Water Management Is an Energy Problem: Mixing Water with Oil

David Zilberman

University of California, Berkeley

Energy Problems Will Dominate Our Future

- The climate change threats are only beginning.
- There is unbalance between the trends of energy supply and demand.
  - The rapid growth of China, India, and other countries has led to continuous growth in energy demand.
  - Extraction capacity of fossil fuel may not catch up.
  - There are many promising alternative energy sources, but most have limited immediate impacts.
  - Biofuels are the only exceptions.
    - Can be be used with minimal change in cars and other equipment.
    - Can be expanded relatively fast.

Perspective on Irrigation

- Irrigated agriculture counts for 20% of farmland, 40% of output, and more than 50% of value.
- It depends on energy for pumping conveyance, etc.
- 40% of irrigated agriculture relies on groundwater; the rest relies on surface water.
- Many surface water systems depend on water for conveyance, others are energy producers (hydro).
- 10-20% of irrigated agriculture depend on pressurized irrigation (sprinkler or drip).

Impact of Rising Energy Prices on Agriculture

- Positive food price effect
  - In addition, the same driver of high energy price, increased income and growth in Asia, contributes to rising food prices
- Transportation cost effects
- Other input price effects; fertilizers, pesticides, and machinery services get expensive as the price of energy increases.

Impact on Rain-Fed Systems

- Substitution of energy with other inputs
- Expansion of land base
- Reduction of chemical pollution per acre
- The impact of biofuels on rain-fed systems
  - Some biofuels are water intensive and may lead to expansion of rain-fed agriculture.
  - New crops may lead to expansion of farming in new regions (southern U. S.) and in both developed and developing countries
  - Forest and rangeland may convert to farming. Total farmland in the U. S. stable for 50 years may increase.

Impacts on Irrigated Water Systems

Elements of Water Systems

- Extraction
- Transport from source to region of use
- Distribution within region of use
- Application

In some cases (groundwater on the farm), only extraction and use matter.

In others (using water delivered by aqueduct), all forms matter.

Impacts of High Energy Prices on Extraction

- Extraction
  - Groundwater pumping
  - Desalinization
  - Lifting river water
- Temporal extraction cost per unit =

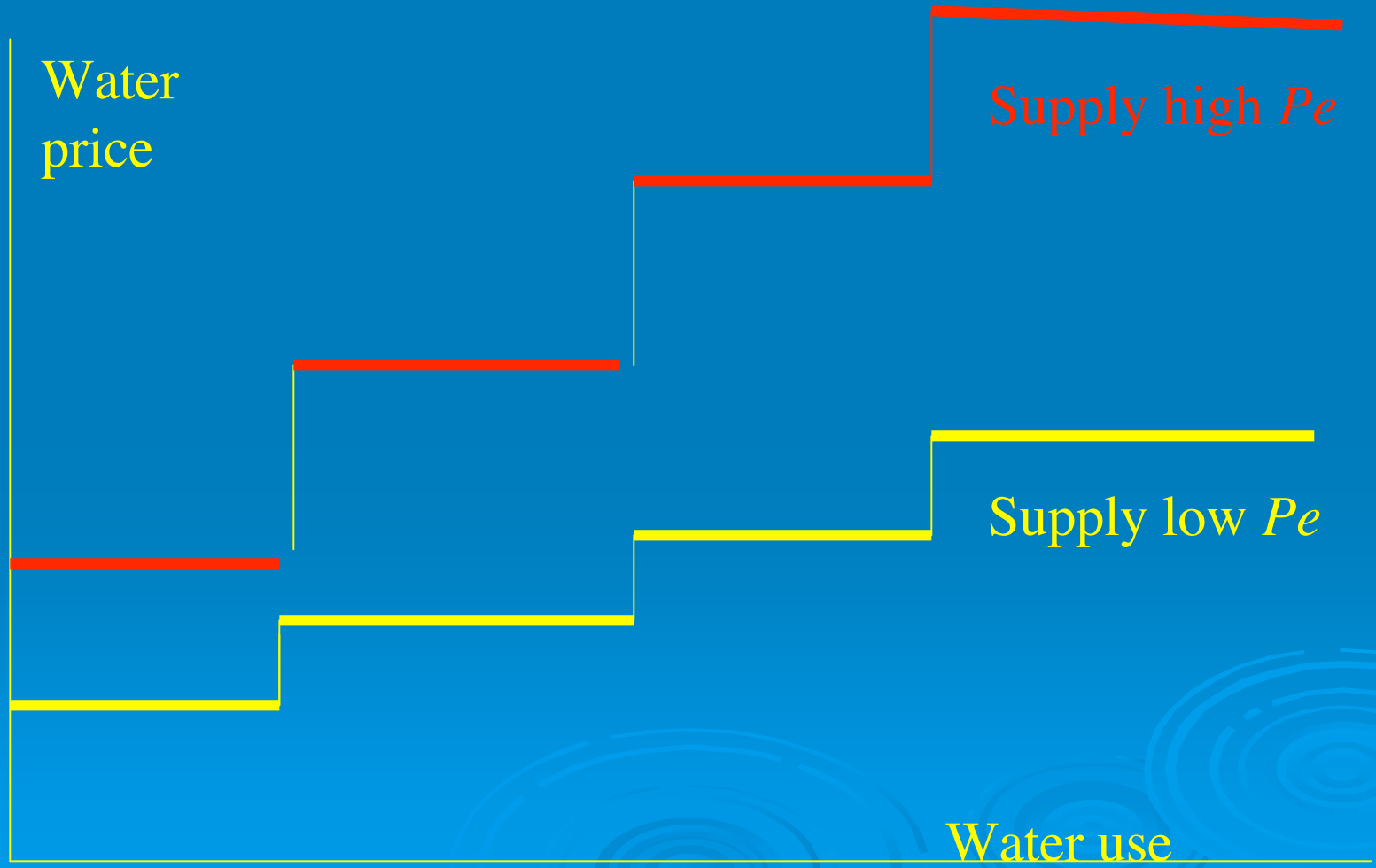
Fixed cost (*F*) +

Distance (D_i) * energy/distance unit (e_k) * energy cost (*Pe*)

Cost = $F + D_i * e_k * Pe$

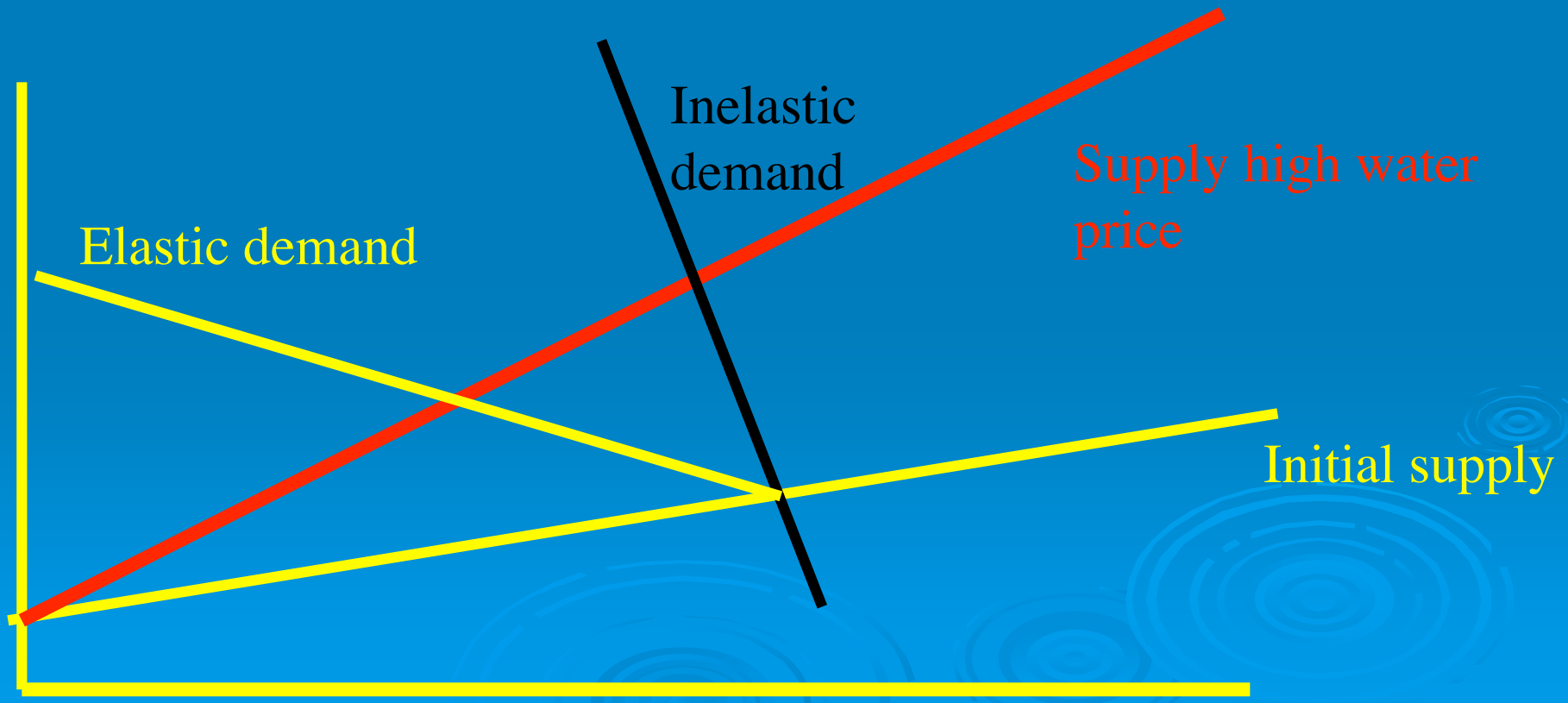
Location index is *i*, and technology index is *k* .

Higher energy prices reduce supply and make it less elastic when water sources are heterogeneous.



When demand is inelastic, increases in energy prices primarily increase water prices.

When demand is elastic, increases in energy prices primarily reduce water use.

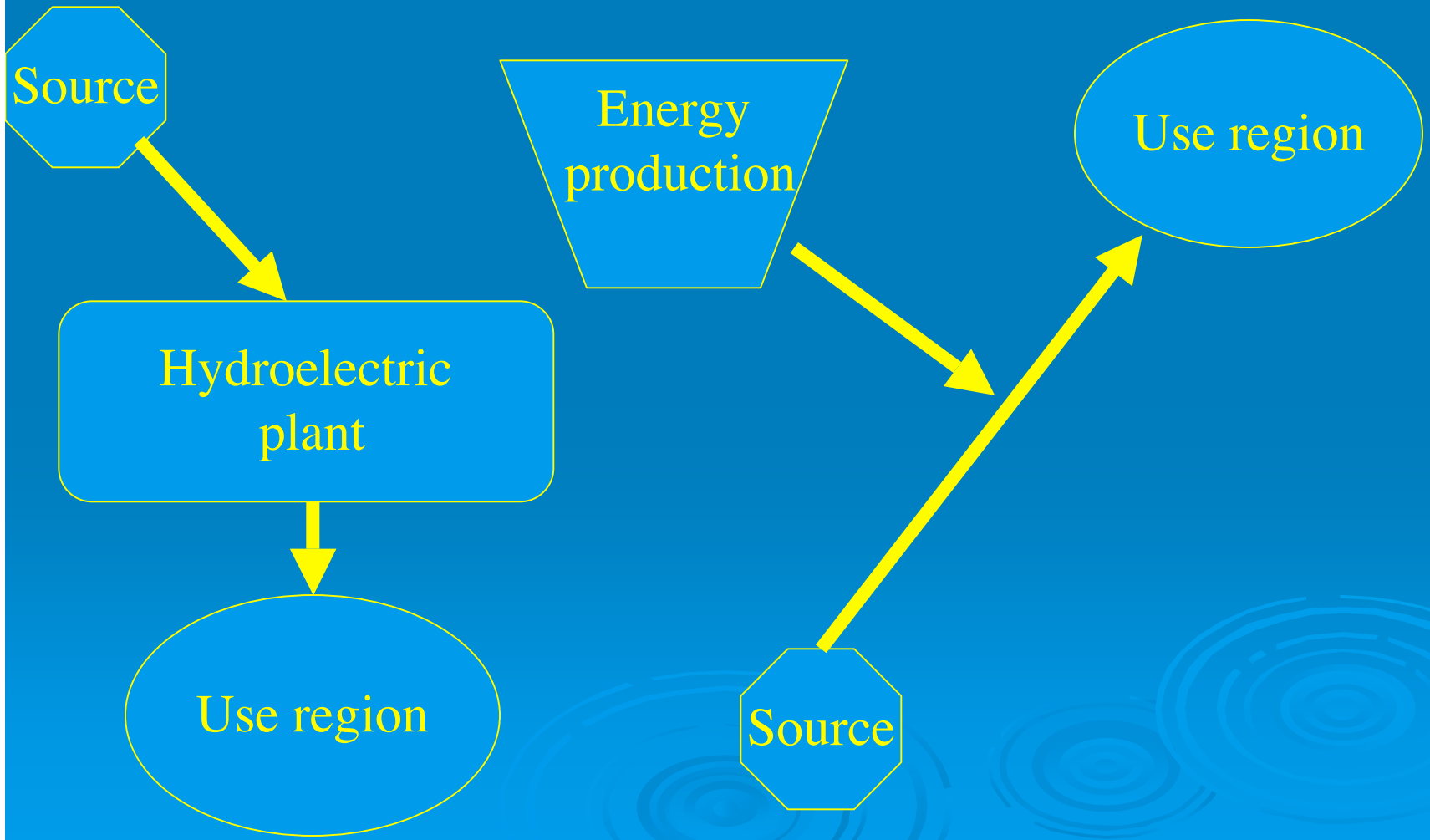


Impacts on Extraction Technology

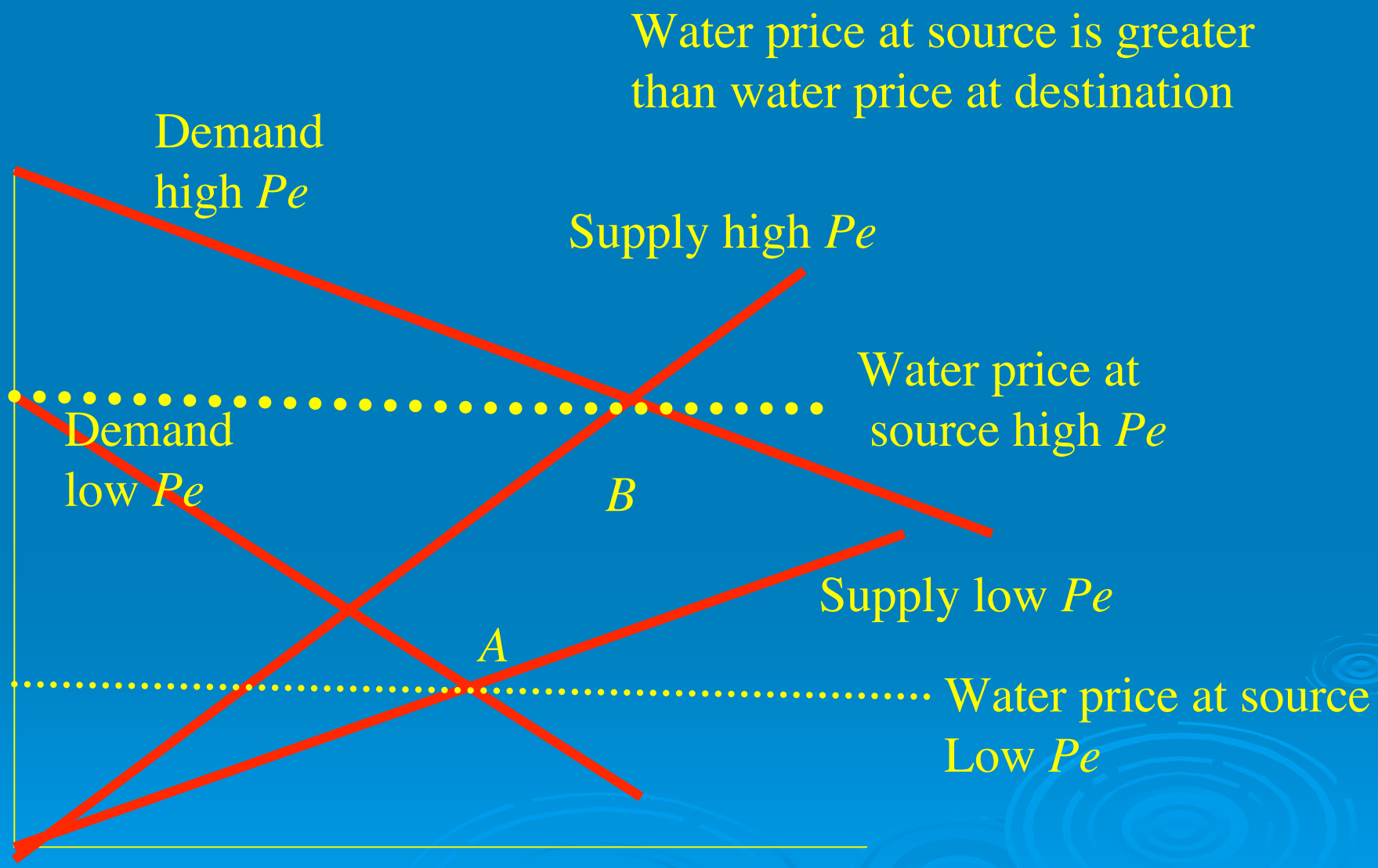
- Higher energy prices will lead owners of deep wells to:
  - Stop production
  - Switch to cheaper energy
  - Improve more efficient pumps
    - Switch in pumping technology will occur if savings in energy costs pay for the equipment
    - E.g., movement to solar-powered pumps
  - Increase institutional and technical innovation

Impacts of Higher Energy Cost on Transfer Cost

The impact of energy cost on transfer depends on whether the source region is above or below the destination.



Impact of high *Pe* when water goes downhill.



When Water Goes Downhill

- With hydroelectric,
  - We distinguish between price at the source and for the agricultural user.
- Higher energy cost may lead to:
  - Increased price water at the source.
  - Increased water use.
  - Reduced water price to final water user.

When Water Goes Uphill

- The systems buy energy.
- Increased energy price leads to:
  - Increased water price at source.
  - Reduced water use.
  - Increased water price for final users.

Under an optimal system, final water users do not necessary lose from high energy prices.

- Losers
  - Groundwater users
  - Surface water users who face an extra transfer cost that dominates hydroelectric gain.
- Winners
  - Surface water users who are part of a system that generates hydroelectric power with low energy requirement for transfer.
- Higher energy prices may lead to reduction of irrigated farming with groundwater and increased irrigation resulting from hydroelectric projects.

Uphill or Downhill: Higher Energy Prices Increase the Value of Investments Reducing Conveyance Loss

When water goes downhill,

- Improved conveyance will increase hydroelectric sales and may reduce pumping.
- It will increase water available for final user

When the water goes uphill,

- Improved conveyance will reduce conveyance cost and marginal cost of water to final users.
- Will reduce water price for the final user, but increase water use.

Distribution

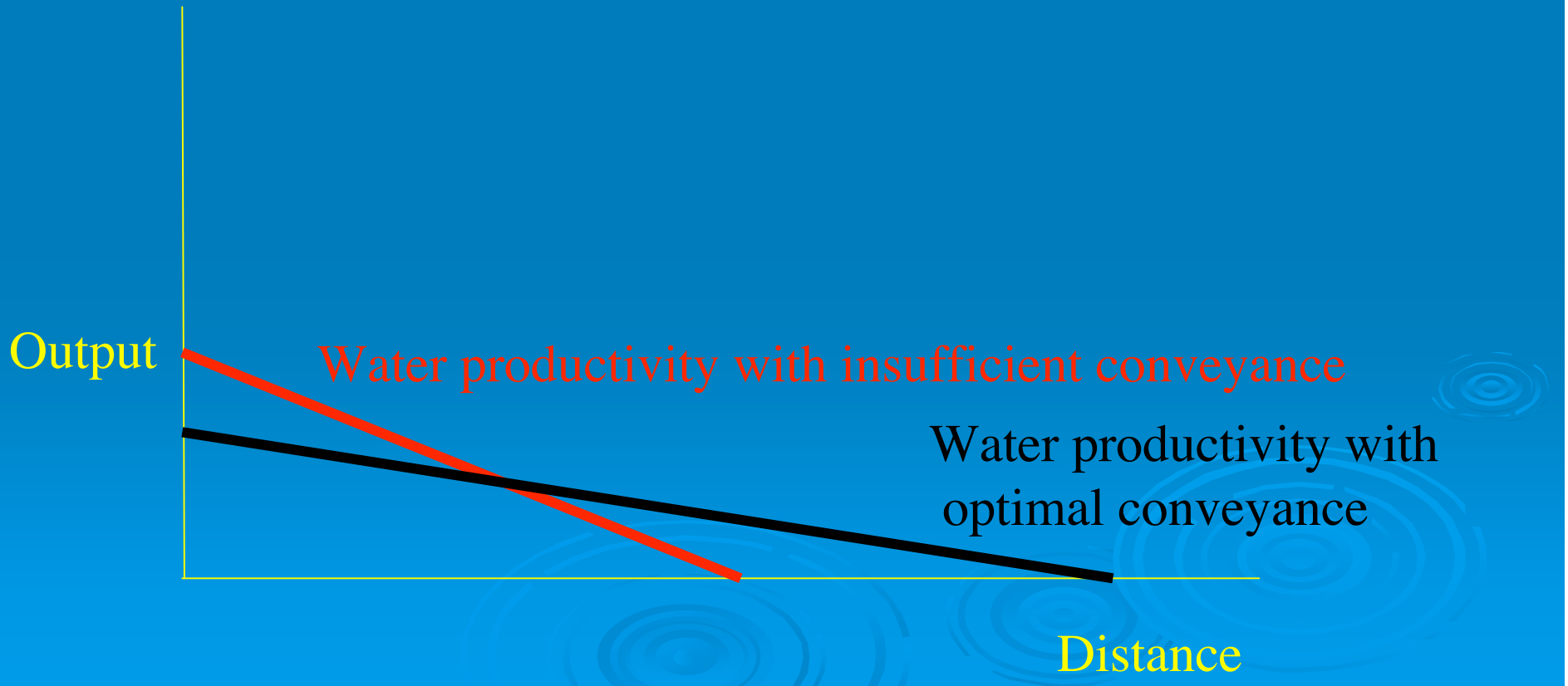
Higher energy prices increase the cost of flawed institutions and policies for distribution.

- Water rights that limit trading result in:
  - Insufficient investment in modern irrigation technology.
  - Overproduction of water-intensive crops.
- Transition from water rights to water trading is costly.
  - The gain from reform increases when water is more scarce.

Higher energy price increases the cost of flawed institutions and policies for distribution.

- Without collective action, farmers underinvest in conveyance for distribution, resulting in:
  - Over irrigation near source
  - Underproduction
  - Waste

Productivity with and without optimal conveyance



When higher energy prices increase water price, reform may include:

- Water user associations that optimize conveyance.
- Water pricing that varies by location to reflec extra conveyance cost.
- Transition to trading and efficient pricing.

Issues in Pricing

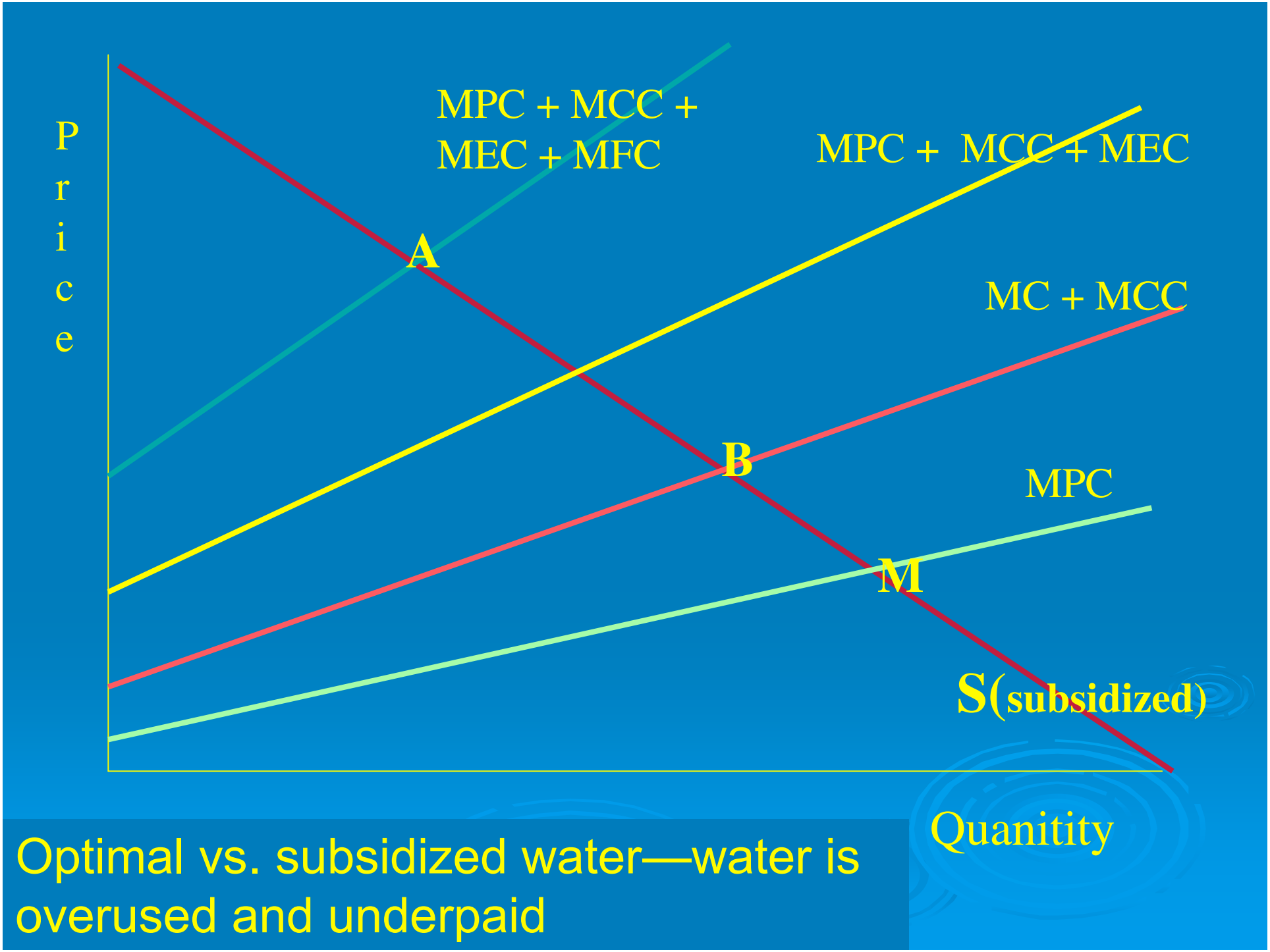
- Efficient price of water
  - Marginal extraction costs +

  marginal transfer and distribution cost +

  marginal future cost (user cost) +

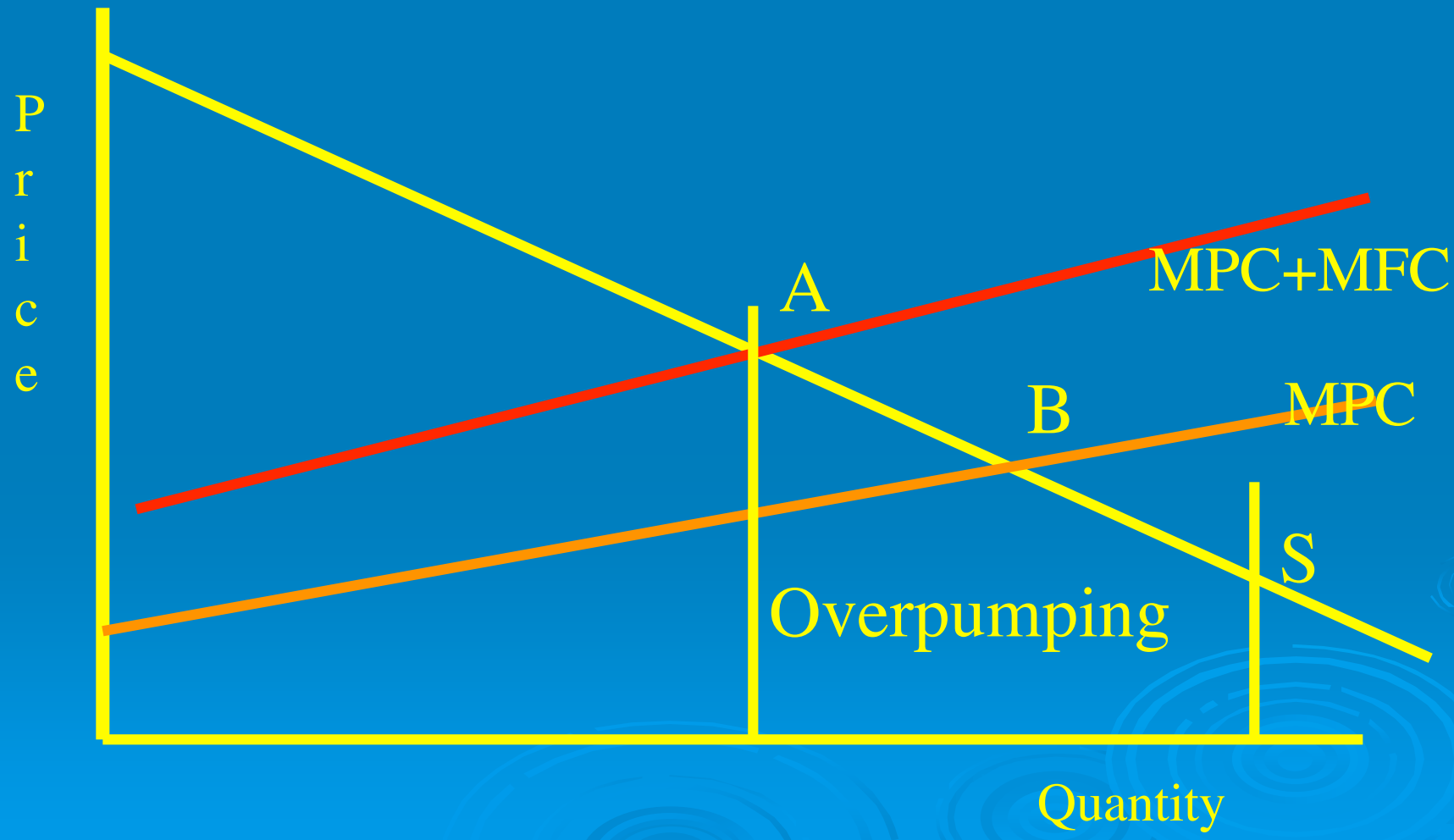
  marginal environmental cost.
- Higher energy costs may change these components requiring changing water pricing and water reform.
- Adjustment for distributional consideration
  - Tiered pricing
  - Transferable rights

Energy Pricing and Water Use

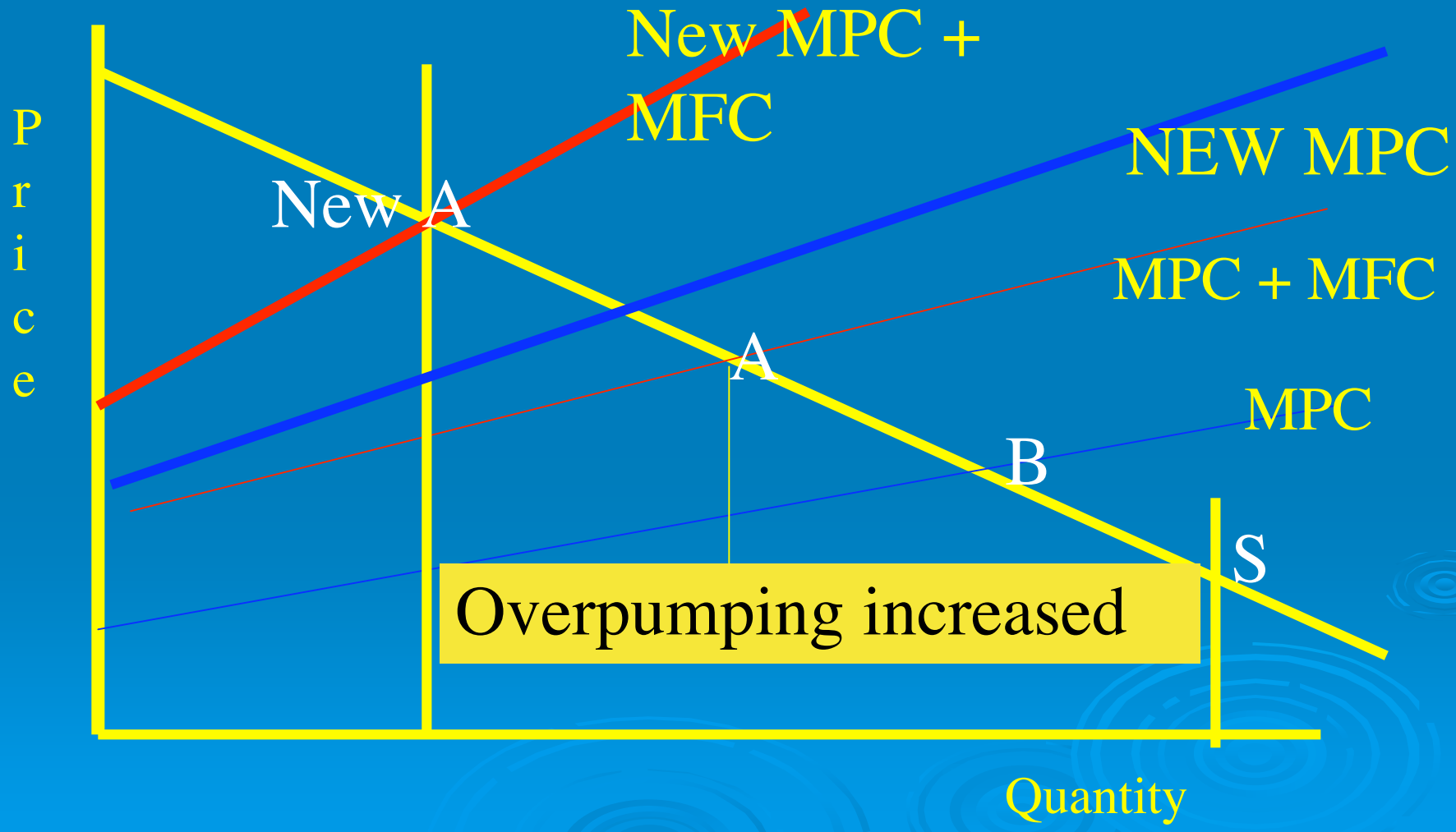


Optimal vs. subsidized water—water is overused and underpaid

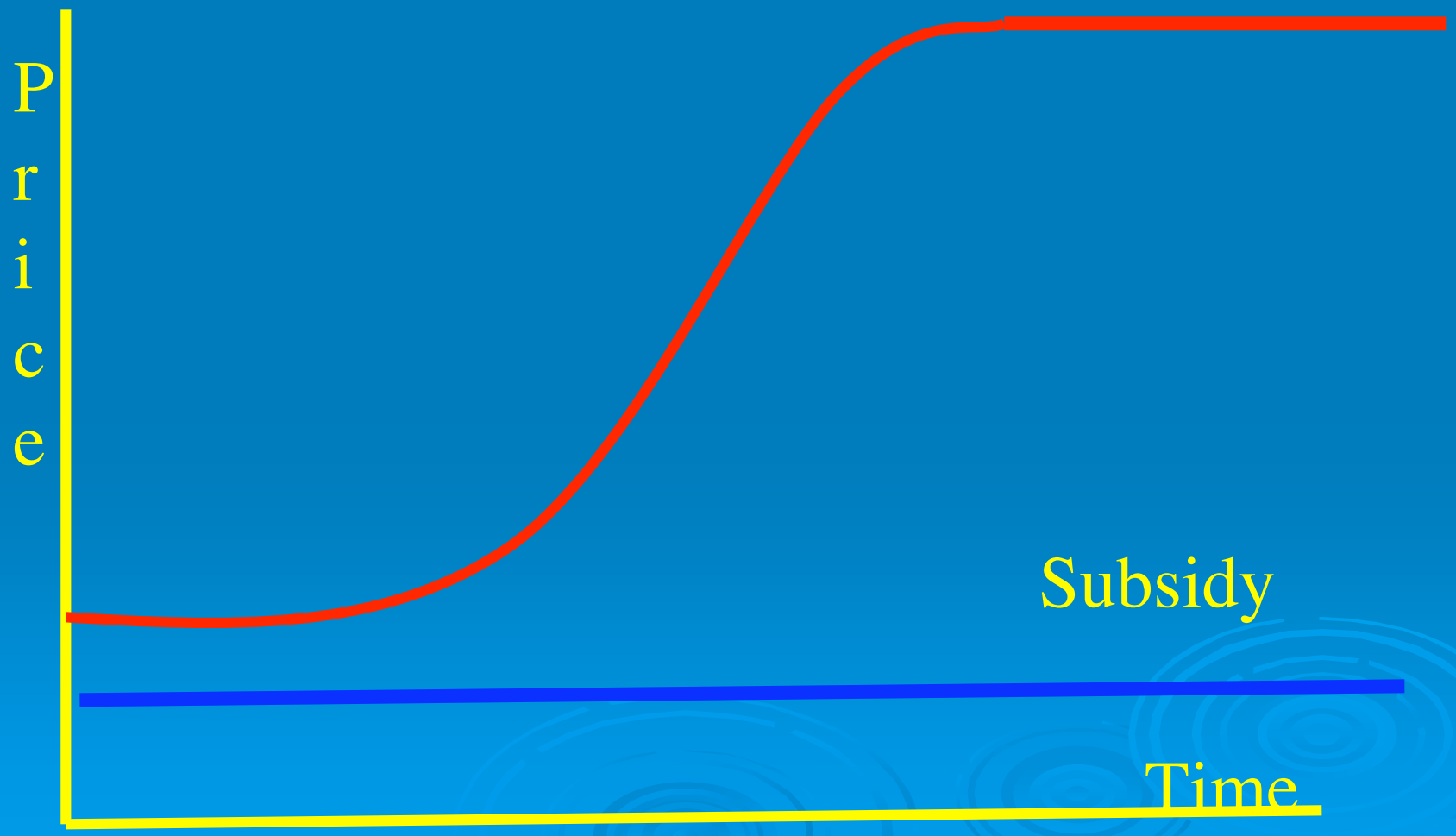
Subsidies are getting worse—groundwater with a big aquifer



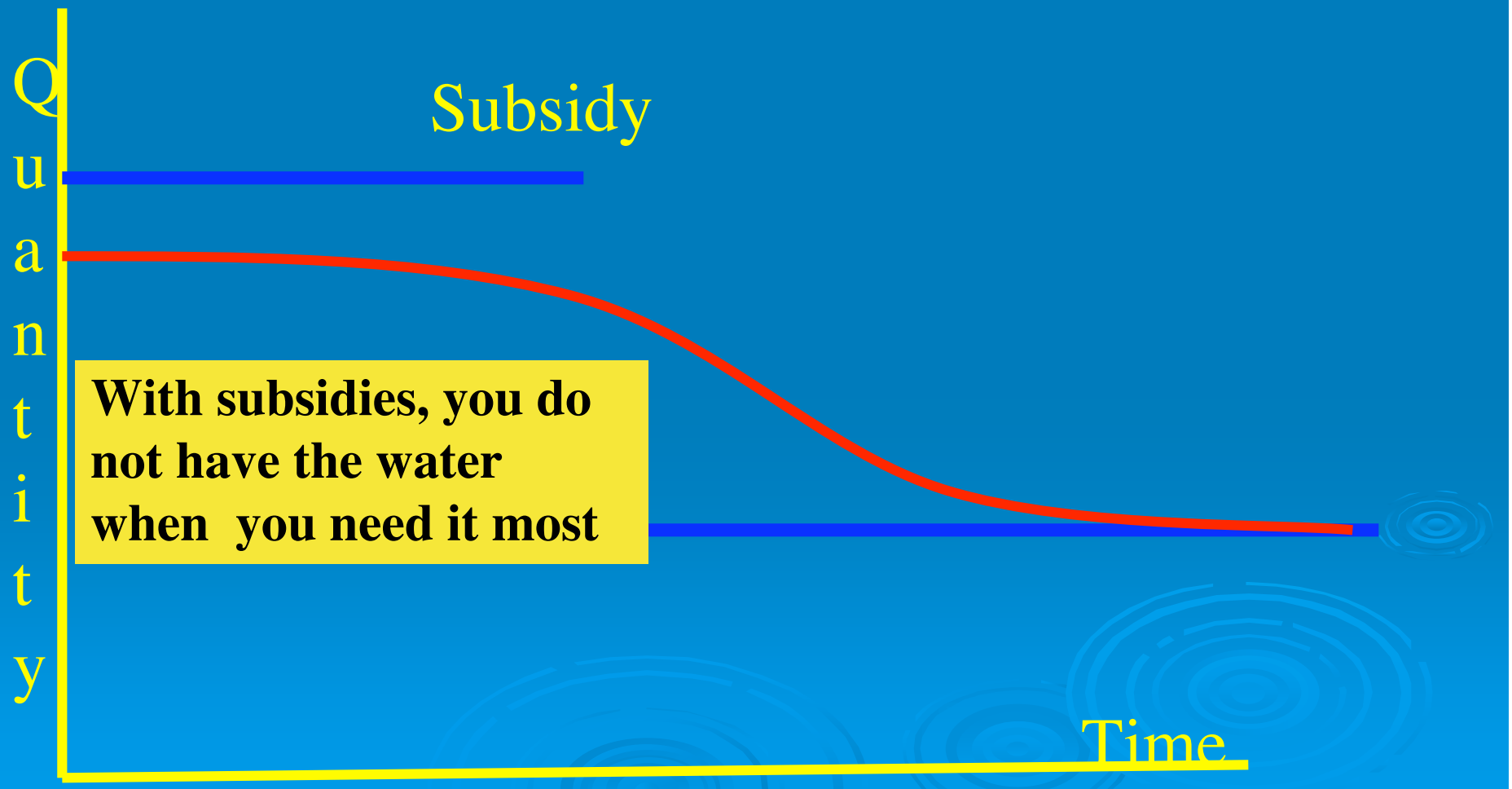
Subsidies are getting worse—groundwater with declining aquifer



The dynamics of optimal groundwater pricing

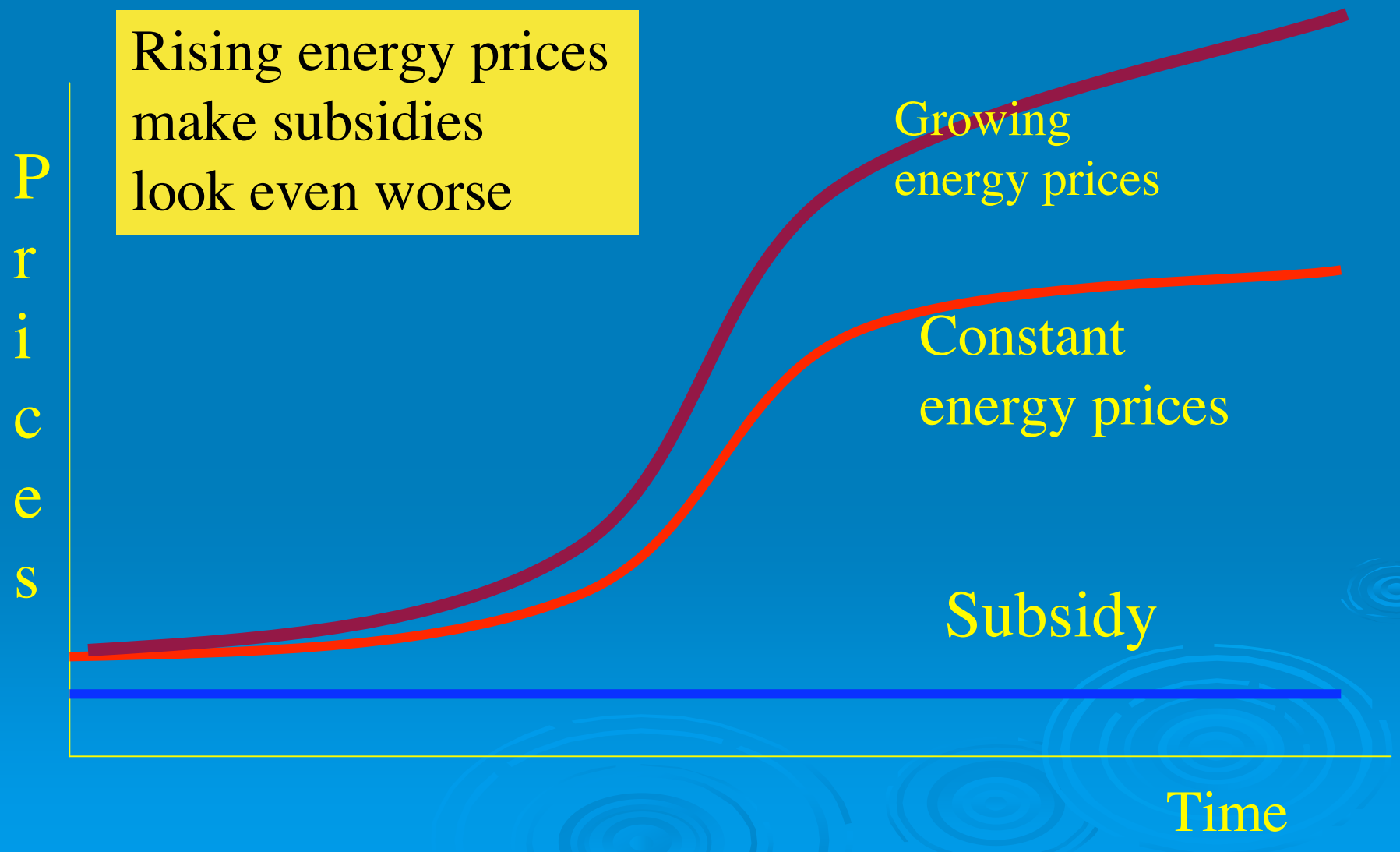


The dynamics of optimal groundwater use



Adding rising energy prices

Rising energy prices make subsidies look even worse



The Groundwater Double Whammy

- If initially the aquifer is 20 m deep
- With 1.50/ m pumping annually and recharge of .5 /m, in 20 years the well depth will increase by 1 meter a year and will double within 20 years.
- If energy price triples in these 20 years, the subsidy cost will increase sixfold.
- With optimal pricing,
  - Less water would have been pumped.
  - There is more water in the aquifer and lower pumping costs.
  - You have water and save energy when you need them.

Energy Cost and Water Use at the Farm Level

- Energy price affects water use and productivity through:
  - Water use with a given technology
  - Crop selection
  - Technology choice
- When higher energy price increases water price, it will reduce water use, e.g., groundwater.
- When it reduces water price to farmers because of expansion of hydropower, it will increase water use.

Energy Price Adoption and Crop Selection

- Adopt conservation technology if
  - Yield effects and water-saving effects are greater than the equipment and pressurization cost.
- Higher energy price increases adoption probabilities if
  - Extra energy costs are greater than extra pressurization cost.
- Likelihood of adoption of conservation technology declines
  - Higher energy costs lead to a decline of water price, e.g., hydropower.
  - Pressurization is too expensive.
- Probability of adoption of drip increases relative to sprinkler increases because of lower pressurization requirements.

Higher energy prices will not necessarily lead to adoption of conservation technologies, but improved varieties are likely to fare better.

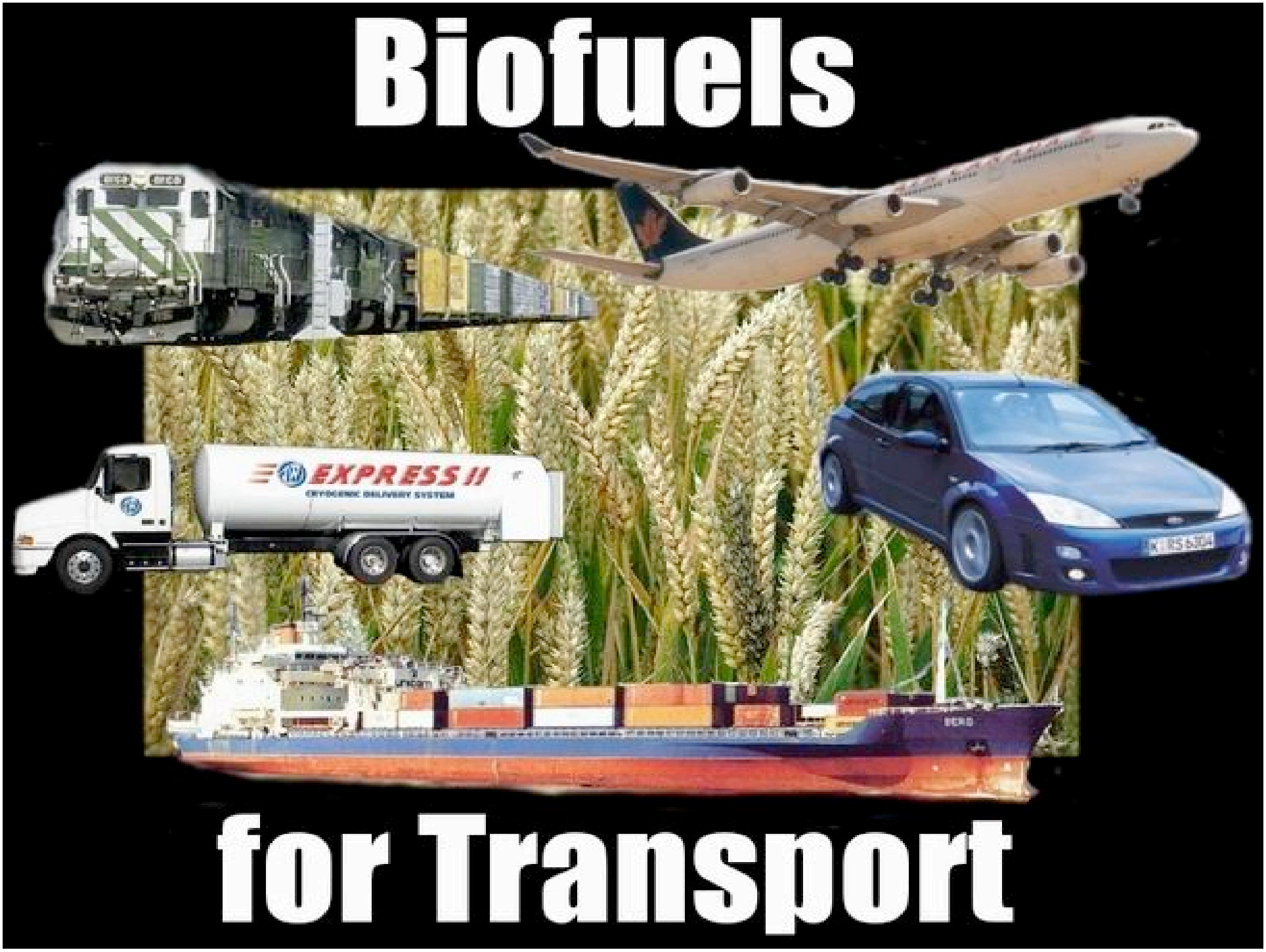
- Adoption of improved varieties occurs if
  - Yield effect and water-saving effect are greater than increase in seed price.
- If energy price increase leads to water price increase, then the value of drought-resistant seed increases.
- If energy price increase leads to increasing output price, it will increase the value of yield-increasing varieties.

Risk and Dynamics

Risks and Uncertainties

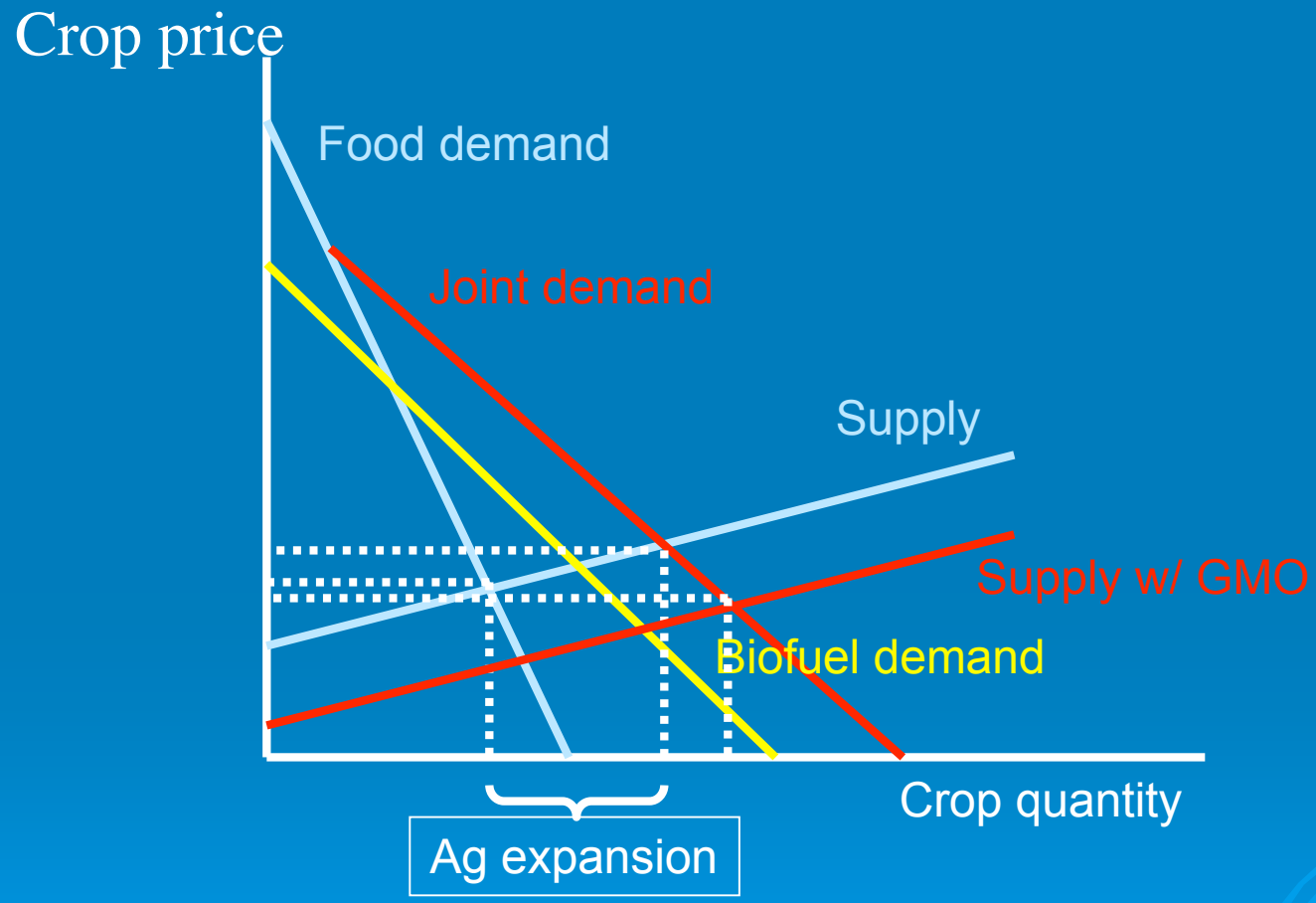
- If energy prices are on an increasing trend, higher price variability will reduce investment in water conservation.
- Instability of energy prices and supply may lead to food prices and supply variability endangering the poor.
- Unstable energy prices and water prices may require:
  - Introduction of water and energy price insurance.
  - Reliance on food inventories to reduce food supplies.

Biofuels



for Transport

Biofuel and the Food Market



Energy Price and Biofuel

- High price of energy will lead to adoption of biofuel.
- That will increase the demand for food (e.g., corn) and put pressure on land.
- It will increase prices of food, and reduce food available for consumption.
- It will negatively affect the poor.
- It may also negatively affect the environment and agricultural land base will increase.

Energy Scarcity and Yield-Increasing Innovation

- Biofuels will have fewer negative effects on agriculture if new yield-increasing varieties or other similar innovations are adopted.
- GMOs have perceived risks, but by increasing yields they reduce the potential environmental damage and poverty impact of higher energy costs.

Biofuels in Perspective

- Biofuels are a mixed bag.
- High energy prices make bad biofuels profitable
  - Corn is not the best choice, but it's the best for the U.S. now.
  - Sugarcane is better.
  - Palm oil has its problems.
- Net contribution to greenhouse gas accumulation is not high; need energy to convert plants to fuel.
- Dimensions of improved efficiency:
  - More energy from plants
  - Better use of residue
  - Reduce input and energy use in process (nitrogen fixation)
  - Different biofuels - better integrated in the paper
- Challenges
  - How to mitigate the negative environmental and social effects of biofuels?
  - Second generation of biofuels

The Future of Biofuels

- Expect a gradual process of technological change.
- It will lead to:
  - Improvements in fuel yield per acre from improvements in crop yield and conversion efficiency.
  - New feedstock – cellulosic sources like switchgrass.
  - Changes in feed per acre.
- Expect continual costs of adjustments
- Future of biofuel depends on:
  - Energy, agriculture, and environmental policies.
  - Alternative energy technologies.

Biofuel, High Energy Prices, and Ag Policy

- Food and energy sector will be integrated.
- Ag policy will become energy and environmental policy.
  - Less demand / justification for traditional ag policy.
  - Government should help establish strategic fuel industry, but then it must compete. Subsidies have their limits.
- However, high food prices may warrant storage and other food policies to prevent hunger.
- Some CRP (and other) land may be returned to production for economic reasons. Forest and rangeland will be converted to production—need criteria and policies for protection recognizing reality.
- Public sector support for research to improve productivity and protect the environment.

Biofuel and the Dynamics of Natural Resources

- Fossil fuel bought us 100 years, but good things end.
- Taxing fuels and conservation are essential elements of policies, but we need renewable alternatives.
- Take small risks to avoid big ones.
- We should not fight yesterday's wars and ignore tomorrow's threats.
- Some of these threats are new (e.g., climate change), but others are old (not enough resources to fill our stomachs and our cars).
- Increased productivity of water and land through better biology can sustain us and even make us prosper.

Rising Energy Prices Will Accelerate Change

- More dams and more conservation.
- Increased irrigation and increased innovation.
- More conflicts and water reform will
  - Likely increase trading and rising water prices.
  - Reduced water subsidies.
- Need to protect the poor and the environment
  - Tiered pricing.
  - Prioritization of environmental protection.
- Increased productivity of the farm system–for food and fuel—will reduce adjustment cost.