OPTIONS TO MITIGATE ENVIRONMENTAL POLLUTIONS

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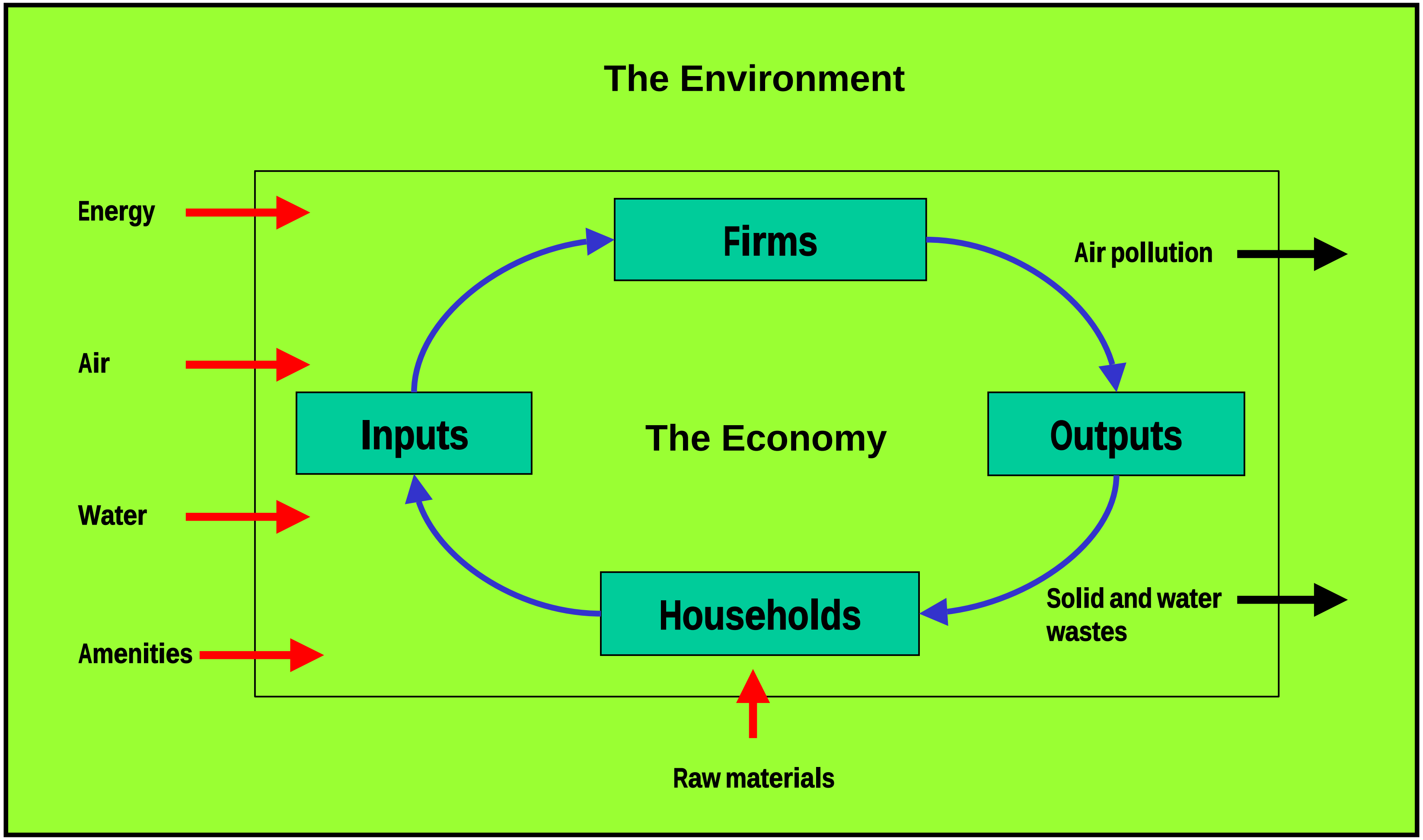
The Economic System and The Environment



The economic System and The Environment

- **The Environment is an Asset, it provides:**
  - **the Economy with raw materials and energy**
  - **direct service to the people (air)**
  - **variety of amenities that no substitute exists (Grand Canyon)**

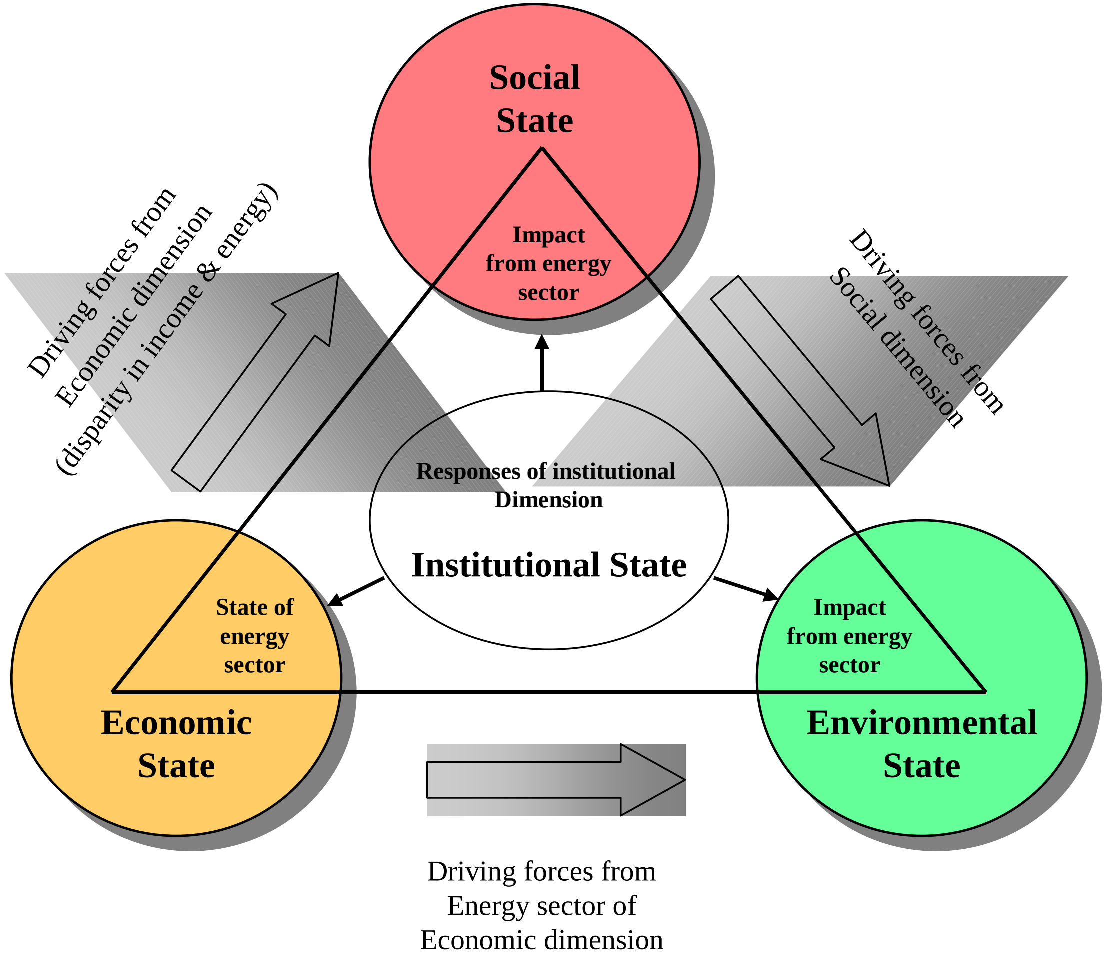
Pollution is "inevitable" ?

- **The laws of thermodynamics imply:**
  - **Energy and matter cannot be created and destroyed**
  - **The mass of materials flowing into the Economic System has to be either accumulated in the economic system or returned to the environment as wastes**
  - **No conversion process from one form of energy to the other is completely efficient**
  - **Consumption of energy is irreversible process**
  - **Some energy is always lost during conversion**
- **Pollution exists as long as there are economic activities**
- **Zero pollution is not desirable**

Key Players and Their Motive

- **Producers**
  - Minimize costs
  - Maximize profits
  - Have best knowledge of their cost and performance and pollution level but not willing to disclose
- **Consumers**
  - Maximize well-being and conveniences
  - Minimize bills
  - Suffer from pollution
- **Government**
  - Acts in the name of the community to preserve “public goods”
  - Empowered with authority to enforce regulations
  - Often is being lobbied by certain groups of community

The Famous Triangle



What else ?

- **There is a market for normal goods**
  - **Price is definitive**
  - **Clear signal to rationalize the consumption**
- **There is not yet a well-established market for public goods**
  - **Environment is tent to be overused**
- **Here is the role for academia, Government, NGOs etc.**

Alternatives towards Cleaner Environment

- Using inputs more completely so that less residual is left over
- Producing less outputs (consuming less products) so that less waste is generated
- With the same inputs producing more outputs
- Recycling the residuals
- Disposing of the wastes
- Cleaning before disposing

Energy System

What Nature Provides

Sources: coal, oil, natural gas, sunlight, uranium, wind, biomass

Extraction Treatment: coal mine, hydro dam, oil rig, cleaning, separation, benefication, liquef-action, gasifi-cation

Conversion Technologies: hydro station, thermal power plant, oil refinery, nuclear generating station, photovoltaic cell, wind converter

Currencies (fuels): electricity, gasoline, methanol, methane, hydrogen, heat

Distribution: electricity grid, gas grid, truck, dewar, railway, district heat grid

Energy Sector

Service Technologies: automobile, light bulb, telephone, furnace, microwave oven, aircraft, PC

Services: transportation, communication, keeping warm/cold, food, potable water, health care, security, consumer goods

What People Want

Looking at the Energy Sector

- **Pollution exist in every stage of the fuel cycle:**
  - **Extraction/production**
  - **Conversion/transformation**
  - **End-uses**
- **For any technology, pollution appears during:**
  - **Construction/building**
  - **Operation/Maintenance**
  - **Decommissioning/Disposal**

Looking at the Energy Sector

- The most significant in terms of potential impacts are:
  - Air pollution, which originates from combustion of fuels, e.g.,
    - ✓ Power plants using coal, oil, gas, biomass
    - ✓ Industrial boilers and furnaces
    - ✓ Household cooking devices
    - ✓ Motor engines in transport sector
  - Water pollution caused by open-pit mining of coal
  - Heat pollution due to discharge of water from cooling system of power plants
  - Impacts of hydro project
  - Impacts due to release of radioactive substances during the production, operation and decommissioning of some energy facilities

Characteristics of Environmental Impacts of Energy Sector

- Heat pollution – local and can be dealt with by establishing release standards.
- Installation at PP heat recovery
  - Reduce heat loss, thus increase economic performance
  - Protect the estuaries from overheating
- Impacts of hydro projects – site specific need investigation
- Air pollution is the most damaging
- Climate change due to increase of concentration of Greenhouse Gases

Approaches to Pollution Control

- **Command and control**
- **Market based (incentive based)**
- **Regulations combining these two approaches**
- **The goal is to achieve the efficient level of environmental quality in a cost-effective manner**

Measure to Reduce Pollution from Energy Sector

- By reducing level of energy consumption
- By reducing level of energy production
- By moving away from “dirty” fuels or technologies
- By installing emission reduction technologies
- These measures can be technology-based, fuel-based or regulatory in nature

Measure to Reduce Pollution from Energy Sector

- **Group 1:**
  - Energy efficiency and conservation in both sides of energy business (demand and supply)
  - Energy conservation at the end use level can be partially achieved through proper pricing
  - Cost-effective demand side management
- **Group 2:**
  - Capturing of pollution before it is emitted to the environment:
    - ✓ Pre-combustion
    - ✓ In-situ
    - ✓ Post combustion

Example of Command and Control Approach

❖ Setting emission standard

- Emission standard is a legal limit on the amount of the pollutant an individual source is allowed to emit
- This limit is normally established based on some criteria, such as to provide an adequate margin of human and ecological health
- Easiest way - uniform standard for all sources
- But is it cost effective ?

Example of Market-based Measure

- **Emission charge:**
  - **A fee collected by the government levied on each unit of pollutant emitted into the air or water.**
- **Emission charge:**
  - **causes sources to choose a cost-effective allocation of the control responsibility**
  - **stimulates the development of newer cheaper means of controlling emissions**
  - **promoting technological progress.**

Emission Standards vs. Emission Charges

- Control authorities base the emission standards on the existing control technologies.
- As new technologies are discovered by control authorities, emission standards are tightened.
- These stricter standards force firms to pay higher costs thus with emission standards, firms have incentive to hide technological changes from control authority.
- With emission charge system, the firms save money by adopting cheaper new technologies. As long as the firms can reduce emission with the cost below emission charge, they invest to adopt new technologies.

Efficiency of Market-based Approach

- **Transferable emission permits**
  - **This allows control authorities to find a cost-minimizing allocation of responsibilities without the information about the control costs**
  - **Market equilibrium for an emission permit system is a cost-effective allocation.**

Pollution Taxonomy

- **Pollution load:**
  - the amount of waste discharged into the environment
- **Absorptive capacity:**
  - the ability of the environment to assimilate the waste
- **Pollutant classification:**
  - Local
  - Regional
  - Global
  - Stock pollutants
  - Fund pollutants

Emission Reduction in End-Use Sectors

- Industry
- Transport
- Household and Tertiary

Industry

- **Technologies and measures for reducing energy-related emissions from industry sector include:**
  - ✓ **improving efficiency:**
    - **energy savings,**
    - **cogeneration,**
    - **steam recovery,**
    - **and use of more efficient motors and other electrical devices;**
  - ✓ **recycling materials and switching to those with lower emissions;**
  - ✓ **and developing processes that use less energy and materials.**

Transport and Tertiary

- **Transport**
  - **Air emissions per unit of energy used could be reduced through the use of solar electricity**
- **Residential and Commercial Sector**
  - **Technical changes might include**
    - ✓ **reduced heat transfers through building structures**
    - ✓ **more efficient space-conditioning and water supply systems, lighting, and appliances.**
  - **Industry and Tertiary sectors are target of DSM programmes**

Options in Electric Power System

- **Existing System Options**
  - Loss reduction in T & D network
  - Re-powering
  - Fuel switching
  - Improving combustion efficiency
  - Dispatch modifications
- **System Expansion Options**
  - Advanced technologies
  - New and renewable technologies
  - Cogeneration
- **Control technologies for both systems**

Reduction of Losses in T&D System

Country	Loss %
Belgium	4.5
Finland	3.5
Germany	4.8
Greece	8.7
Hungary	14.0
Poland	11.6
Portugal	8.6
Sweden	8.2
UK	8.3

Source IEA database 2002

Reduction of Losses in T&D System

- Reduction of T&D losses reduces the production of electricity therefore reduce pollution
- For example:
  - In 2000 (GWh)
    - ✓ UK: loss = 30796 compared with import = 14308
    - ✓ Sweden: loss = 11681 compared with 54800 produced by 11 NPP
    - ✓ Hungary: loss = 5040 compared with 14200 produced by 4 NPP

Control Technologies

- **End-of-Pipe technologies:**
  - **Removal of particulate matters**
    - ✓ **ESP**
  - **Removal of NOx**
    - ✓ **SCR**
  - **Reduction of SO2**
    - ✓ **Flue gas desulfurization**

Electrostatic Precipitator

- **Applicable pollutants:**
  - PM including PM less than or equal to 10 and 2.5 micro-meter in aerodynamic diameter and hazardous air pollutants that are in particulate form
- **Achievable Emission Reduction:**
  - Removal efficiency between 99 % to 99.9 %
  - Factor influencing the efficiency:
    - ✓ Size of ESP, and thus, retention time
    - ✓ Strength of the magnetic field
    - ✓ Dust resistivity
    - ✓ Chemical composition
    - ✓ Particle size and distribution

Electrostatic Precipitator

❖ Operation of ESP:

- Particles are given an electrical charge
- Electrical force to move particles to collector plates
- Particles from plates slid downward into a hopper where they are collected
- Dust is collected and disposed off

❖ Cost information:

- Capital cost: 21,000 to 70,000 USD per sm3
- O&M cost: 6,400 to 74,000 USD per sm3 annually
- Annualized cost: 9,100 to 81,000 USD per sm3 annually
- Cost effectiveness: 38 to 260 USD per ton of PM removed

Electrostatic Precipitator

- **Advantages:**
  - High efficiency even for very fine particles
  - Low pressure drop
  - Can handle gas flow with high temperature (700 oC)
  - Can handle relatively large gas slow rate
- **Disadvantage:**
  - High costs
  - Not effective in handling variable flows (fluctuation of flow rate, temperature)
  - Large size not suitable in small space or retrofitting

Selective Catalytic Reduction

- **Applicable Pollutant:**
  - Nitrogen Oxides (NOx)
- **Achievable Emission Reduction:**
  - Between 70 % to 90 %
- **Operation:**
  - Chemical reaction reduces Nox into N2 and water
  - The waste gas enters into the catalyst together with reagents
  - Reagent reacts selectively with NOx

Selective Catalytic Reduction

❖ Cost information:

Unit type	Capital cost ($/MMBtu)	O&M cost ($/MMBtu)	Annual cost ($/MMBtu)	Cost per ton ($/ton)
Industrial coal boiler	10,000 - 15,000	300	1,600	2,000 - 5,000
Industrial gas, wood, oil boilers	4,000 - 6,000	450	700	1,000 - 3,000
Large gas turbine	5,000 - 7,500	3,500	8,500	3,000 - 6,000
Small gas turbine	17,000 - 35,000	1,500	3,000	2,000 - 10,000

EPA-CICA Fact Sheet, SRC

Selective Catalytic Reduction

- **Advantages:**
  - Higher reduction efficiency than other techniques
  - Applicable to sources with low NOX concentration
  - Does not require modification of combustion unit
- **Disadvantages:**
  - Significant higher capital costs than other techniques
  - Large volume of reagent and catalyst required
  - Results in ammonia in the waste gas stream which may impact plume visibility

Flue Gas Desulfurization (FGD)

- **Applicable pollutant:**
  - **Sulfur dioxides (SO_2)**
- **Achievable Emission Reduction:**
  - **Between 50 % and 98 % depending on the type of process of scrubber**
  - **Highest efficiency is associated with wet FGD**
- **Operation:**
  - **A calcium based reagent is injected into the flue gas stream.**
  - **SO_2 is absorbed neutralized or oxidized by the alkaline reagent into solid compound, which is removed from the waste gas stream**

Flue Gas Desulfurization (FGD)

❖ Cost information:

Scrubber type	Unit size (MW)	Capital cost ($/kW)	O&M cost ($/kW)	Annual cost ($/kW)	Cost per ton ($/ton)
Wet scrubber	> 400	100 – 250	2 – 8	20 – 50	200 – 500
Wet scrubber	< 400	250 – 1500	8 – 20	50 – 200	500 – 5000
Spray dry	> 200	40 – 150	4 – 10	20 – 50	150 – 300
Spray dry	< 200	150 – 1500	10 – 300	50 – 500	500 – 4000

EPA-CICA Fact Sheet, SRC
O&M cost – assuming 80% capacity factor

Flue Gas Desulfurization (FGD)

❖ Advantages:

- High SO_2 removal efficiency (up to 98 % is possible)
- Products of reaction may reusable
- Inexpensive and readily available reagents

❖ Disadvantages:

- High capital and O&M costs
- Disposal of waste product significantly increases O&M costs
- Deposit of wet solids on absorber and downstream equipment
- Wet system generates a wet waste product and may result in visible plume

Analytical Tools

❖ Environmental Impact Assessment

- Environmental situation without the project
- Environmental situation with project
- Impact classification
- Measures to mitigate impacts:
  - ✓ During construction
  - ✓ During project operation
  - ✓ After project decommissioning
- Monitoring system
- Evaluation of impacts

Analytical Tool

- **Cost-Benefit Analyses**
  - **Comparing costs and benefits of a project a regulation a standards, etc**
  - **This involves economic evaluation of costs and benefits**
  - **Internalization of environmental costs**

THANK YOU FOR YOUR ATTENTION