TECHONOMICS

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cyclotronroad

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Overview

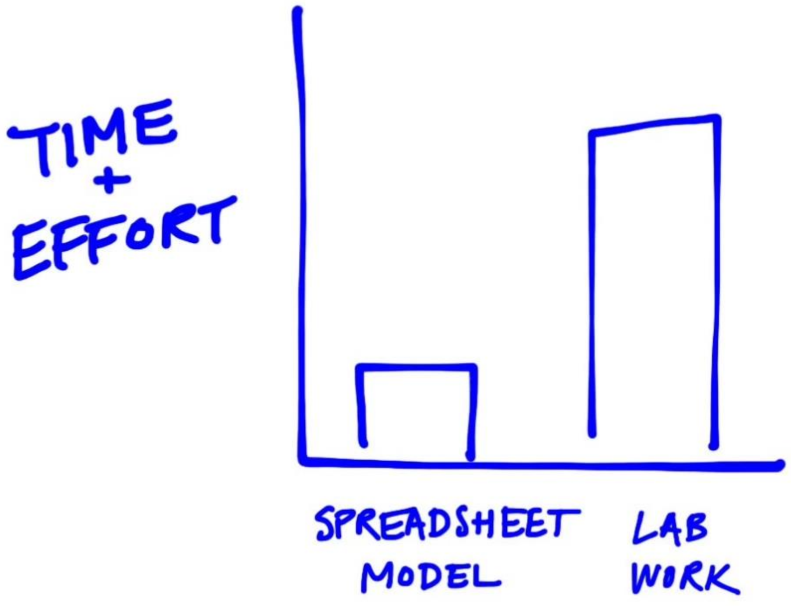
- What is techno-economic analysis, why/when to use it
- Value proposition in hard tech
- Widget tech vs. Process tech
- Case study: graphene membranes
- Methods to quantify cost and value (how to use it)
- Important metrics in energy and cleantech

Why do techno-economic analysis?

VALUE > COST

Why should you care?

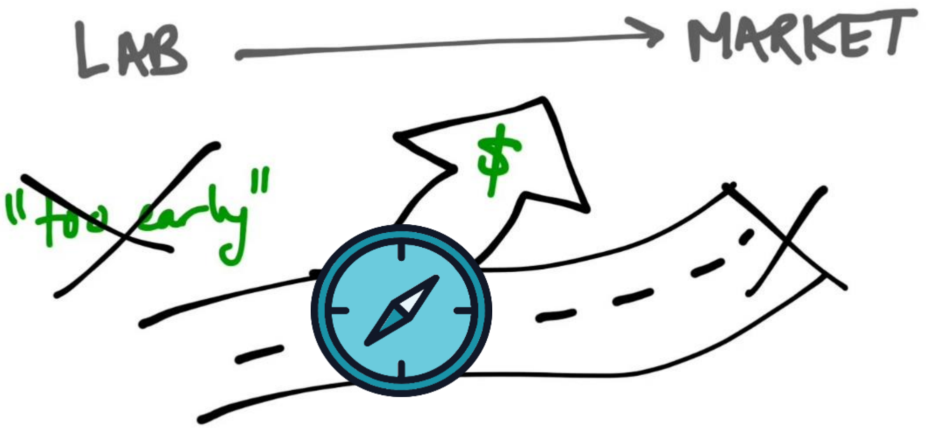
#1 Don't waste your time, your most precious resource.



Why should you care?

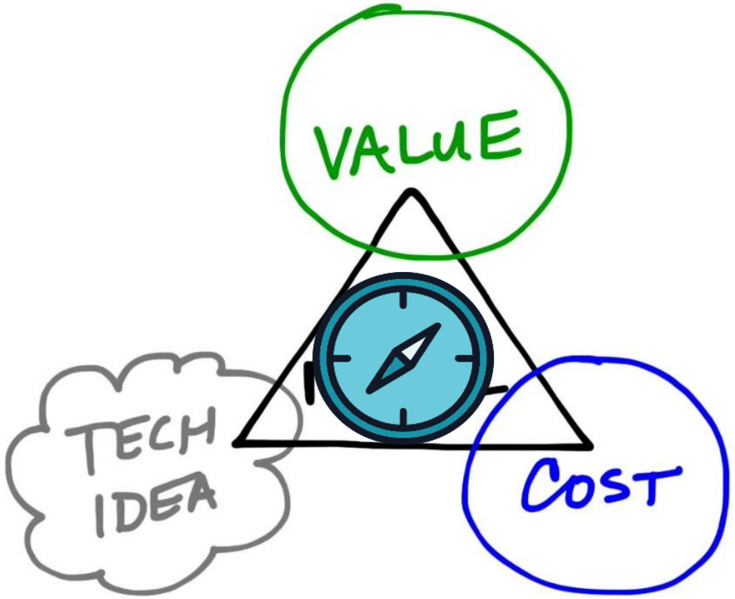
#2 Avoid dead ends and pivot early.

You may not get another chance spend other people's $$$



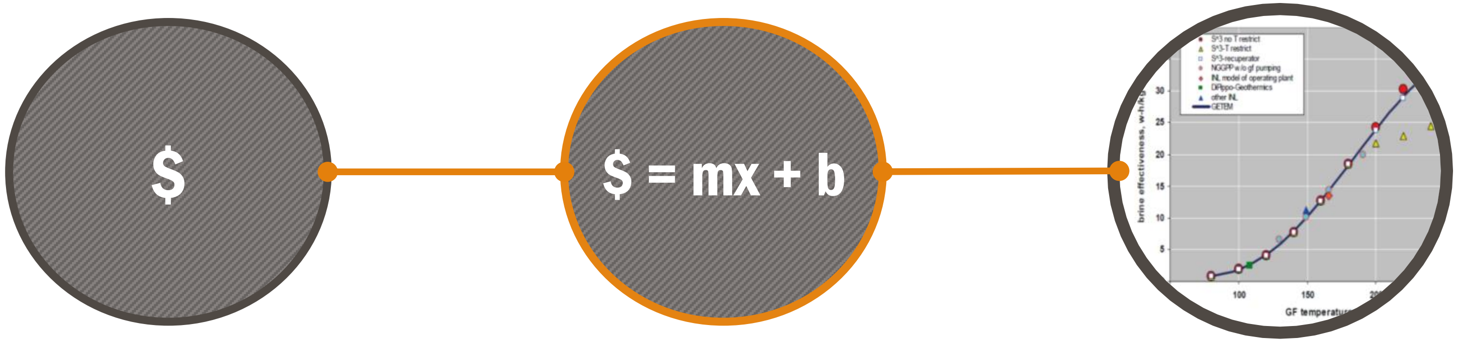
Why should you care?

#3 Optimize R&D and product development to attack biggest cost/value drivers



In an early stage venture, the model is a connection point

Technical milestones



Business people

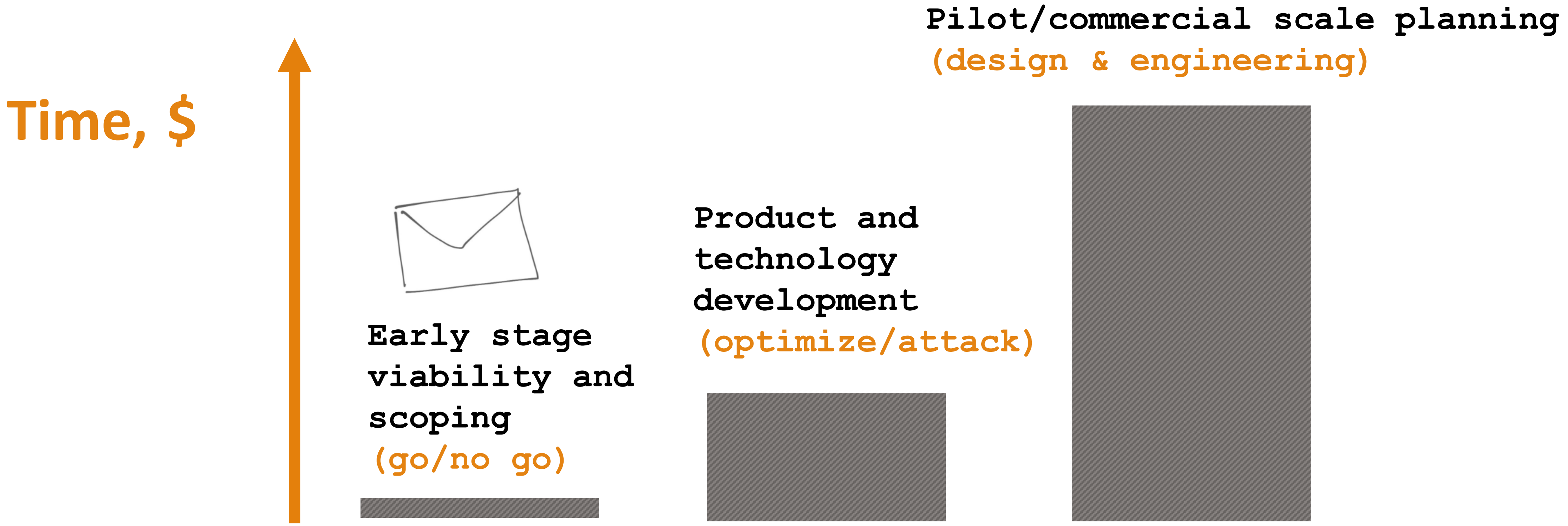
Money metrics

model

Technical people

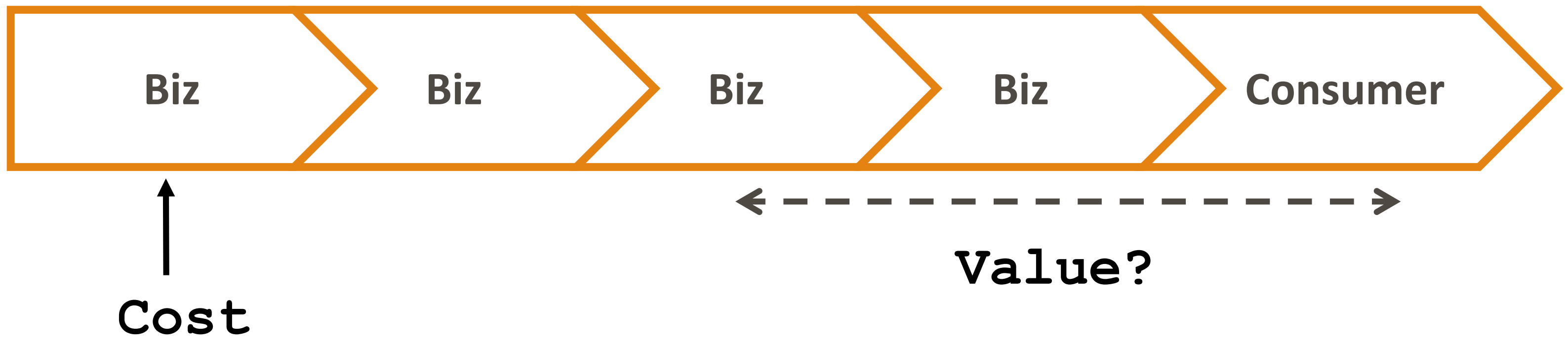
Technical metrics

Modeling is used differently as the venture moves forward



VALUE > COST

Where/how you quantify cost and value depends on the value proposition



All companies need to model cost

→ For many, the value-side model (application) is also critical

Cost-Side Model

Antora – Grid storage
Visolis - Chemicals
Fervo – Geothermal
Seeo – Batteries
Cuberg – Batteries
Noon energy – Grid storage

Value-Side Model

Cinderbio – Industrial enzymes
Hybrid XL – Commercial vehicles
Via Separations – Chem/Pharma/Food processes
Astrileux – Semiconductor coatings
Spark Thermionics – Small-scale power

VALUE > COST

Value Proposition in Hard Tech

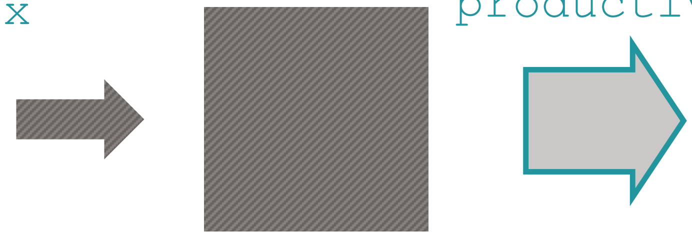
Value proposition must do (at least) one of these

MAKE A BETTER **PROCESS**

Lower OpEx

Lower CapEx

Increase productivity



Inputs $

Assets $

MAKE A BETTER **PRODUCT**

Increase sales

Increase price

Product * Price

units $/unit

Understand:	Production process	Market forces
Talk to:	Engineering & operations people	Sales & marketing people

Where to crunch the numbers? Find the center of gravity of value, and focus there

Question:

Identify a customer for your product. Now imagine **you work for that company.**

What is the math you need to show to **demonstrate to your company, quantitatively**, that it will profit from adopting the new tech?

Two types of energy tech

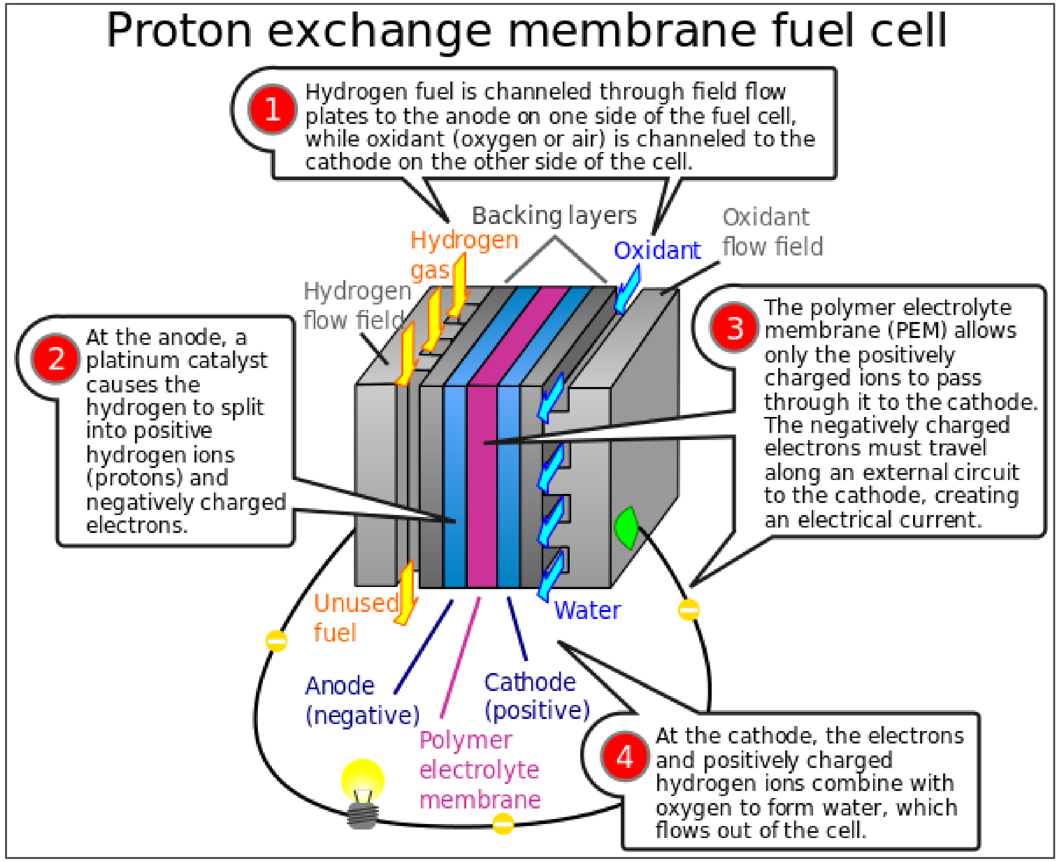
Is your tech a widget or process tech?

Widget technologies in energy

- **Batteries**
- **Solar panels**
- **Electrochemical devices**

→ **Bill of materials** dominates commercial viability

→ Techno-economic models focus on **design vs. performance**



Source: https://en.wikipedia.org/wiki/Fuel_cell

Process technologies in energy

- **Power production** (from burning stuff)
- **Fuels & chemicals production**

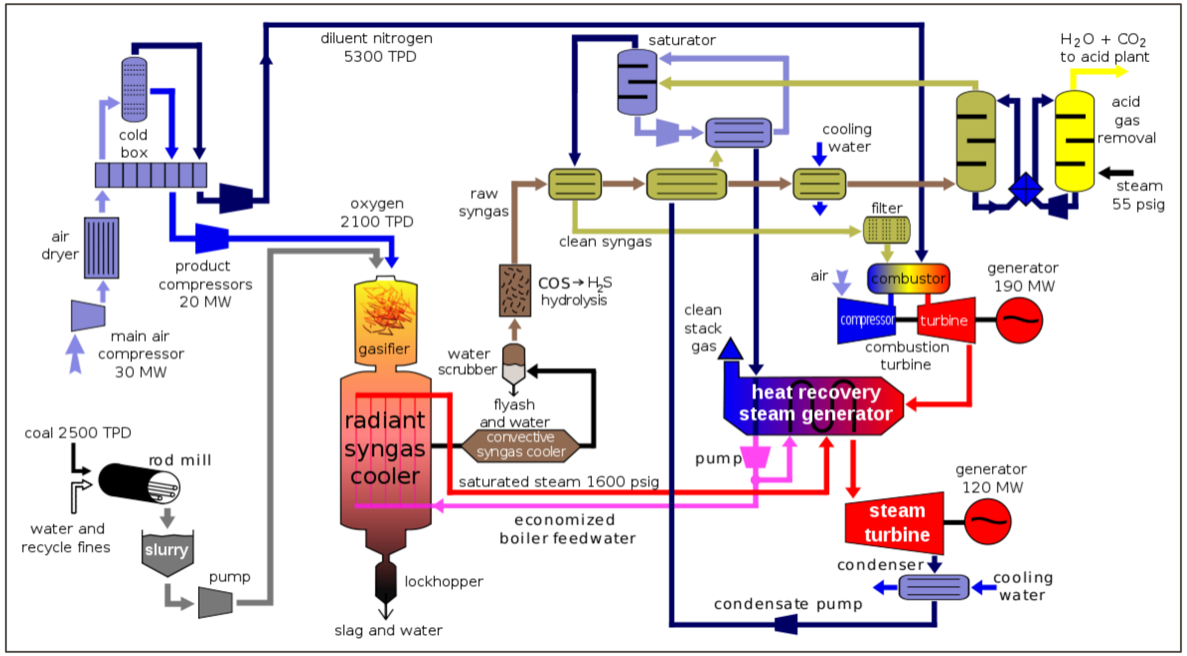
→ Heat, gas, & steam

→ Large economies of scale

→ **CapEx** dominates commercial viability

→ Techo-economic models focus on **production cost**

Combined Cycle Power Plant



Source: https://en.wikipedia.org/wiki/Integrated_gasification_combined_cycle

Case study: graphene membranes

Via Separations, a MIT graphene membrane startup

2500%

increase in graphene and graphene oxide nanofiltration articles since 2010

20%

papers that claim to be scalable

4%

papers that mention any quantitive cost analysis

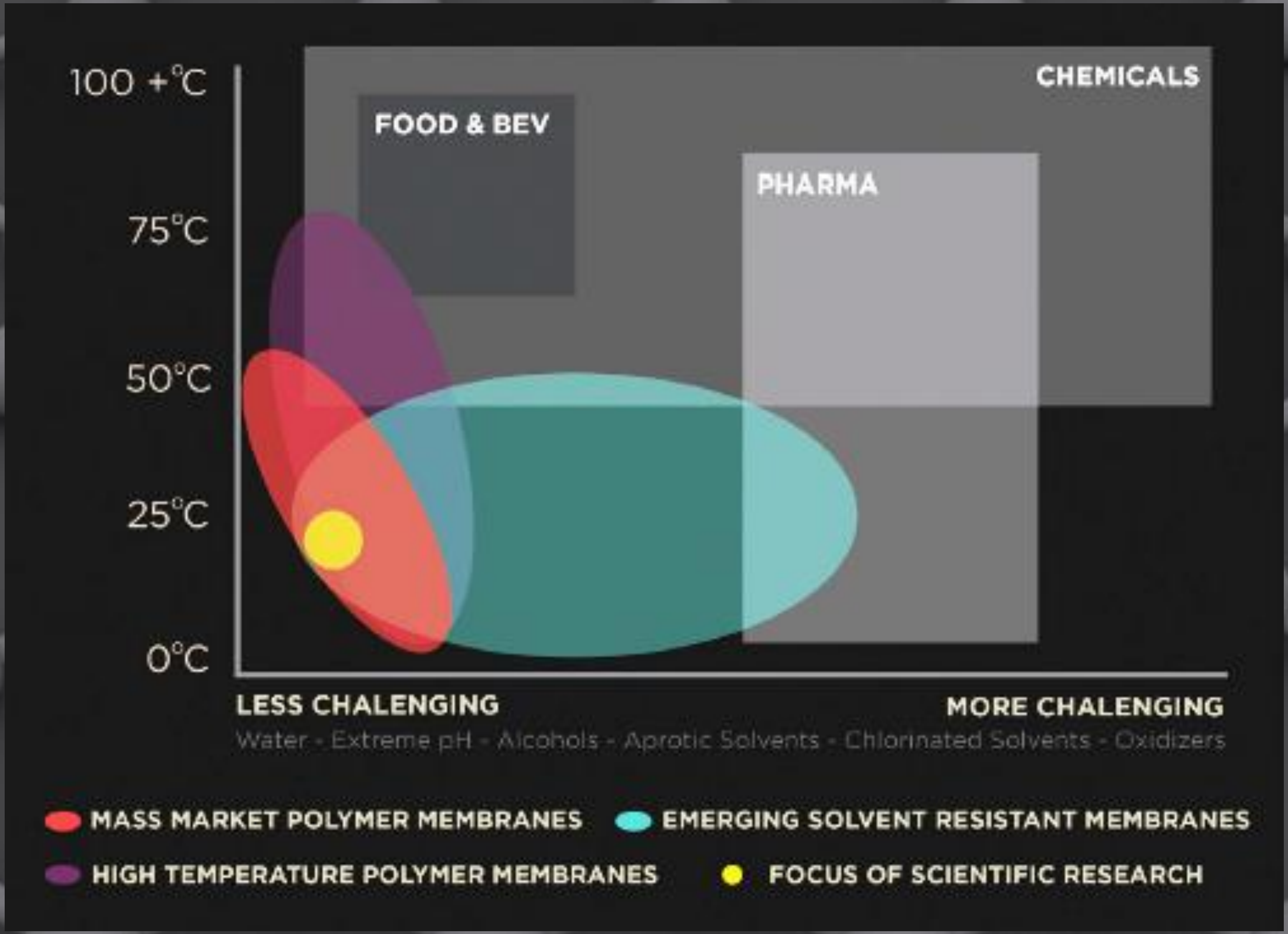
Joule

COMMENTARY

Six Degrees of Separation: Connecting Research with Users and Cost Analysis

Shreya H. Dave,[1,2,*]
Brent D. Keller,[2]
Karen Golmer,[2]
and Jeffrey C. Grossman[1,2,*]

Value depends on where the membrane can operate



Via needs two techno-economic models

Cost-Side Model

Cost of production:
Membranes

Value-Side Model

Process model:
Chemical X

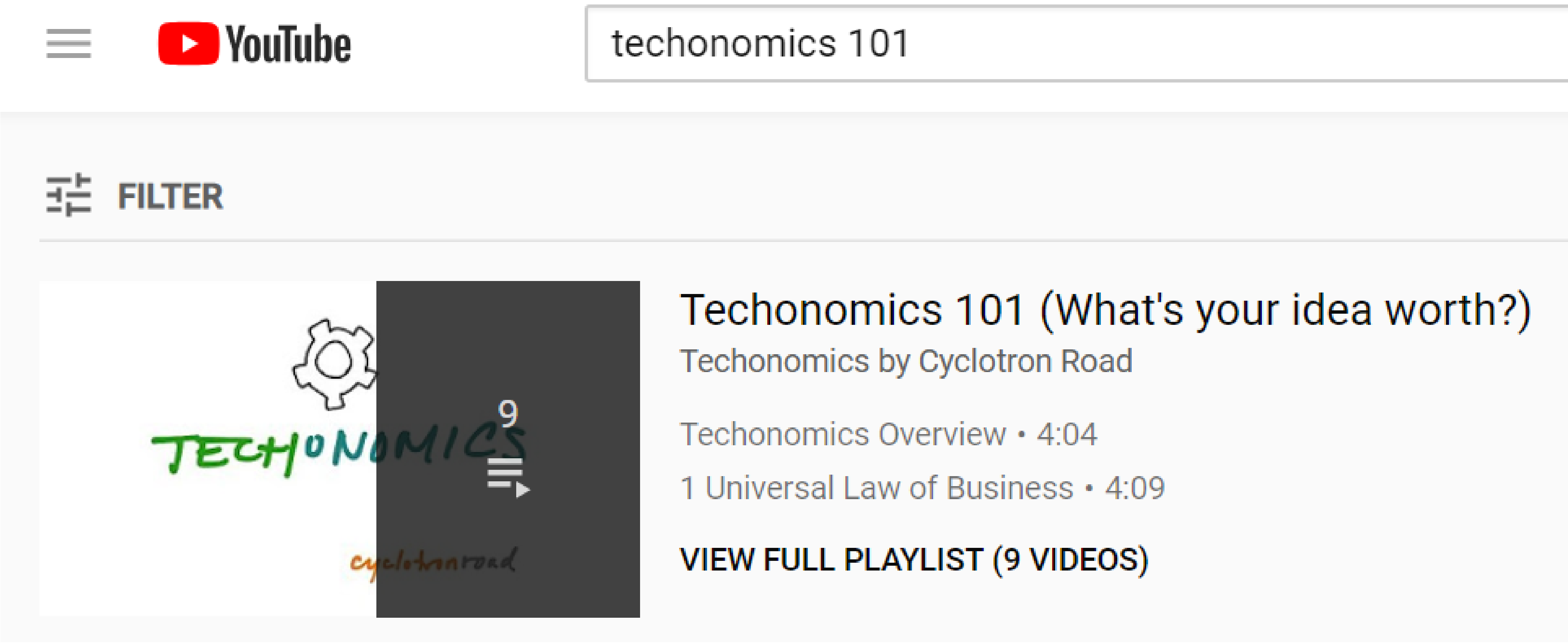
VIA SEPARATIONS

TECHNOLOGY ABOUT PRESS CONTACT US

MOLECULAR FILTRATION FOR INDUSTRIAL PROCESSES

Building a model

Resources for getting started



TECHONOMICS

Home | Model downloads | Model building | About

Build the future physical world

Are you developing technology for commercial impact?

Here, you'll find:

1. 5-minute videos on how to quantify the value of your technology
2. Free to download Excel models to learn from and hack
3. Playthrough videos - Learn how to build your own models

Download example models

https://sites.google.com/cyclotronroad.org/techonomics
(or access through Youtube channel)

These spreadsheet models are free to use, download, and modify

Super performance frisbee

Can we make it for under $6.00 and maintain performance?

Product specs & parameters		
Frisbee diameter	30	cm
Frisbee height	1.2	cm
Green layer thickness	4.5	cm
Green layer material	SuperPower	

Criteria	Target	Predicted
Total material costs	$6.00	$6.24
Inertia, g-cm2	80,000-85,000	80,533

Layer name	Tr	Density	Mat'l cost	Inner rad.	Outer rad.	Volume	Mass	Inertia	Layer cost
-	cm	g/cm3	$/kg	cm	cm	cm3	g	g-cm2	$
Blue	8.0	0.35	$2.05	0.0	8.0	241	84	2,702	$0.17

Simple cost-performance model

FOUNDER'S PLAYBOOK

Beta

cyclotronroad

PLAYBOOKS | FILE TREE

search for topics like IP, team building, etc.

Tech + Product 59

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- 06 - Product Market Analysis 3

Techno-economic model - Polymer synthesis

This is a model for a new super-polymer synthesis method.

Process parameters

Production rate	500	t/yr
Utilization	95.0%	
Overall conversion (reactor yield)	95.0%	of monomer
Separation yield	98.0%	

Reaction parameters

Single pass conversion	4.0%	of monomer
Catalyst dosing	0.0010	kg/kg monomer
Reactor pressure	5.0	bar
Reactor pressure drop	1.0	bar

Costs

Polymer product	$7,000	/t
Catalyst	$1,150	/t
Monomer	$1,050	/t
Hydrogen	$2,100	/t
Electrical power	$0.11	/kWh
Cost per operator	$72,000	/yr

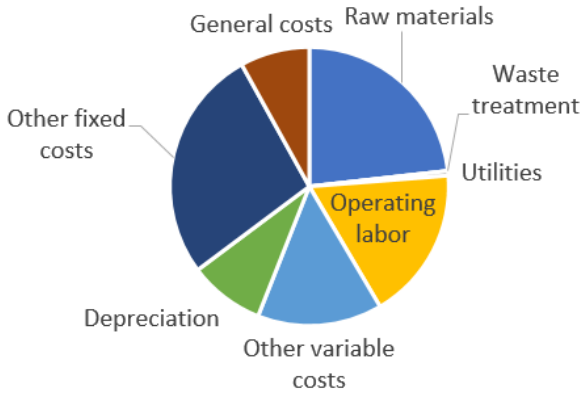
Financial results

CapEx	$2.46	MM
OpEx less depreciation	$3.58	/kg product
Revenue	$7.00	/kg product

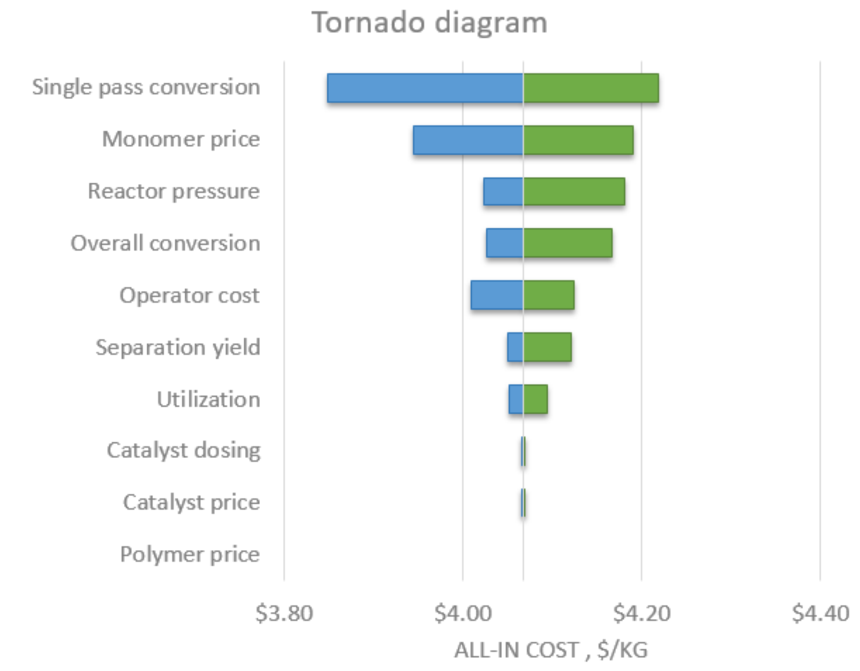
(Equipment size is within cost correlation range.)

Profitability metrics

All-in cost	$4.01	/kg product
Payback period	2.8	years



Tornado diagram sensitivity analysis



Settings	Worst	Expected	Best	Units	Reference
Utilization	90%	95%	98%	-	95.0%
Overall conversion	90%	95%	97%	of monomer	95.0%
Separation yield	95%	98%	99%	-	98.0%
Single pass conversion	3.0%	4.0%	7.0%	of monomer	4.0%
Catalyst dosing	0.0015	0.0010	0.0008	kg/kg monomer	0.0010
Reactor pressure	4.0	5.0	5.5	bar	5.0
Polymer price	$13,500	$14,100	$14,600	/t	$7,000
Monomer price	$1,155	$1,050	$945	/t	$1,050
Catalyst price	$2,310	$2,100	$1,890	/t	$2,100
Operator cost	$76,000	$74,000	$72,000	/yr	$72,000

Refresh Tornado

Metric: **All-in cost , $/kg**

User instructions:

1. *In 'Settings' table, enter best-case, expected-case, and worst-case values for each parameter.*
2. *Select output metric from drop down menu below table.*
3. *Click 'Refresh Tornado' button.*
4. *Customize chart format if desired.*

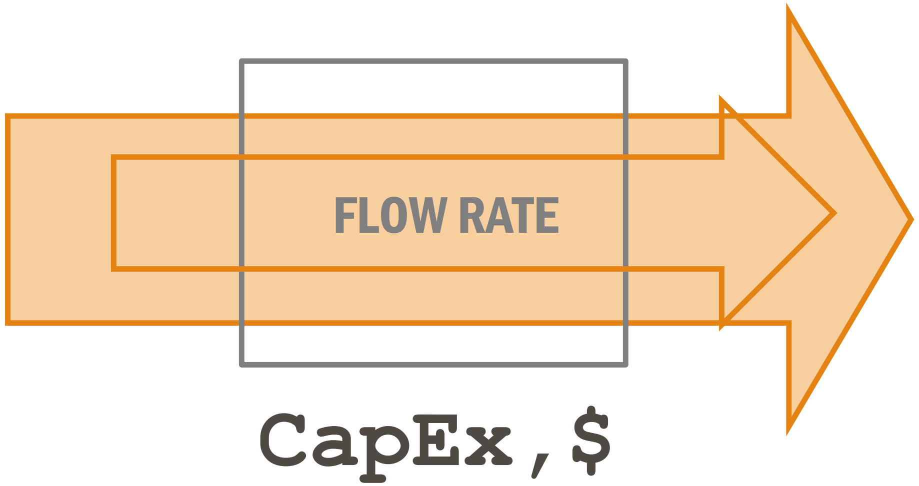
VALUE > COST

Plant economics

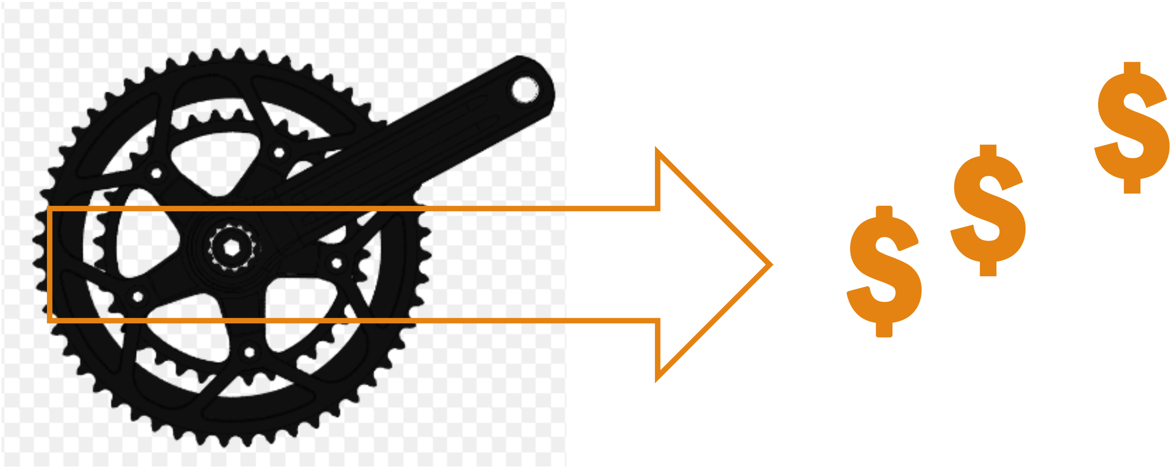
Key factors affecting economics

- Rate — Increasing output with available infrastructure
- Yield — More efficient conversion of inputs to product
- Utilization — Uptime. Operates 24/7 for best economics

Rate



Rate



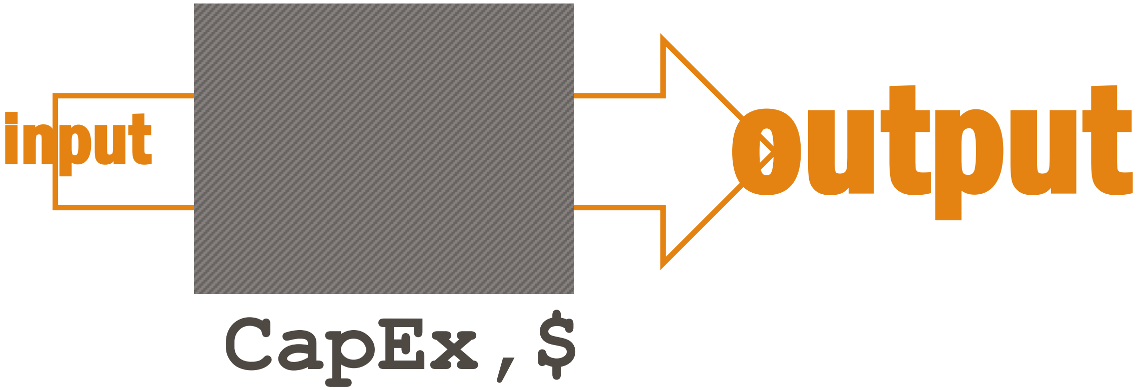
Cranking out dollar bills!

Economics of power generation are similar to other production systems

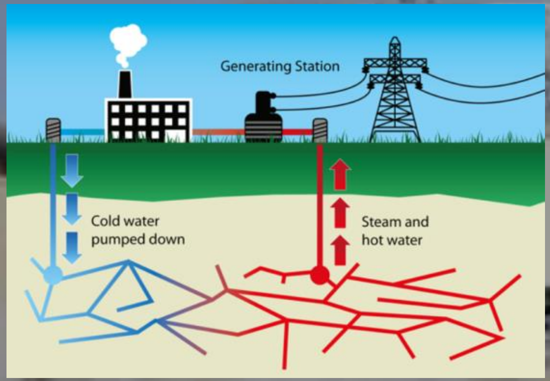
- Capital intensive
- Commodities – lower cost is everything
- CapEx is critical

Key number in production plant investment decisions – “apples to apples”

$CapEx / output capacity



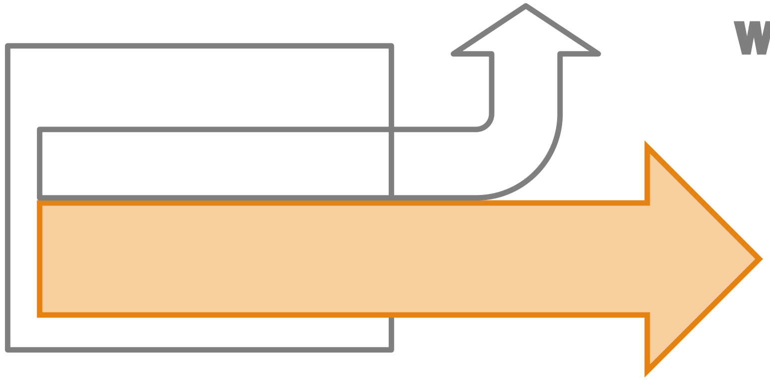
$/mgy	fuels
$/MT/yr	chemicals
$/kW	electricity
$/kWh/yr	battery manufacturing



Low heat flux, high CapEx constrains geothermal

Higher wind speeds at higher elevation

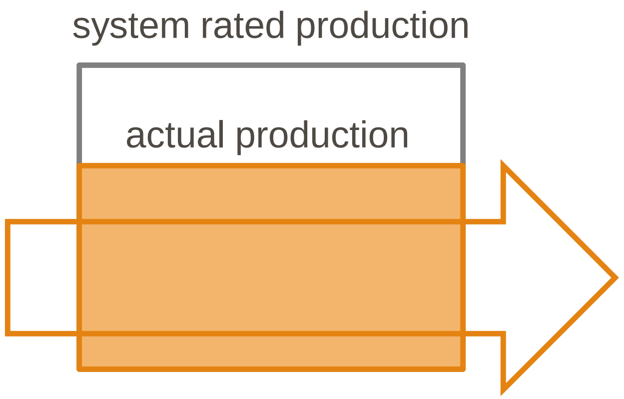
Yield



`Yield = actual/potential product`

Higher efficiency of solar panels

Utilization



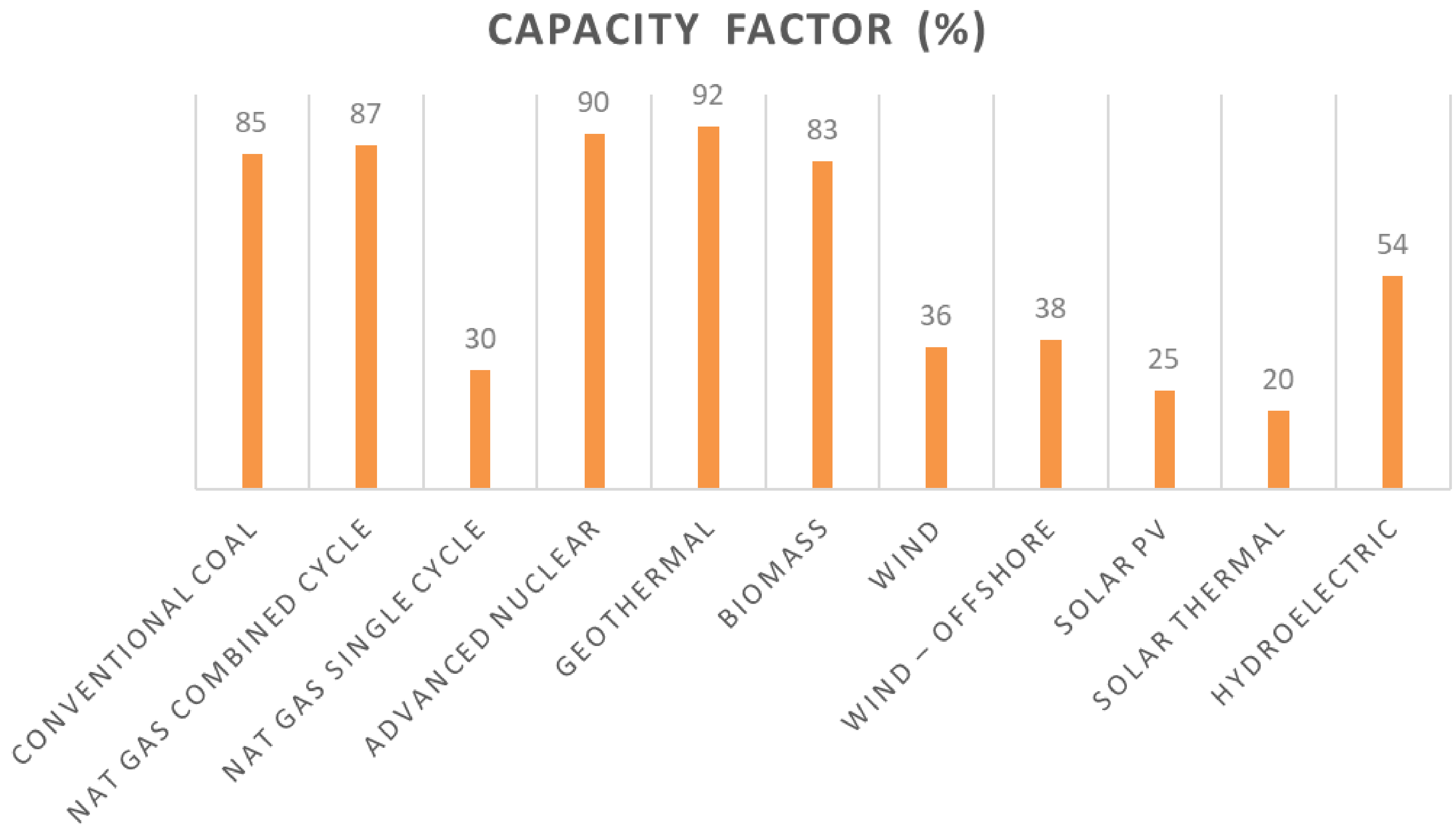
`= actual / rated output`

If your customer is producing something and they are…. They want to…

Below Capacity → MINIMIZE COST

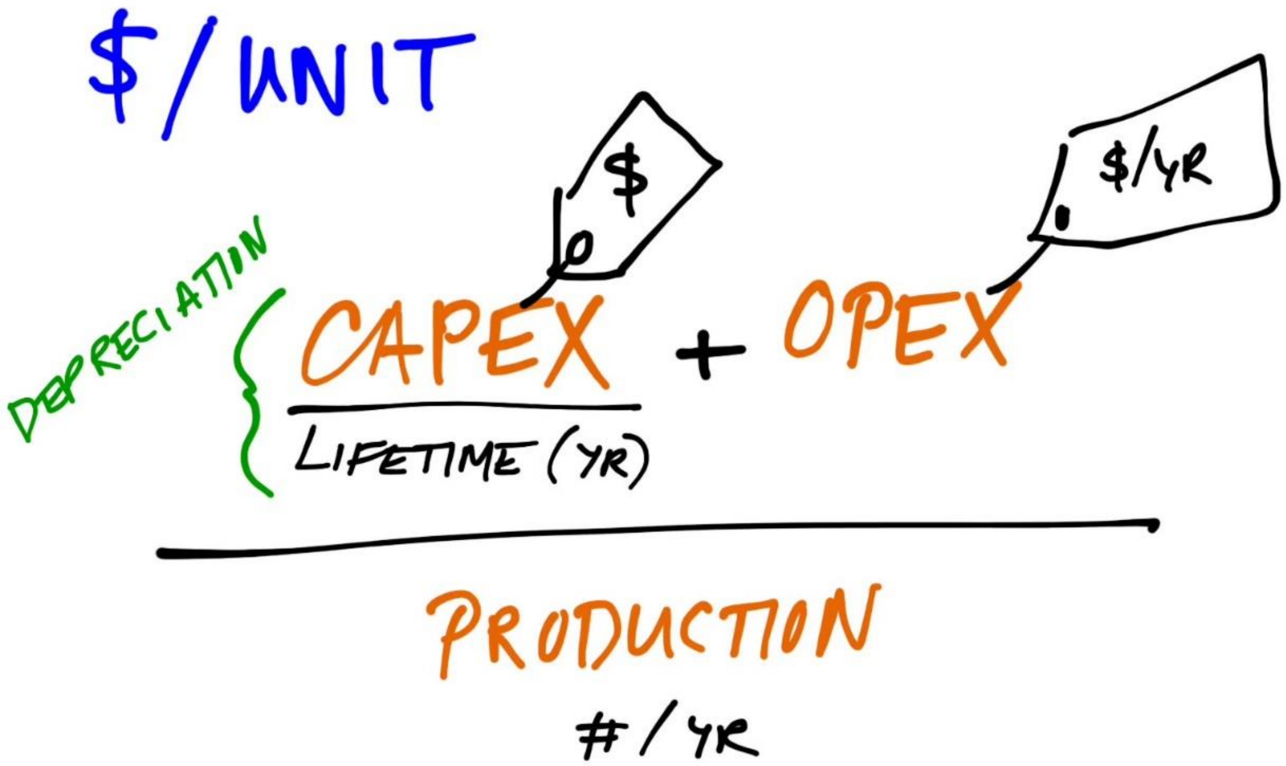
At/near Capacity → MAXIMIZE OUTPUT

Utilization of generation technologies



Source: EIA Annual Energy Outlook

Cost per unit – back of the envelope method



Questions?