

## 1 ☐ Energy: Nuclear Energy

EVPP 111 Lecture

Dr. Largen

## 2 ☐ Outline

- Cautionary Tale of Chernobyl
- Nature of nuclear energy
- History of Nuclear Energy
- Nuclear reactors
- Nuclear fuel cycle
- Nuclear weapons
- Concerns about nuclear energy
- Waste disposal

## 3 ☐ Fig. 11.1a

## 4 ☐ Outline

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## 5 ☐ Energy: Nuclear Energy

- **Chernobyl**
  - 4/26/86
  - series of explosions in one of reactors at plant
    - blew roof (1102 ton) off reactor building
    - flung radioactive debris and dust high into atmosphere

## 6 ☐

## 7 ☐ Energy: Nuclear Energy

- **Chernobyl**
  - **cause of accident**
    - most automatic safety and warning systems were turned off
    - safety design was inadequate
    - design flaw led to unstable operation at low power

## 8 ☐ Energy: Nuclear Energy

- **Chernobyl**
  - **response to accident**
    - after explosion
      - remains of reactor encased in 19-story concrete tomb

## 9 ☐ Energy: Nuclear Energy

- **Chernobyl**
  - **response to accident**
    - new tomb is needed
      - estimated cost is \$1.5 billion
      - Ukrainian government cannot afford

## 10 ☐ Energy: Nuclear Energy

- **Chernobyl**
  - **consequences of accident**
    - evacuation
      - ~116,000 people

## 11 ☐ Energy: Nuclear Energy

- **Chernobyl**
  - **consequences of accident**
    - immediate deaths & injuries
      - 31 fatalities
      - 500 hospitalizations
        - » 237 with acute radiation sickness
    - long-term death toll
      - Ukrainian government official total
        - » 3,576 (in 1998)
      - Greenpeace Ukraine
        - » 32,000 as of 1995

## 12 ☐ Energy: Nuclear Energy

- **Chernobyl**
  - **consequences of accident**
    - long-term health issues
      - Belarus (70% of radiation was deposited)
        - » thyroid cancer rates among children are 10-100 times the level before the accident

- rates of non-cancer diseases increasing disproportionately among ~600,000 “liquidators”

### 13 ☐ Energy: Nuclear Energy

- **Chernobyl**
  - **consequences of accident**
    - environmental impacts
      - lethal doses of radiation
      - long-term contamination

### 14 ☐ Energy: Nuclear Energy

- **Chernobyl**
  - **consequences of accident**
    - public opinion
      - percent of people opposed to nuclear power plants before versus after Chernobyl
        - » UK: before, 65% - after, 83%
        - » Germany: before, 46% - after, 83%
        - » US: before, 67% - after, 78%

### 15 ☐ Energy: Nuclear Energy

- **Chernobyl**
  - **consequences of accident**
    - nuclear plant orders
      - were declining even before Chernobyl
      - since 1980 many countries have cancelled nuclear plant orders:
        - » Argentina, 4 plants
        - » Brazil, 8 plants
        - » Mexico, 18 plants
        - » US, 54 plants (no new plants have been ordered since 1974)

### 16 ☐ Energy: Nuclear Energy

- **Chernobyl**
  - **consequences of accident**
    - *a major nuclear accident anywhere is a nuclear accident everywhere*

### 17 ☐ Outline

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## 18 ☐ Energy: Nuclear Energy

- **Nature of nuclear energy**
  - **nuclear energy**
    - energy from disintegrating atomic nuclei

## 19 ☐ Energy: Nuclear Energy

- **Nature of nuclear energy**
  - **nuclear energy**
    - some isotopes of atoms are
      - **radioactive**
  - **radioactive half-life**
    - time it takes for 1/2 of radioactive material to spontaneously decompose

## 20 ☐ Table 11.1

## 21 ☐ Energy: Nuclear Energy

- **Nature of nuclear energy**
  - **nuclear energy**
    - **radiation**
      - energy released from nucleus during nuclear disintegration
      - three major types
        - » **alpha**
        - » **beta**
        - » **gamma**

22 ☐ Energy: Nuclear Energy

- **Nature of nuclear energy**
  - nuclear energy
    - radiation
      - alpha

23 ☐ Energy: Nuclear Energy

- **Nature of nuclear energy**
  - nuclear energy
    - radiation
      - beta

24 ☐ Energy: Nuclear Energy

- **Nature of nuclear energy**
  - nuclear energy
    - radiation
      - gamma

25 ☐ Energy: Nuclear Energy

- **Nature of nuclear energy**
  - nuclear energy
    - **nuclear fission**
      - process in which moving neutrons hit nuclei of certain other atoms, causing them to split
        - » **nuclear chain reaction**

26 

## 27 Energy: Nuclear Energy

- **Nature of nuclear energy**
  - nuclear energy
    - **nuclear chain reaction**
      - **critical mass**
        - two materials most commonly used are
          - » uranium-235
          - » plutonium-239
      - will continue until
        - » fuel is spent
        - » neutrons are prevented from striking other nuclei

28 

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## 30 Energy: Nuclear Energy

- **History of nuclear energy**
  - first controlled fission
  - atomic bombs
  - nuclear weapon research and testing
  - construction of world's 1st electricity-generating reactor,
  - explosion of nuclear devices by India and Pakistan

## 31 Energy: Nuclear Energy

- **History of nuclear energy**
  - 1950's predictions
    - by President Dwight D. Eisenhower, in "Atoms for Peace" speech , 1953

– “Nuclear reactors will produce electricity so cheaply that it will not be necessary to meter it . The users will pay an annual fee and use as much electricity as they want. Atoms will provide a safe, clean and dependable source of electricity.”

- by researchers
  - by the year 2000, at least 1800 nuclear power plants will supply 21% of world's commercial energy (25% of US's energy)

## 32 Energy: Nuclear Energy

- **History of nuclear energy**
  - 2004 reality
    - nuclear is the most expensive method of producing electricity
    - several accidents have caused worldwide concern
    - no new plants ordered since 1974
    - in 2000, plants supply 16% of world and 20% of US electricity
    - some predict use of nuclear energy
      - to decline as existing plants age and are retired
      - to increase as concern over greenhouse gas emissions from fossil fuels increases

33 

## 34 Outline

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## 35 Energy: Nuclear Energy

- **Nuclear reactor**
  - device that permits a controlled fission chain reaction

36 

## 37 Energy: Nuclear Energy

- **Nuclear reactor**
  - **controlling the reaction**
    - reactors contain
      - **fuel rods**

- control rods

### 38 ☐ Energy: Nuclear Energy

- **Nuclear reactor**
  - **controlling the reaction**
    - reactors contain
      - **moderator**

### 39 ☐ Energy: Nuclear Energy

- **Nuclear reactor**
  - in generation of electricity
    - serves the same function as any fossil-fuel boiler

### 40 ☐ Energy: Nuclear Energy

- **Nuclear reactor**
  - reactors
    - differ in
      - moderator used
      - cooling of reactor core
      - how heat from core is used to generate steam
    - types
      - fission
      - breeder
      - fusion

### 41 ☐ Energy: Nuclear Energy

- **Nuclear reactor**
  - **fission reactors**
    - major types
      - light-water reactors (LWR)
        - » boiling-water reactors (BWR)
        - » pressurized-water reactors (PWR)
      - heavy-water reactors (HWR)
      - gas-cooled reactors (GCR)

### 42 ☐ Energy: Nuclear Energy

- **Nuclear reactor**
  - **fission reactors**
    - **light-water reactors (LWR)**

### 43 ☐ Energy: Nuclear Energy

- **Nuclear reactor**
  - **fission reactors**
    - boiling-water reactors (BWR)



44 

## 45 Energy: Nuclear Energy

- **Nuclear reactor**
  - **fission reactors**
    - pressurized-water reactors (PWR)

46 

## 47 Energy: Nuclear Energy

- **Nuclear reactor**
  - **fission reactors**
    - heavy-water reactors (HWR)

## 48 Energy: Nuclear Energy

- **Nuclear reactor**
  - **fission reactors**
    - gas-cooled reactors (GCR)

## 49 Energy: Nuclear Energy

- **Nuclear reactor**
  - **breeder reactors**
    - nuclear fission reactor that
      - produces heat to be converted to steam to generate electricity
      - forms a new supply of radioactive isotopes

50 

## 51 Energy: Nuclear Energy

- **Nuclear reactor**
  - **breeder reactors**
    - type
      - **liquid metal fast-breeder reactor (LMFBR)**
        - » after ~10 years of operation, enough plutonium-239 is produced to operate a second reactor
        - »

## 52 Energy: Nuclear Energy

- **Nuclear reactor**
  - **breeder reactors**
    - type
      - **liquid metal fast-breeder reactor (LMFBR)**
        - » reactions can be difficult to regulate
        - » high potential for accidents
        - » waste is very hazardous
        - » plutonium-239 can be made into weapons

- » only 5 such plants exist in world
- » only 1 in US is experimental and scheduled to be shut down

53 

## 54 Energy: Nuclear Energy

- **Nuclear reactor**
  - **nuclear fusion**
    - process in which 2 lightweight atomic nuclei combine to form a heavier nucleus, releasing a large amount of energy

## 55 Energy: Nuclear Energy

- **Nuclear reactor**
  - **nuclear fusion**
    - holds huge potential
      - amount of energy that would be released by combining the deuterium ( $H^2$ ) in 1 cubic kilometer of ocean water would be greater than that contained in world's entire supply of fossil fuels

56 

## 57 Energy: Nuclear Energy

- **Nuclear reactor**
  - **nuclear fusion**
    - problems
      - three conditions must be met simultaneously
        - » high temperature
        - » adequate density
        - » confinement

## 58 Energy: Nuclear Energy

- **Nuclear reactor**
  - **nuclear fusion**
    - problems
      - high temperature
        - » if heat is used to provide energy necessary for fusion, temperature must approach that of center of sun
        - » walls of vessel containing atoms would have to be able to resist that heat

## 59 Energy: Nuclear Energy

- **Nuclear reactor**
  - **nuclear fusion**
    - problems
      - confinement
        - » positively charged nuclei repel each other

## 60 Energy: Nuclear Energy

- **Nuclear reactor**

- **nuclear fusion**
  - problems
    - development being delayed by
      - » economic costs
      - » fear of accidents

61 

## 62 Energy: Nuclear Energy

- **Nuclear reactor**
  - **locations**
    - world
      - 439 plants in 31 countries
      - supplying ~16% of electricity
    - US
      - 103 plants in 31 states
      - supplying ~20% of electricity

63 

64  Table 11.2a

65  Table 11.2b

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