

# **Smil Discussion Group: Understanding Our Material World**

Chapter 3 pt 1  
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# The Four Pillars of Modern Civilization

- Energy and materials are the backbones needed to fuel electricity-related advances
- While all materials are important, four are particularly indispensable, ubiquitous, and have great demand:





- 4.5 billion tons
- No other materials are as strong, versatile, and durable as reinforced concrete



- 1.8 billion tons
- No metal is as ubiquitous
  - Extract energies
  - Produce food
  - Create essential infrastructure



- 370 million tons
- No other materials are as malleable, durable, or light weight



- 150 million tons
- Ammonia-based fertilizers for crops cannot be feasibly substituted

In 2019 alone...



# The Four Pillars of Modern Civilization

- Global production of cement, steel, plastics, and ammonia
  - 17% of the world's primary energy supply
  - 25% of all CO<sub>2</sub> emissions from fossil fuels
  - No alternatives for producing these materials have been commercialized

# Ammonia: the gas that feeds the world



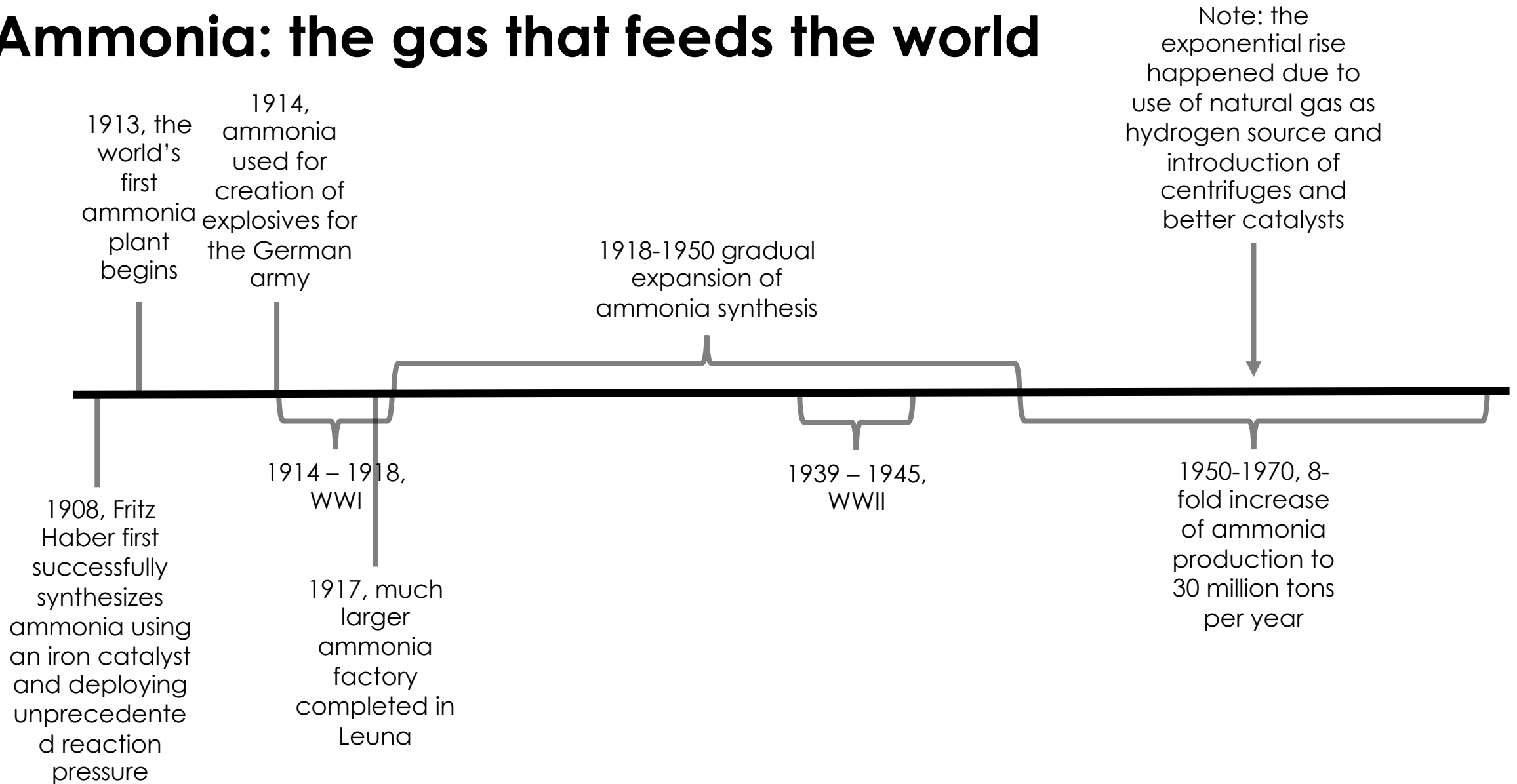
# Ammonia: the gas that feeds the world

- Dominant nitrogen fertilizer
  - Without it would be impossible to feed 40-50% of today's 8 billion people
    - 3.2-4 billion people
- Inorganic compound of one nitrogen and three hydrogens (NH<sub>3</sub>)
- Invisible gas with a distinct unpleasant smell
  - Inhaling ammonia can have varying health affects
    - Low concentrations = headache, nausea, vomiting
    - Higher concentrations = irritate eyes, nose, mouth, throat, and lungs
    - Very high concentrations = instantly fatal

# Ammonia: the gas that feeds the world

- Unlike accidental inventions (i.e., Teflon), the synthesis of ammonia was intentional.
- 1850 – 1900 saw rapid urbanization
  - Population grew from 300 million to 500 million
  - 200 million hectares of grasslands were converted to grain fields
- Increased supplies of nitrogen and phosphorus needed to secure adequate food supply
  - William Crookes – “all civilized nations stand in deadly peril of not having enough to eat”
  - Solution? Tap into the unlimited mass of nitrogen in the atmosphere and convert it into compounds assimilable by plants

# Ammonia: the gas that feeds the world

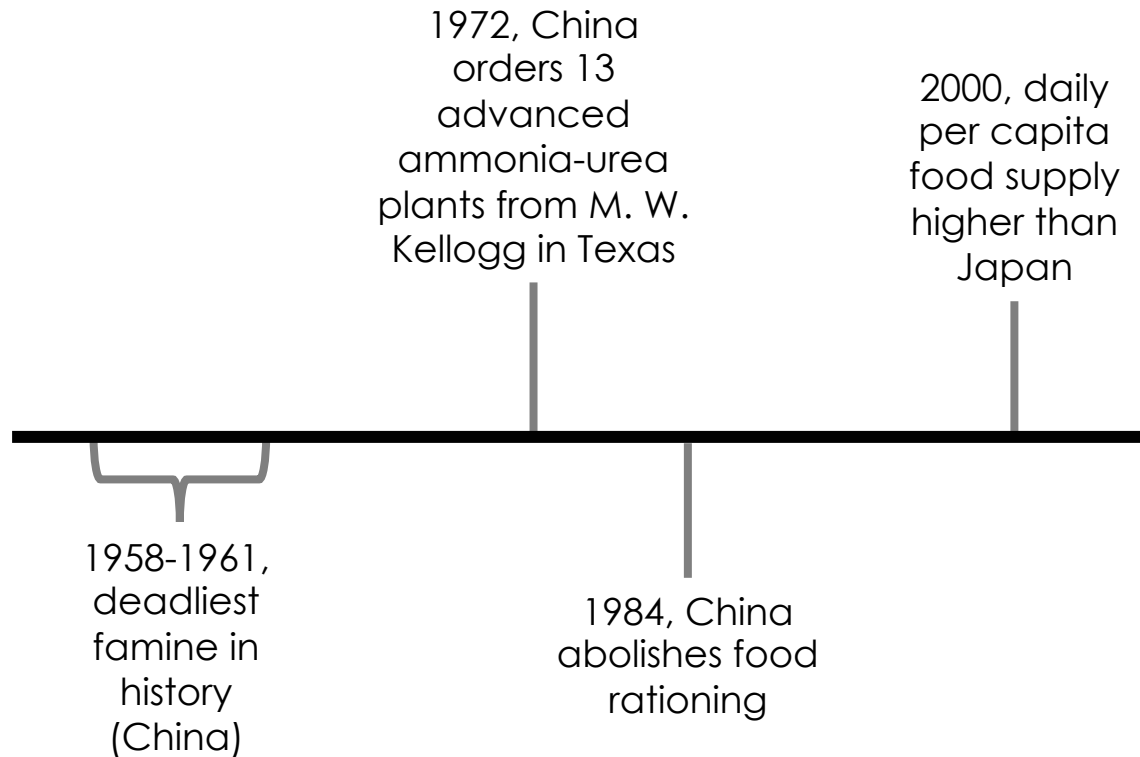


Note: the exponential rise happened due to use of natural gas as hydrogen source and introduction of centrifuges and better catalysts



# Ammonia: the gas that feeds the world

China takes the lead...



- Achieved by breaking China's nitrogen barrier raising grain harvest to 650 million tons per year
- Recent times, crops coming from synthesized ammonia feed 60% of the Chinese population, 50% worldwide (mean)
  - Lower if the affluent world switched to the meatless Indian diet
  - Reduce ammonia dependence by cutting our food waste

# Ammonia: the gas that feeds the world

- 80% of global ammonia production is used for producing solid and liquid nitrogenous fertilizers for crops
  - Other 20% used to make nitric acid, explosives, rocket propellants, dyes, fibers, and window and floor cleaners
- 55% of all nitrogen is applied to the world's fields
  - Widely used in Asia to support rice and wheat harvests
- Once applied to fields it's impossible control their natural losses
- Direct solutions to field losses of nitrogen?
  - The spreading of slow-release compounds (expensive)
  - Precision farming and as needed fertilizer application (more practical)

# Plastics: diverse, useful, troublesome



# Plastics: diverse, useful, troublesome

- Large group of synthetic (or semisynthetic) organic materials
  - Fit for forming (molding)
  - Begins with monomers, ethylene and propylene, bonded to make polymers
- Malleability of plastics mean they can form any shape (thin film to heavy-duty pipes) at ranging sizes and durability.
- Global output dominated by thermoplastics – polymers softened when heated, hardened when cooled
  - Low weight, high strength
  - Polyethylene accounts for 20% of the world's plastic polymers, polypropylene 15%, polyvinyl chloride (PVC) 10%

# Plastics: diverse, useful, troublesome

- First plastics produced in small amounts from 1870 – 1900
- First thermoset plastics—resists softening when heated—prepared in 1907 by Leo Baekeland
  - General Bakelite Company was the first industrial producer of plastic
- Plastics have encompassed a wide variety of uses
  - Absorbent cloths and wipes, synthetic rubber, fabrics and upholstery, plexiglass, toothbrush bristles, stockings, fishing nets, parachutes, disposable cups and plates, furniture foams, adhesives, drink bottles, optical lenses, windows, etc.
- Global annual production boomed
  - 1925 – 20,000 tons
  - 1950 – 2 million tons
  - 2000 – 150 million tons
  - 2019 – 370 million tons

# Plastics: diverse, useful, troublesome

- Most useful role is in health care
- Plastic items in hospitals are made from different kinds of PVC
  - Flexible tubes (e.g., delivering oxygen, feeding patients), catheters, IV containers, blood bags, sterile packaging, assorted trays, bedpans and bed rails, thermal blankets, and (as we know well) countless pieces of labware
- PVC accounts for > 25% of all health-care products
- PVC is in numerous parts of modern homes
  - Wall and roof membranes, window frames blinds, hoses, cable insulation, electronic parts, office supplies, and toys
- Plastic pollution concerns will be addressed in the environmental chapter

# Links shared during discussion:

- The Potential of Bamboo as Building Material in Organic Shaped Buildings - Esti Asih Nurdiah
  - <https://www.sciencedirect.com/science/article/pii/S1877042815061844>
- How can we make steel green? - Ajit Nirranjan
  - <https://www.dw.com/en/green-steel-climate-solutions-coal-carbon-capture-storage-hydrogen/a-62011017>
- The 411 on Recycled Concrete: Uses, Benefits, and How To
  - <https://ozinga.com/blog/the-411-on-recycled-concrete-uses-benefits-and-how-to/>