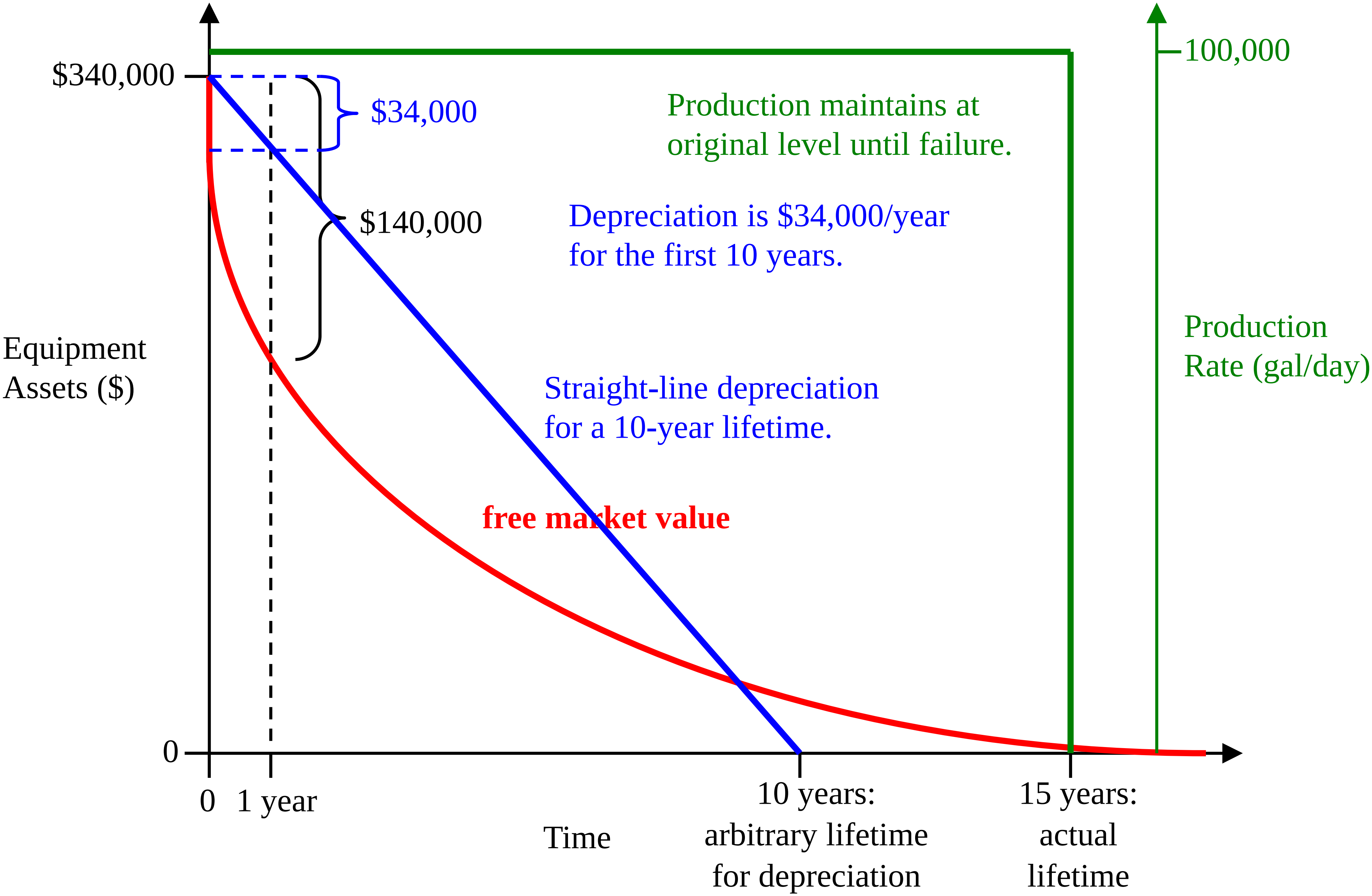
Always deduct as much as you are allowed.

Always postpone paying taxes.

How much depreciation should you claim the first year? $84,613, so profit = 0, taxes = 0.

The IRS is aware of this tactic. Rates of depreciation are dictated by tax law.

Capital equipment is also consumed, but slower than consumables.



Example 2. Your friend purchases a desalinator ($340,000).

revenue = 801,175 \$/year (same as before)

$$\text{depreciation} = \frac{\text{capital cost}}{\text{lifetime}} \qquad \text{(straight-line method)}$$

$$= \frac{340{,}000\ \$}{10\ \text{years}} = 34{,}000\ \$/\text{year}$$

$$\text{operating costs} = \text{electricity} + \text{rent} + \text{labor} + \text{depreciation}$$

$$= 516{,}000\ \$/\text{year} + 38{,}400\ \$/\text{year} + 162{,}162\ \$/\text{year} + 34{,}000\ \$/\text{year}$$

$$= 750{,}562\ \$/\text{year}$$

$$\text{profit} = \text{revenue} - \text{operating costs}$$

$$= 801{,}175 - 750{,}562 = 50{,}613\ \$/\text{year}$$

Still Nice! … or is it?

How to judge if \$50,000/year profit is good?

A teenager with a neighborhood lawn-mowing service? \$50,000/year profit is good. *Very* good.

An Intel Fabrication Line? \$50,000/year profit is bad. *Very* bad.

Mid-Semester Survey

Please pass to the center,
then pass to the front.

The Ultimate Economic Parameter is Return On Investment (ROI)

At least, in EngrD 2190 …

$$\text{ROI} = \frac{\text{profit}}{\text{capital cost}} \qquad \text{units are } \frac{\$/\text{year}}{\$} = \frac{1}{\text{year}} \qquad \text{or percent per year}$$

$$\text{Desalinator:} \quad \text{ROI} = \frac{50{,}613\ \$/\text{year}}{340{,}000\ \$} = 0.15/\text{year} = 15\%\ \text{per year}$$

$$\text{Billy's Mowing Service:} \quad \text{ROI} = \frac{50{,}000\ \$/\text{year}}{10{,}000\ \$} = 5.0/\text{year} = 500\%\ \text{per year}$$

$$\text{Intel Fab Line:} \quad \text{ROI} = \frac{50{,}000\ \$/\text{year}}{2{,}500{,}000{,}000\ \$} = 0.00002/\text{year} = 0.002\%\ \text{per year}$$

For every process, calculate the ROI.