

PEAKING OF WORLD OIL PRODUCTION:

IMPACTS, MITIGATION, RISK MANAGEMENT

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The Situation

- **THE PROBLEM:** Soon world conventional oil production will no longer meet demand.
- **WHY THE PROBLEM?**
 - World conventional oil resources are finite.
 - Oil discovery has lagged consumption for two decades; the resource is being rapidly depleted.
- **WHEN WILL PEAKING OCCUR?**
 - No one knows for sure.
 - Some think 1-10 years.
- **WHY CAN'T THE PROBLEM BE FIXED QUICKLY?**
 - The scale of consumption worldwide is enormous.
 - Mitigation will take a decade or more, based on crash programs.
 - With timely mitigation, dire economic consequences can be avoided.

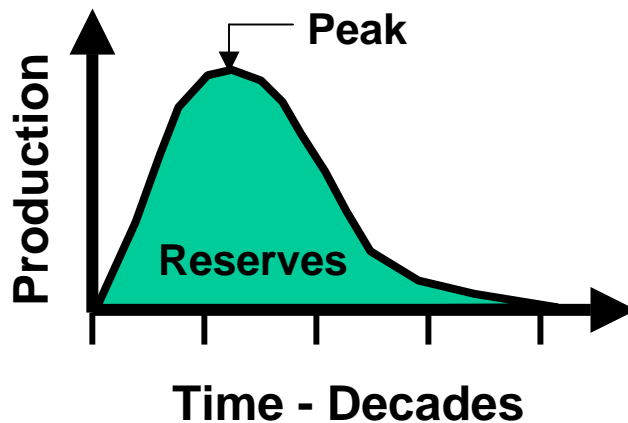
Peaking = The world's first forced energy transition.

THIS PRESENTATION

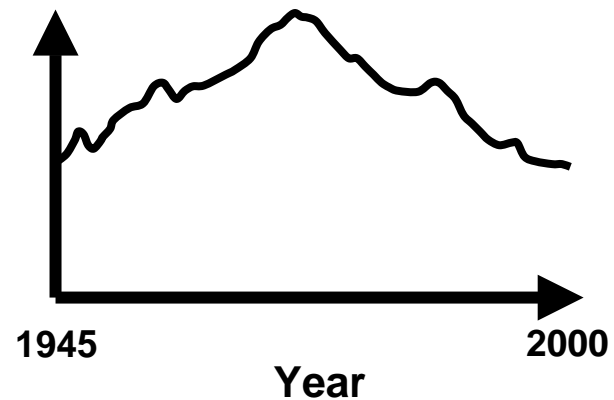
- **THE PROBLEM**
- **LEARNING FROM EXPERIENCE**
- **TRANSPORTATION FLEET LIFETIMES**
- **MITIGATION OPTIONS**
- **THREE MITIGATION SCENARIOS**
- **PRUDENT RISK MANAGEMENT**

FUNDAMENTALS

- Oil is the lifeblood of modern civilization, esp. transportation.
- Geologists agree: World conventional oil production will peak.



Notional Individual
Reservoir



U.S Lower 48 States
Hundreds of Reservoirs

FUNDAMENTALS

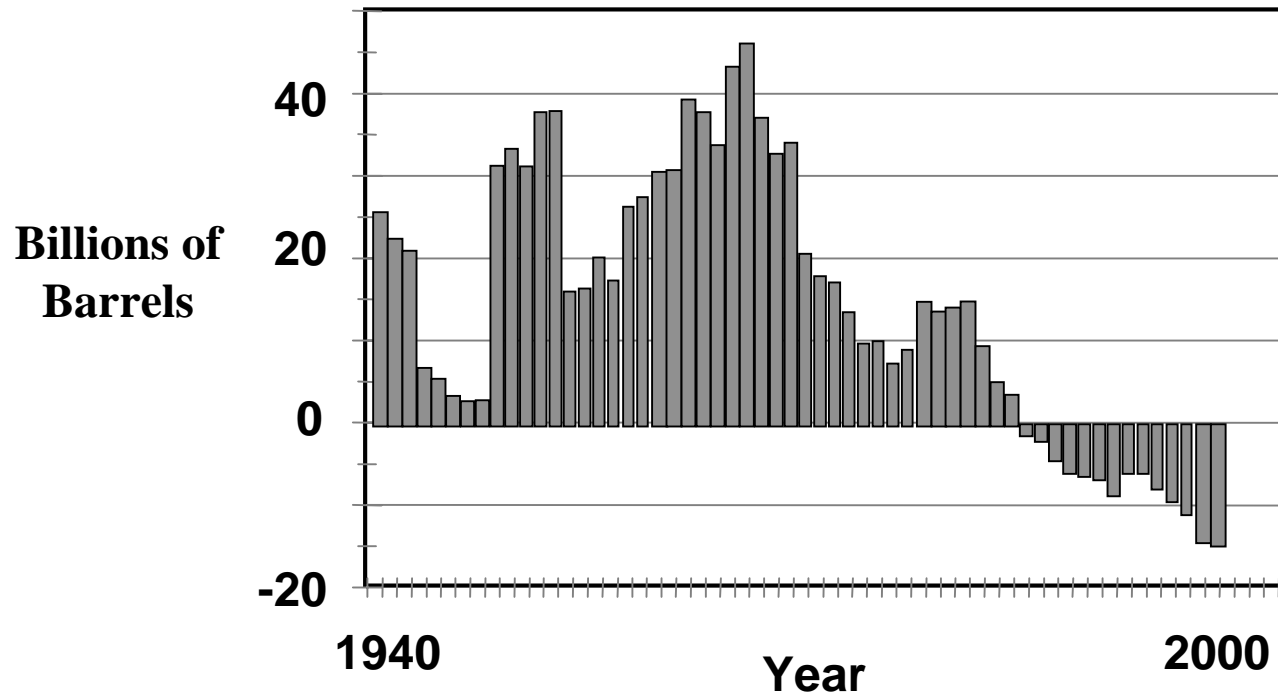
Peaking is maximum production,
not running out.

It's a liquid fuels problem.

OBSERVATIONS

- World oil demand is huge & growing.
- Most past peaking predictions were wrong.
 - + Hubbert was right on the U.S. Lower 48
 - + Recent predictions may be right.
 - + Wrong isn't forever.
- Why reconsider peaking now?
 - World oil consumption outstripping new discoveries
 - Extensive drilling worldwide - Large database
 - Advanced technology: Modern geology & 3D seismic
 - Many experts are pessimistic.
 - The economic consequences could be dire.

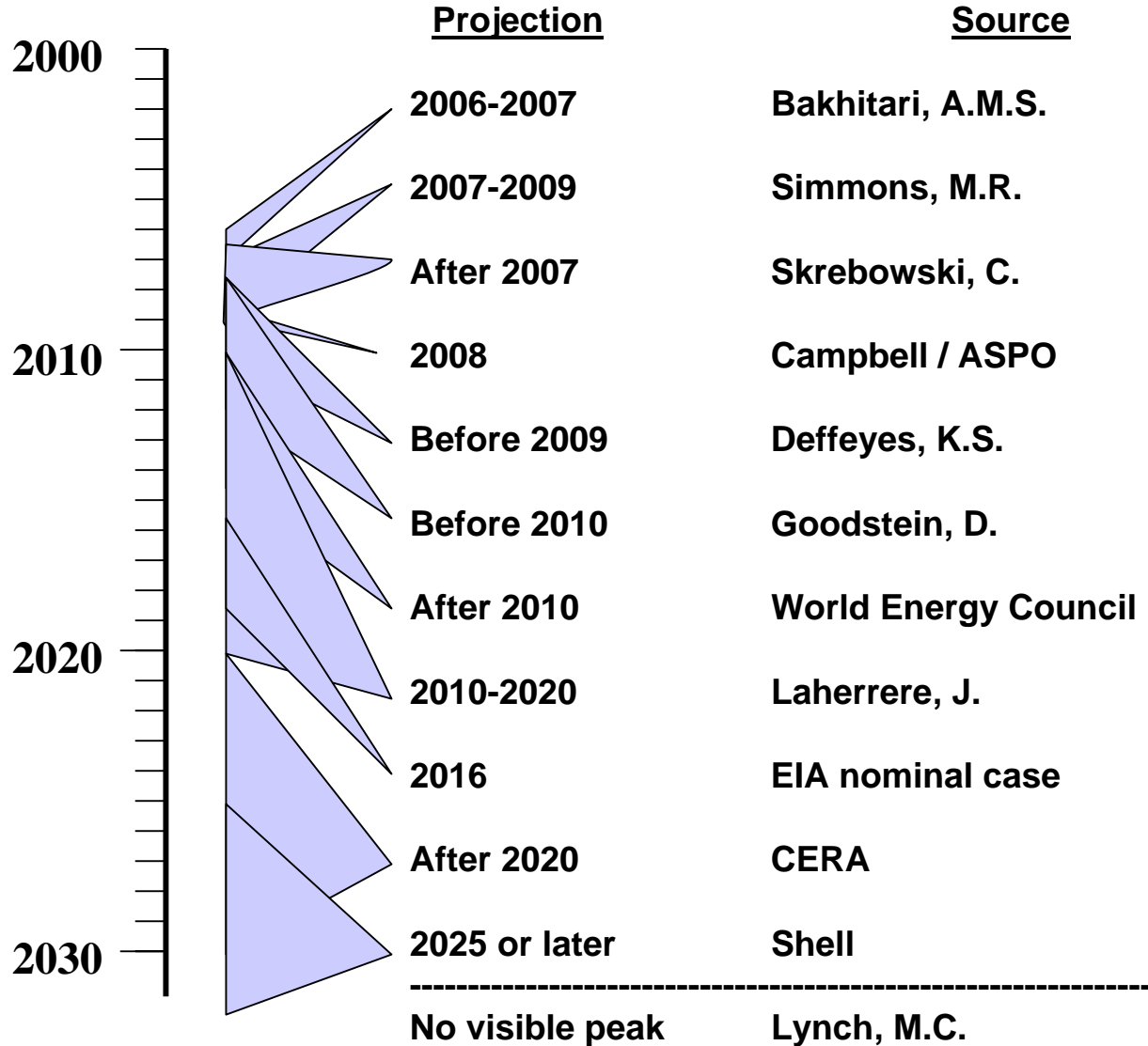
ANNUAL WORLD OIL BALANCE IS NEGATIVE*



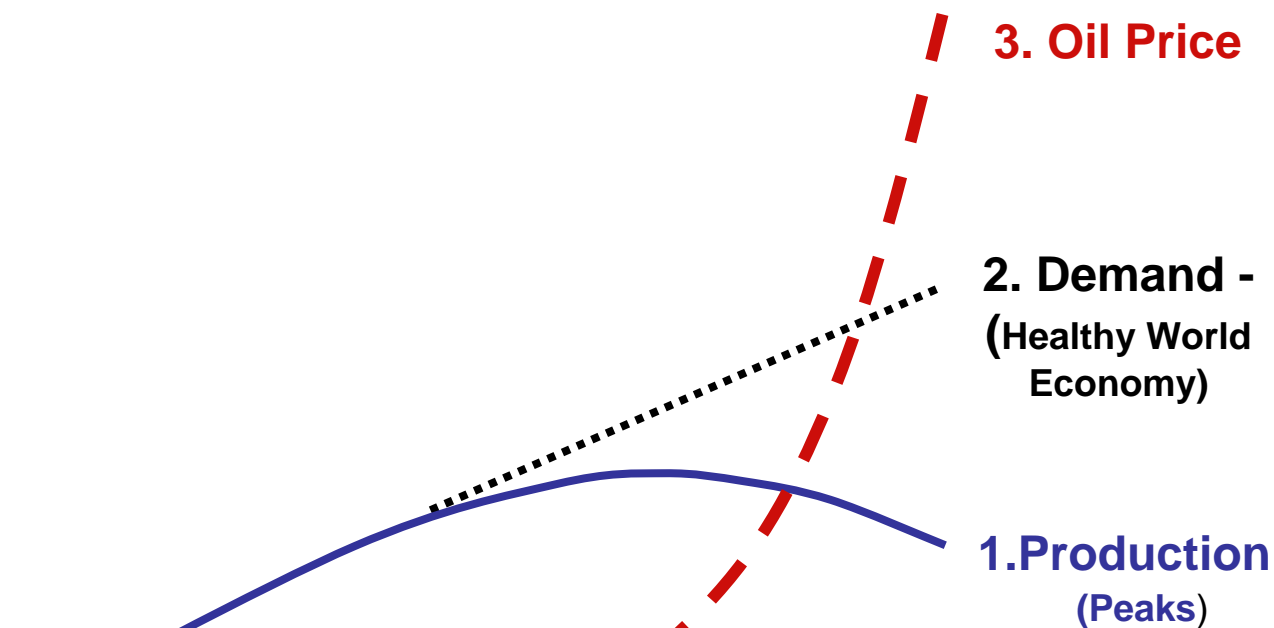
* Reserves additions minus consumption

FORECASTS OF WORLD CONVENTIONAL OIL PRODUCTION PEAKING

(Not all of the latest forecasts)



LIKELY TRENDS NEAR WORLD OIL PEAKING



A LIQUID FUELS PROBLEM

LEARNING FROM EXPERIENCE

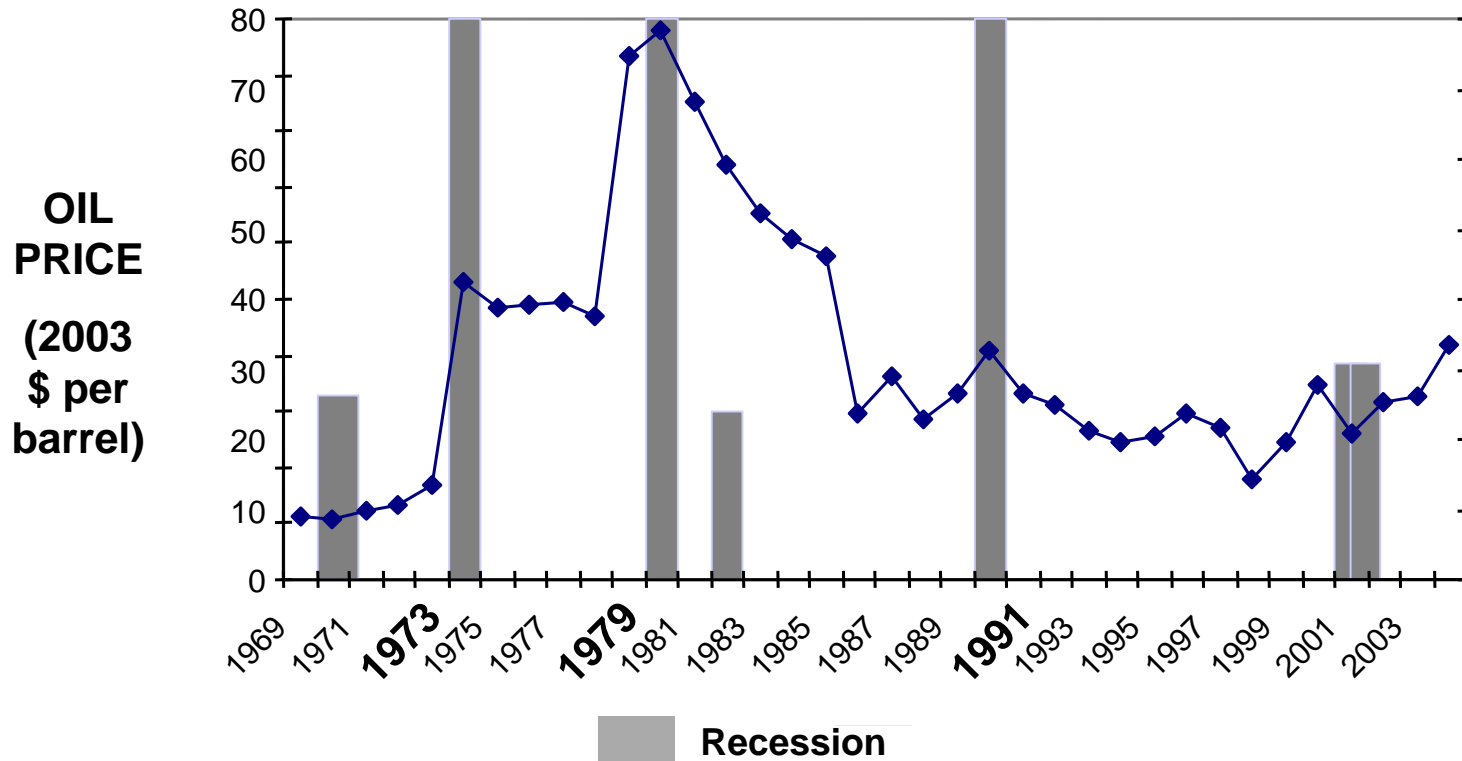
- **North American natural gas**
- **U.S. Lower 48 states oil production**
- **Economic impacts in 1973 & 1979**

EXPERIENCE: NORTH AMERICAN NATURAL GAS

- **Experts overestimated North American natural gas reserves & future production as late as 2001.**
 - National Petroleum Council - 1999
 - DOE EIA - 1999
 - Cambridge Energy Research Associates - 2001
- **U.S. natural gas production is now flat / in decline.**

- **Natural gas & oil geology have similarities.**
- **If wrong on natural gas, what's the risk on oil?**

EXPERIENCE: Oil PRICE SPIKES CAUSED SOME U.S. RECESSIONS



Over 30 years, four recessions followed oil price spikes.

EXPERIENCE: MAJOR OIL INTERRUPTIONS

- Impacts of world oil production peaking are exemplified by the 1973 & 1979 oil interruptions.

+ Inflation

+ Unemployment

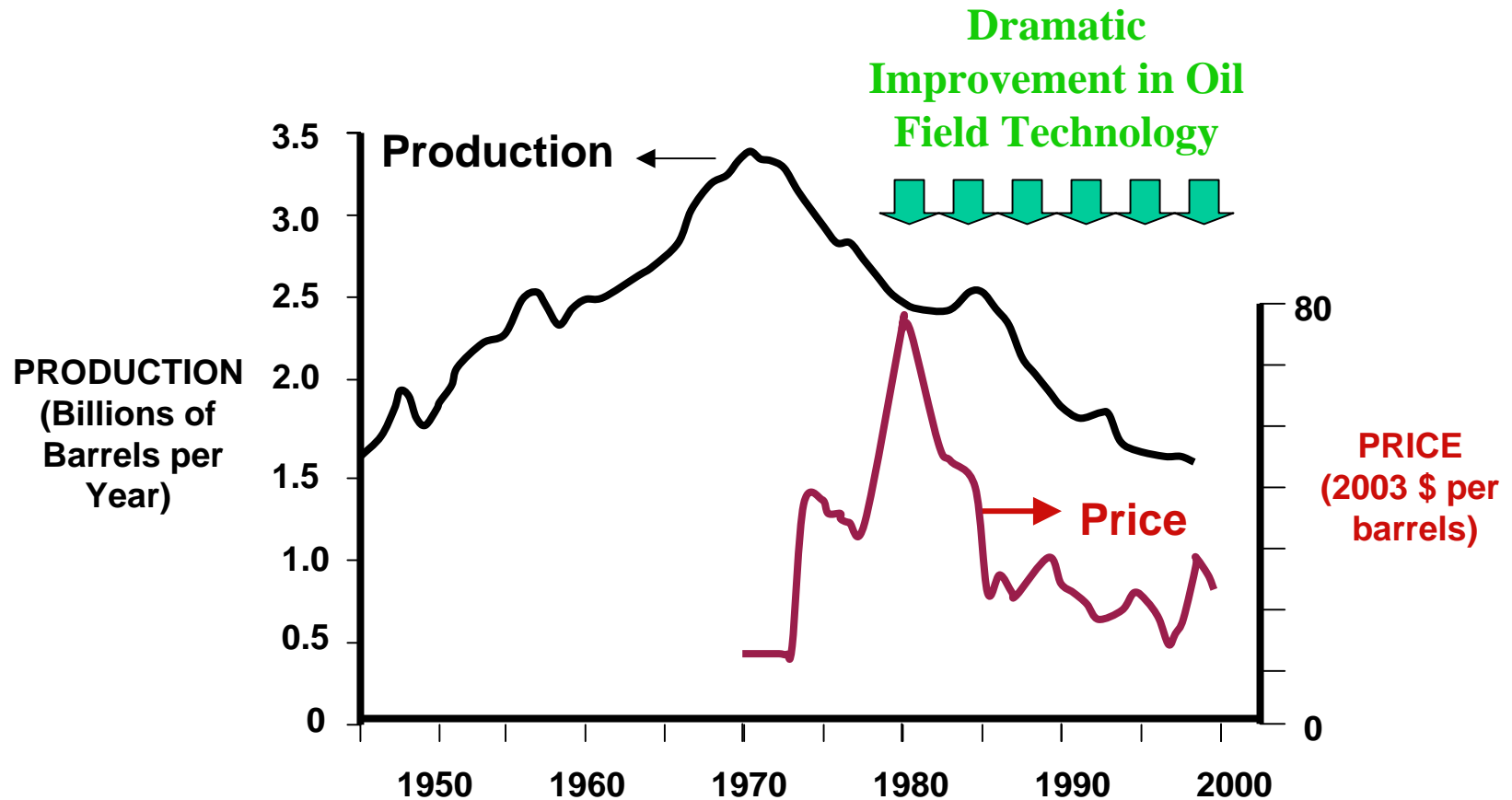
+ Recession

+ High interest rates

- 1973 & 1979 were relatively brief.
- World oil peaking impacts could last a decade or more.

The world has never faced a problem like oil peaking.

EXPERIENCE: U. S. LOWER 48 OIL PRODUCTION



High prices & advanced technology did not reverse trends!

U.S. OIL USE

- **U.S. 2003 consumption: ~20 MM bpd**
 - ~25% of world oil demand
 - ~Two thirds used in transportation
- **The U.S. transportation fleet**
 - + Very large
 - + Huge investment
 - + Evolves slowly



U.S. TRANSPORTATION FLEETS

Fleet	Size	Median Lifetime (Years)	Cost to Replace Half the Fleet (2003 \$)
Automobiles	130 million	17	\$1.3 trillion
Light Trucks, SUVs, etc.	80 million	16	\$1 trillion
Heavy Trucks, Buses, etc.	7 million	28	\$1.5 trillion
Aircraft	8,500	22	\$.25 trillion

TRANSPORTATION EQUIPMENT CHANGES

- **Large efficiency improvements possible in some fleets, smaller in others.**
- **Some fuel switching possible in the short term, more longer term.**

Change is slow & expensive.

Fuel must be provided for existing fleets.

THREE MITIGATION SCENARIOS

- **Scenario I** - No action until peaking occurs
- **Scenario II** - Mitigation started 10 years before peaking
- **Scenario III** - Mitigation started 20 years before peaking

Assumptions:

- » All mitigation initiated immediately
- » Crash program implementation

Optimistic limiting case

MITIGATION OPTIONS

Commercial or near-commercial technologies to impact LIQUID FUEL MARKETS

- **Vehicle Fuel Efficiency**
- **Gas-To-Liquids (GTL)**
- **Heavy Oil / Oil Sands**
- **Coal Liquefaction**
- **Enhanced Oil Recovery (EOR)**

OPTIONS NOT INCLUDED

<u>Option</u>	<u>Reasoning</u>
– Nuclear <u>ELECTRIC / NOT LIQUID FUELS</u>
– Wind	
– Solar	
– Hydrogen.....	Neither ready nor economic
– Biomass.....	Not economic
– Shale Oil.....	Not commercial

VEHICLE FUEL EFFICIENCY

- Automobiles & light trucks (LDVs) are the largest liquid fuel consuming opportunity.
 - Diesel engines are up to 30% more efficient than gasoline engines.
 - Hybrids are 40% more efficient in small cars / 80% in medium cars.
 - Enhancements to existing technologies can also contribute.

Estimates based on 30%, then 50% improvements

GAS-TO-LIQUIDS

- Now commercial & could be significant
- Must compete with LNG
- Non-U.S. resource

Estimates based on 2x recent GTL projections

HEAVY OIL / OIL SANDS

- Canada + Venezuela: 3-4 trillion barrels
- ~600 billion barrels economic
- Only part clean fuels - Canada: 0.6 of 1.0 MM bpd
- Current plans - Canada: 3 MM bpd synthetic oil by 2030
- Large energy input required
- Oils harder to refine
- Significant environmental problems

Estimates based on 2-2.5x recent projections.

COAL-TO-LIQUIDS

- Now commercial / near-commercial.
- Cost: \$30-35/bbl
- Huge coal resource in U.S., elsewhere
- Liquids don't need refining

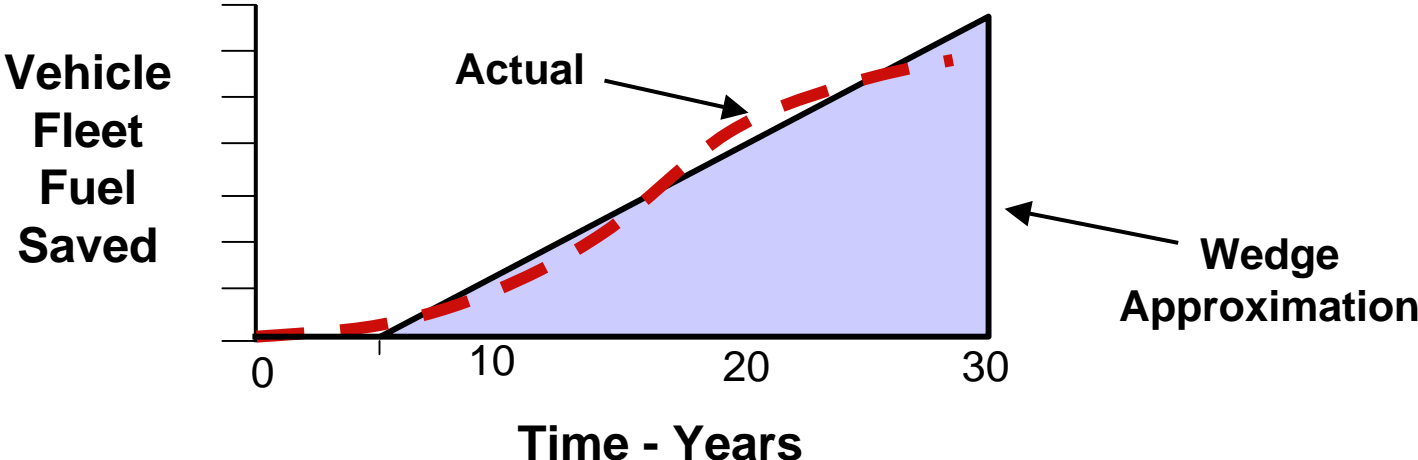
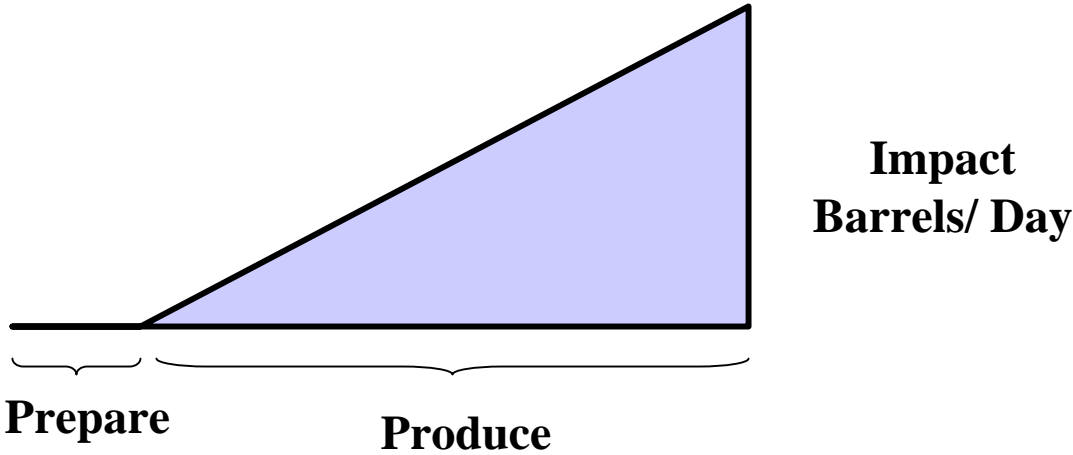
Based on five new 100,000 bpd production plants/year.

ENHANCED OIL RECOVERY

- EOR has been utilized for decades.
- It's usually applied after primary and secondary recovery.
- It helps recover additional oil from reservoirs past peak production.

Production estimates paced by CO₂ availability.

WEDGES USED TO SHOW MITIGATION

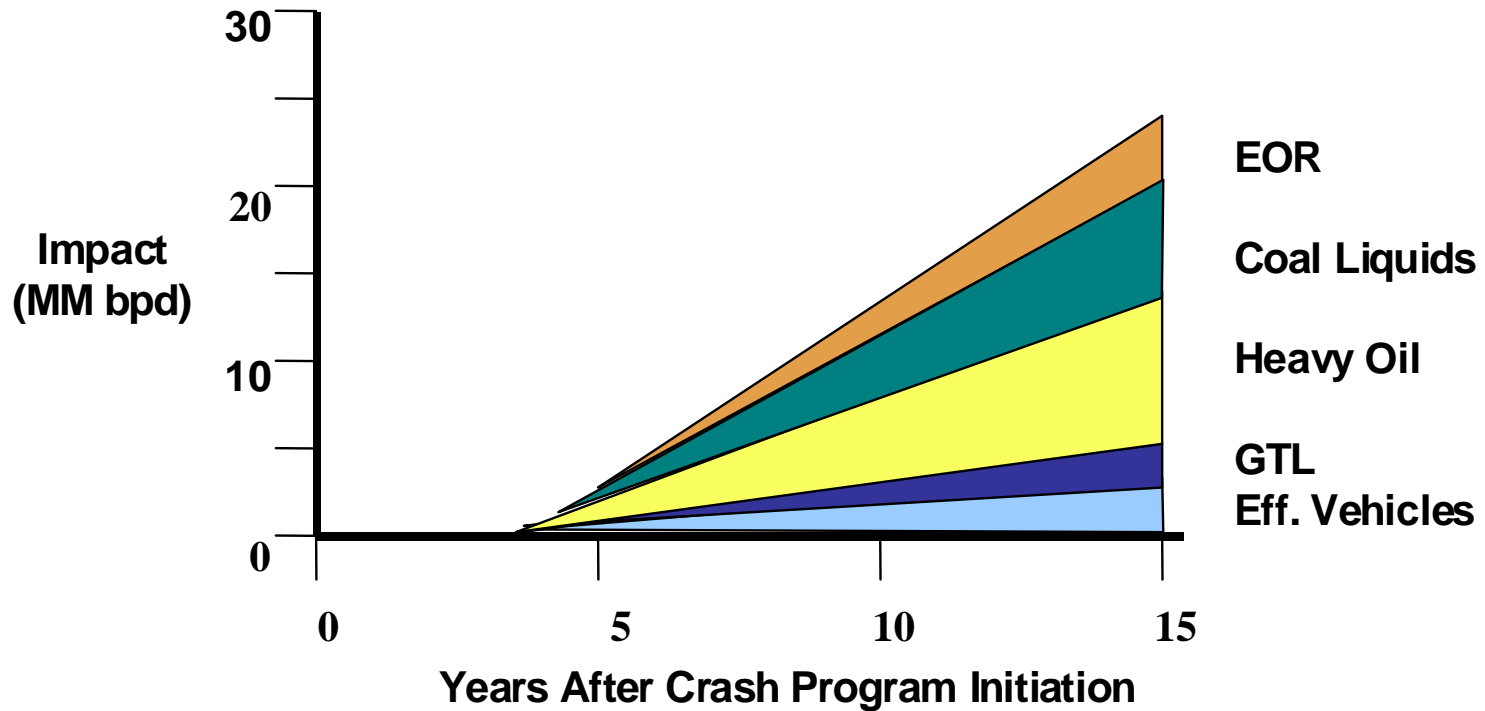


WEDGES VALUES IN THIS STUDY

<u>Mitigation Option</u>	<u>Preparation Delay (Years)</u>	<u>Impact 10 Years Later (MM bpd)</u>
– Vehicle Efficiency	3	2
– Gas-To-Liquids	3	2
– Heavy Oils / Oil Sands	3	8
– Coal Liquids	4	5
– Enhanced Oil Recovery	5	3

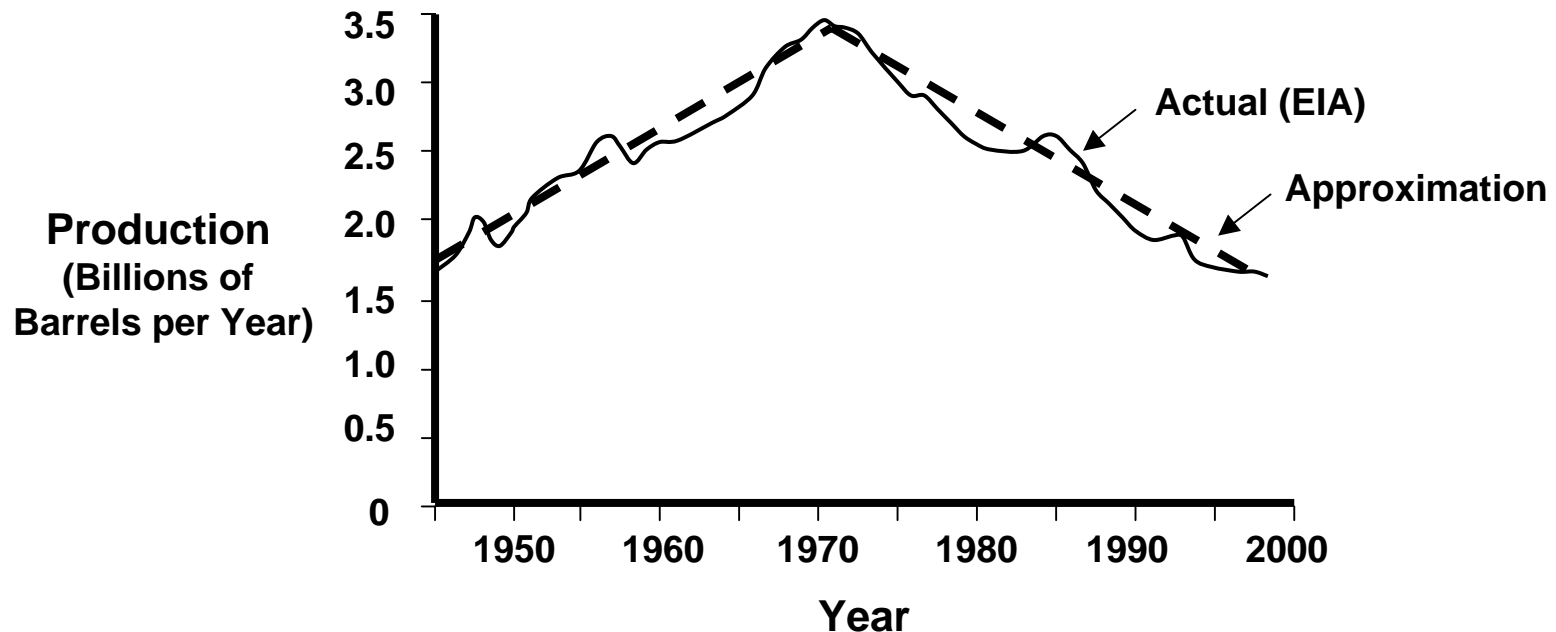
Potential contributions vary.

SUM OF WEDGES



- Delay, then rapid growth.
- Roughly 25 MM bpd at 15 years after crash program start.

U.S. LOWER-48 OIL PRODUCTION PEAKED & DECLINED

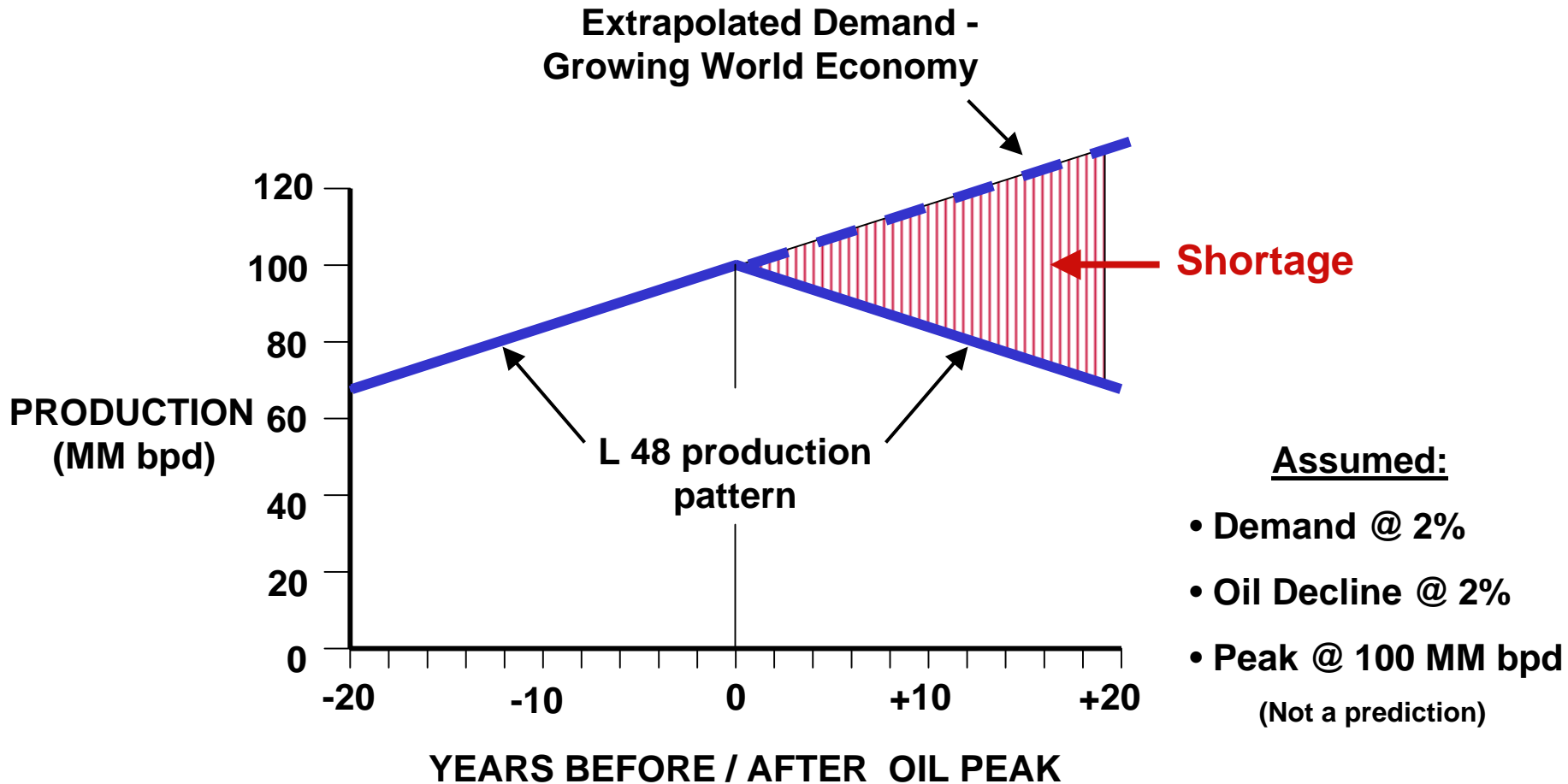


A huge, complex & geologically varied oil province.

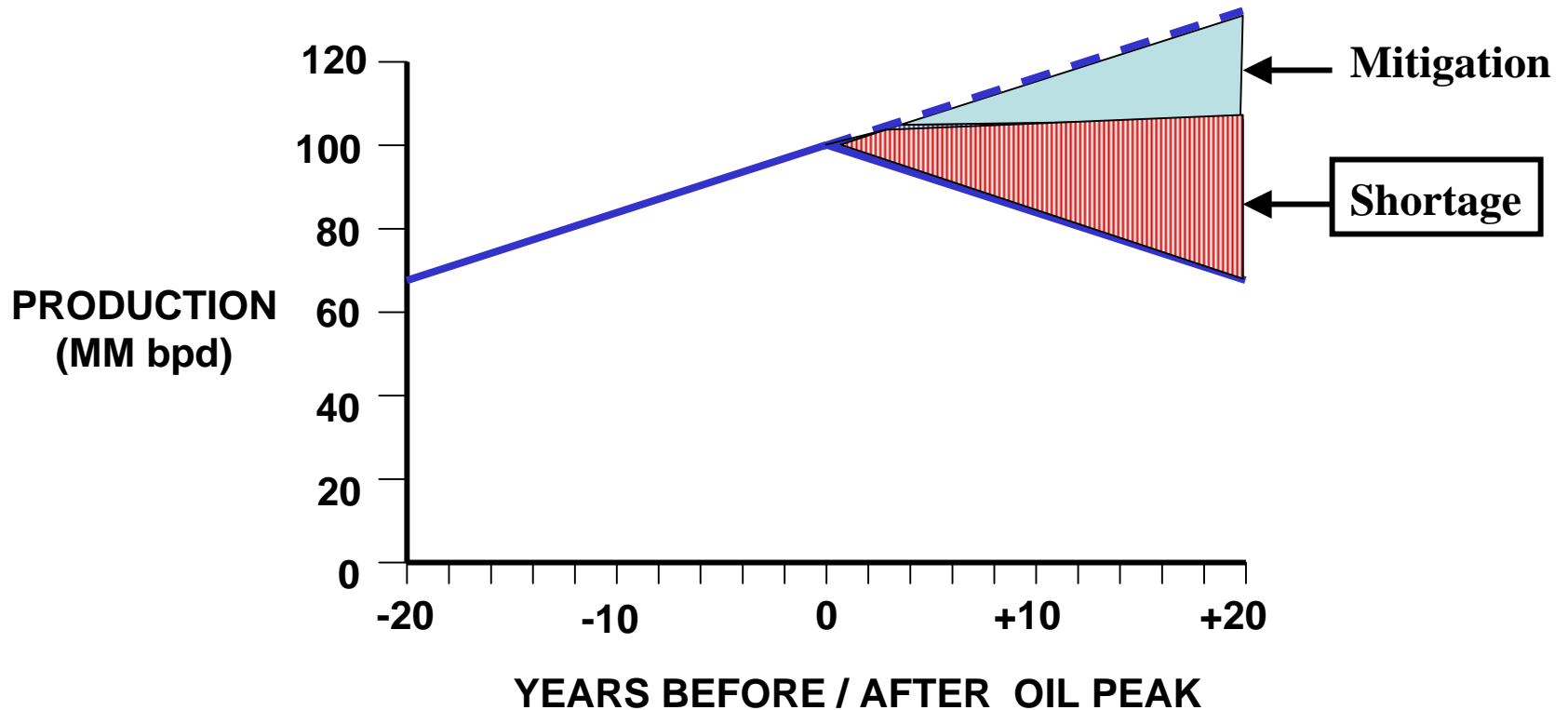
Used as a surrogate for the world.

WORLD OIL SUPPLY & DEMAND:

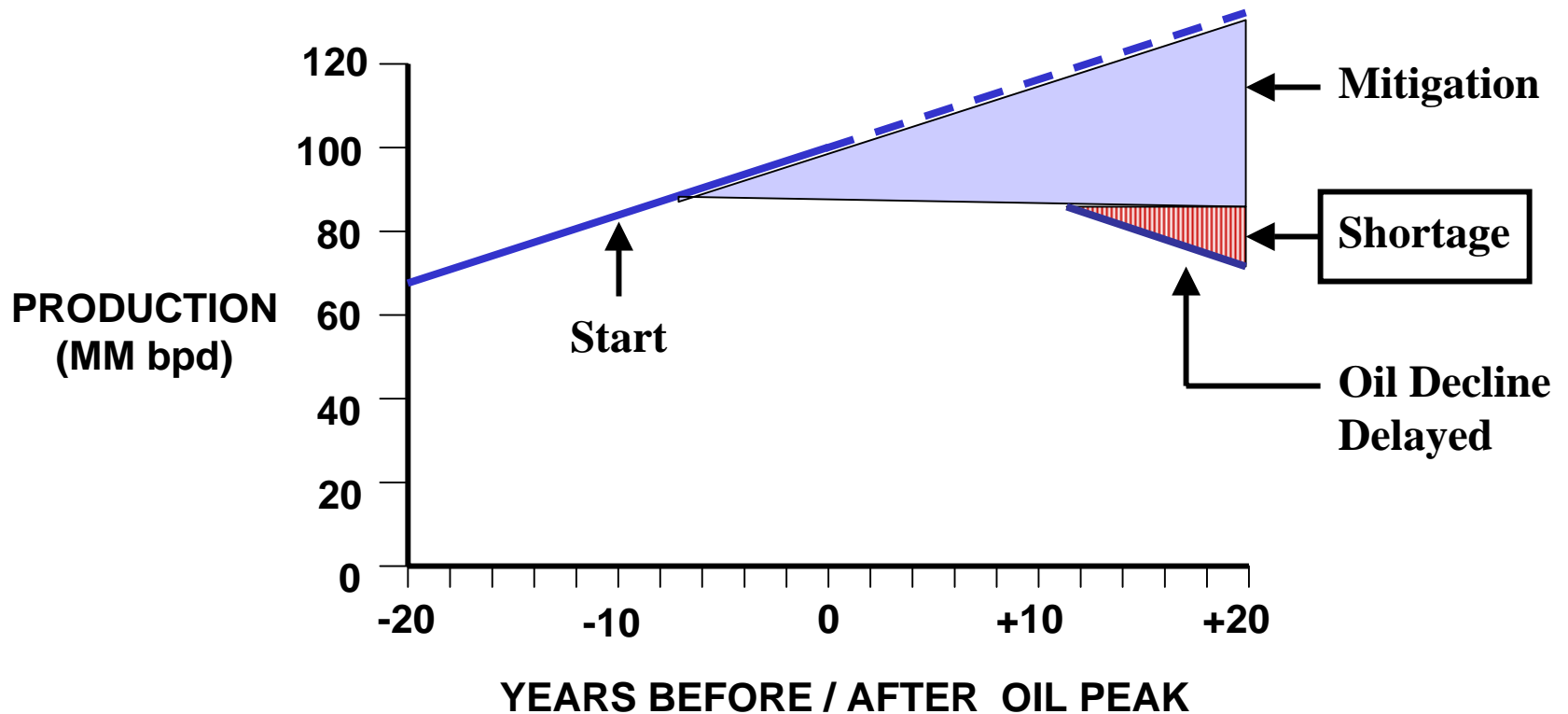
LOWER 48 PRODUCTION PATTERN & EXTRAPOLATED DEMAND GROWTH



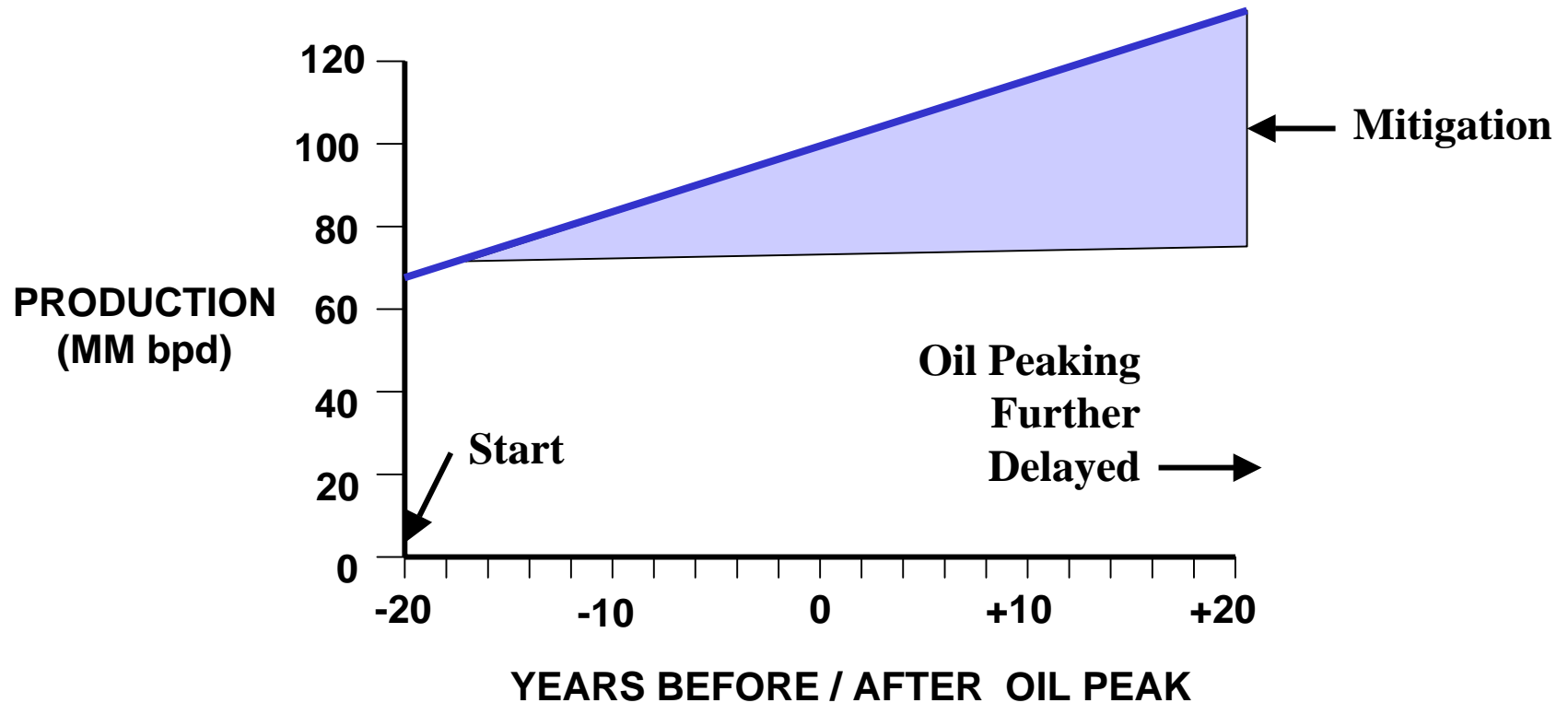
SCENARIO I: MITIGATION @ PEAKING



SCENARIO II: MITIGATION 10 YEARS BEFORE



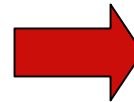
SCENARIO II: MITIGATION 20 YEARS BEFORE



SCENARIOS ANALYSIS CONCLUSIONS

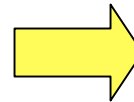
Basis: Immediate crash program mitigation

I. Wait for peaking



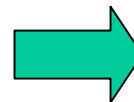
Oil shortages largest,
longest lasting

II. Start 10 years early



Delays peaking; still
shortages

III. Start 20 years early



Avoids the problem;
smooth transition

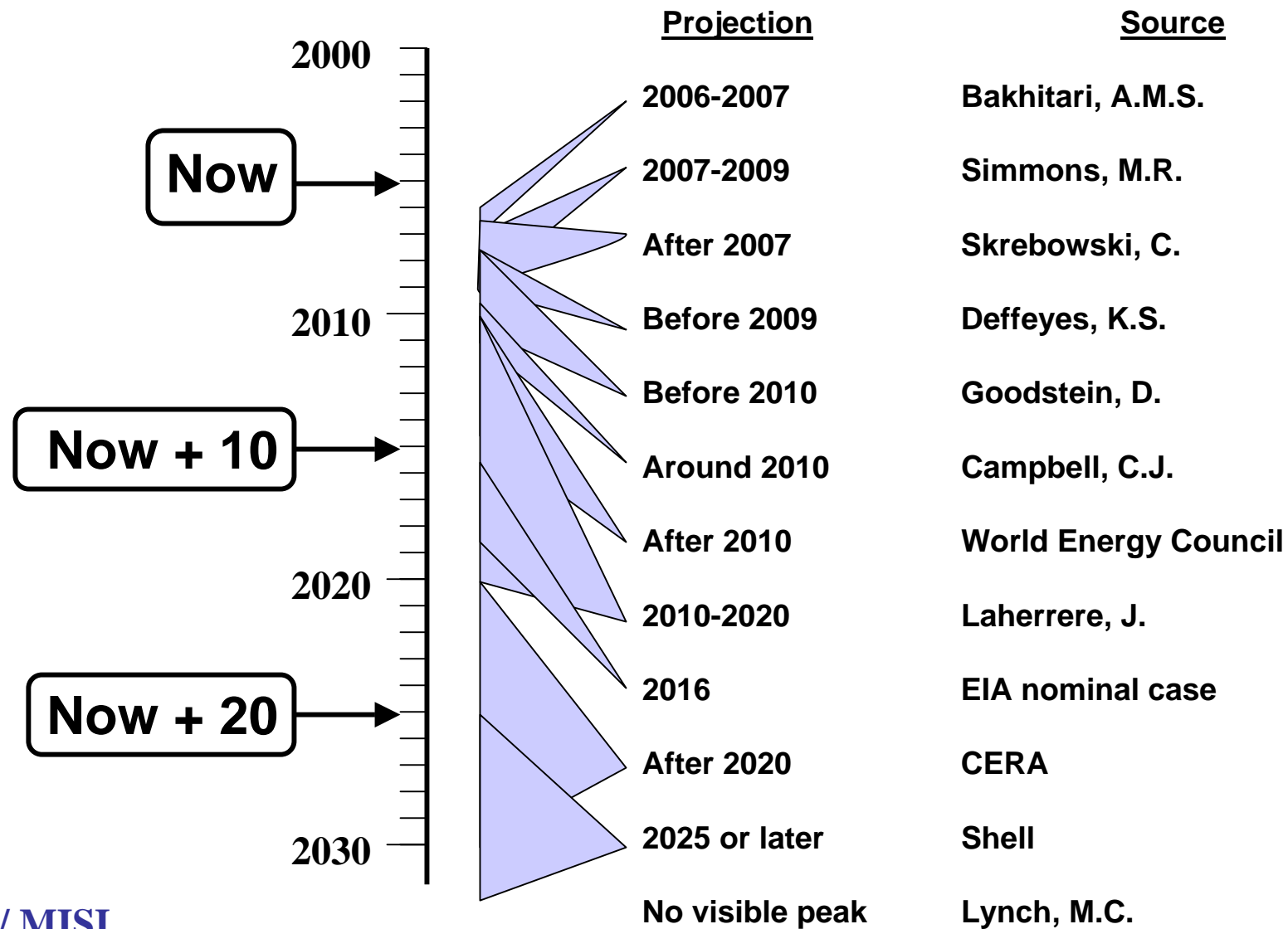
RAPID OIL PRODUCTION DECLINES AFTER PEAKING HAVE BEEN FORECAST

EIA (Hakes, J.)	~ 8%
Saudi Aramco (Al-Husseini, S).....	3-5%
ExxonMobil.....	4-6%

On a base of 100 MM bpd, 3-8% declines correspond to 3-8 MM bpd annual declines.

Mitigation would be much more difficult!

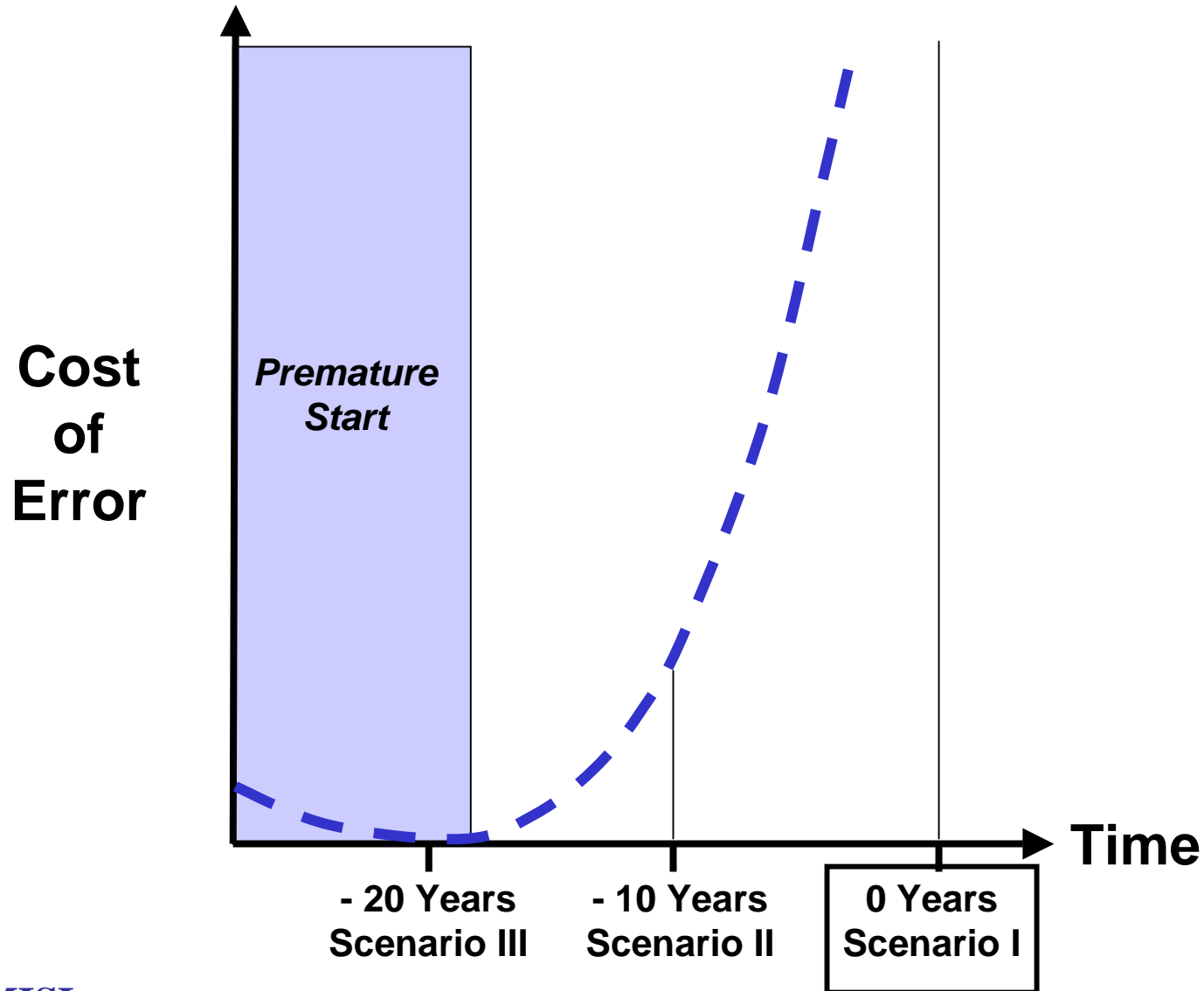
WORLD OIL PEAKING FORECASTS



SOME ISSUES

- Skilled workers & industrial capacity worldwide are in short supply for the level of effort described herein.
- Massive commercial crash programs are rare. Startup will almost certainly be much slower than assumed in this analysis.
- Some countries may delay, others will proceed rapidly with mitigation. China may have started (Canada, Venezuela).
- It is not clear how environmental protection will fare if there is widespread joblessness, high inflation & severe recession.

PRUDENT RISK MANAGEMENT



SUMMARY & CONCLUSIONS

- Oil peaking timing is uncertain.
 - It may be soon.
 - “Soon” is less than 20 years hence.

- The world’s first forced energy transition.

- It’s a world liquid fuels problem.

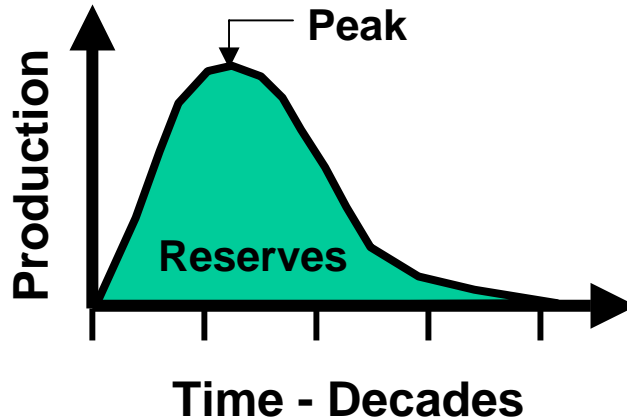
- A number of mitigation technologies are ready.

- With timely mitigation, economic damage minimized.

- Prudent risk management = Early action, not reaction after the fact.

Backup Slides

Oil Production & Reserves



In all oil fields, production increases to a peak & then declines.

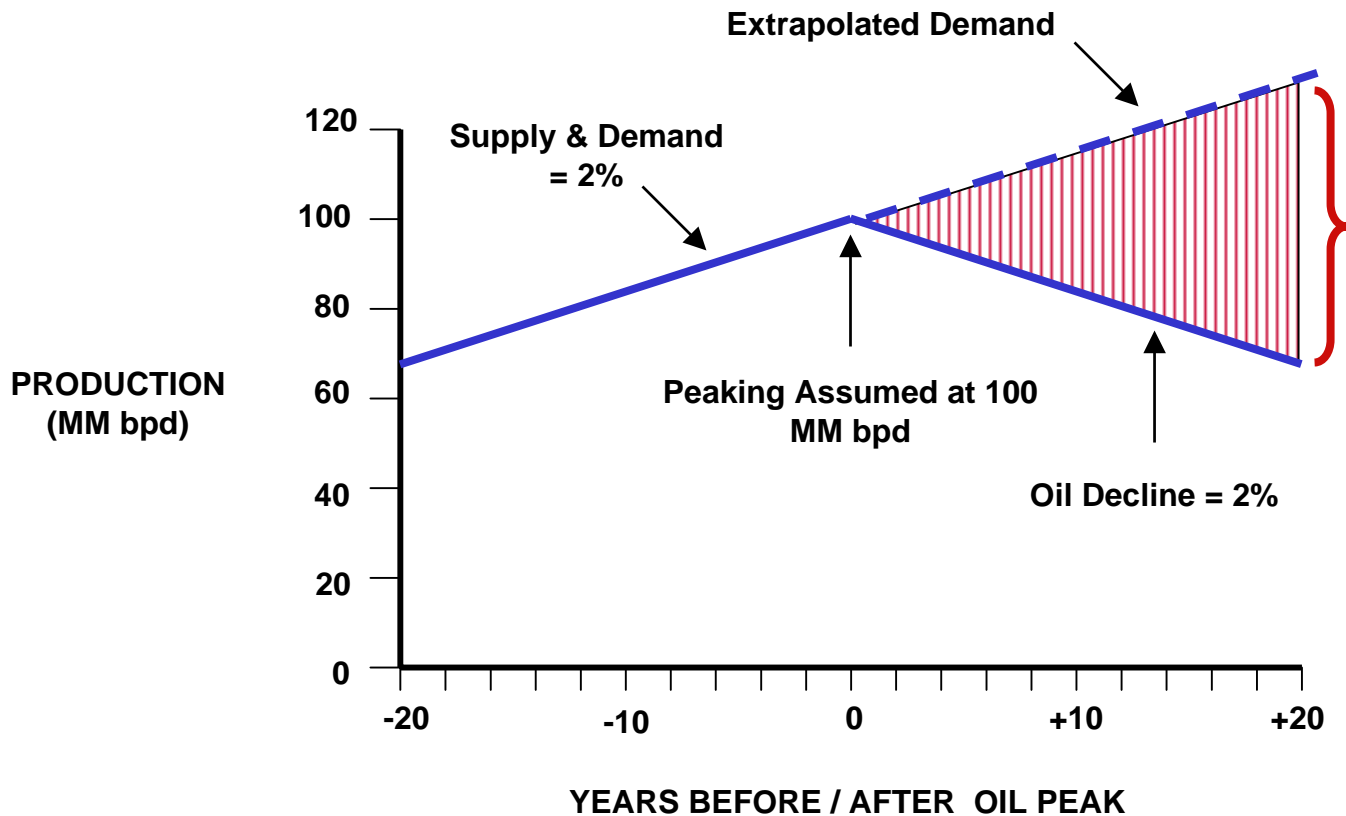
- The total producible oil in a field = reserves.
- Reserves are estimated & re-estimated over the life of a field.
 - + Reserve estimation is often influenced by politics.
- Peak production occurs after roughly half is produced.

Reserves do not foretell when oil peaking will occur.

Some Facts

- World's last Super Giant oil fields found in the 1960s.
- From 1996-1999, >\$400 billion in E & P only kept production flat.
- In mid 1980s, OPEC production quotas became partly based on “reserves.”
 - + From 1986 to 1990 “reserves” increased by ~300 Gb
 - + Only ~10 Gb were actually discovered.
 - + Games then / honest now?

LOOK AGAIN AT THE SHORTFALL



**The
“shortage”
after 20 years
could be 80%
of today’s
world oil
consumption**

65 / 82 ~ 80%

"...it's tempting just to let the brain shut down in denial over something too scary to contemplate and just hope for the best."

**Williams, B.
Shrinking OPEC Cushion Bodes Scary Surprises.
OGJ. June 14, 2004.**