UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

GREEN CHEMISTRY

INTRODUCTION:
CHEMICALS IN THE SOCIETY

MODULE 1 - MORNING SESSION I
1-DAY PRESENTATION

www.greenchemistry-toolkit.org

EVERYTHING IS A CHEMICAL

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But what does that mean?

- Name everything in the room that is a chemical
- Name everything in the room that is not a chemical

Chemicals are related to:

- Food
- Transportation
- Communication
- Information Technology
- Economy

CHEMICALS AND FOOD

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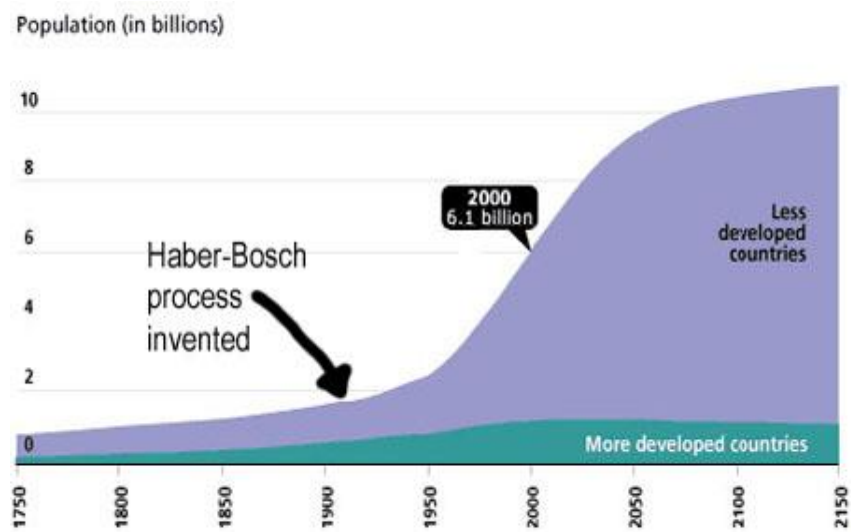
- Fertilizers
  - More food can be grown for the population
  - Revolution came with the Haber Bosch process
- Pesticides
  - Mosquitos carrying deadly diseases can be controlled
  - Algal blooms which lead to eutrophication are controlled
- Food preservatives
  - Longer shelf life leads to population spreading to less favorable places



In the early 1900s, the Haber-Bosch process allowed incorporation of Nitrogen from the air and lead to population growth.

Image source: Wikipedia

CHEMICALS IN TRANSPORTATION

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- ❑Gasoline/Diesel
  - Fast ground transportation was enabled
- ❑Jet Fuel
  - Air transportation was enabled
  - Globalization and international trade is possible
- ❑Rocket Fuel
  - Satellites placed on the Earth’s orbit allow communication and navigation
- ❑Vulcanized Rubber
  - Tires, shoe soles, hoses and conveyor belts can be made
- ❑Deicing of plane wings
  - Aviation in all conditions is made possible

Apollo 15 launching

Image source: Wikicommons

CHEMICALS IN COMMUNICATION

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ELEMENTS OF A SMARTPHONE

ELEMENTS COLOUR KEY: ALKALI METAL · ALKALINE EARTH METAL · TRANSITION METAL · GROUP 13 · GROUP 14 · GROUP 15 · GROUP 16 · HALOGEN · LANTHANIDE

SCREEN

49 In Indium · 8 O Oxygen · 50 Sn Tin

Indium tin oxide is a mixture of indium oxide and tin oxide, used in a transparent film in the screen that conducts electricity. This allows the screen to function as a touch screen.

13 Al Aluminium · 14 Si Silicon · 8 O Oxygen · 19 K Potassium

The glass used on the majority of smartphones is an aluminosilicate glass, composed of a mix of alumina (Al_2O_3) and silica (SiO_2). This glass also contains potassium ions, which help to strengthen it.

39 Y Yttrium · 57 La Lanthanum · 65 Tb Terbium · 59 Pr Praseodymium · 63 Eu Europium · 66 Dy Dysprosium · 64 Gd Gadolinium

A variety of Rare Earth Element compounds are used in small quantities to produce the colours in the smartphone's screen. Some compounds are also used to reduce UV light penetration into the phone.

ELECTRONICS

Copper is used for wiring in the phone, whilst copper, gold and silver are the major metals from which microelectrical components are fashioned. Tantalum is the major component of micro-capacitors.

29 Cu Copper · 47 Ag Silver · 79 Au Gold · 73 Ta Tantalum

Nickel is used in the microphone as well as for other electrical connections. Alloys including the elements praseodymium, gadolinium and neodymium are used in the magnets in the speaker and microphone. Neodymium, terbium and dysprosium are used in the vibration unit.

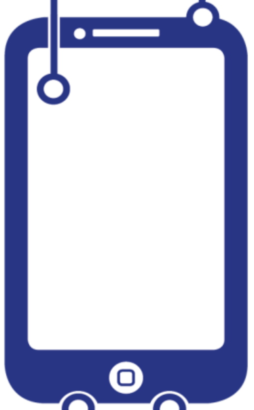
28 Ni Nickel · 66 Dy Dysprosium · 59 Pr Praseodymium · 65 Tb Terbium · 60 Nd Neodymium · 64 Gd Gadolinium

Pure silicon is used to manufacture the chip in the phone. It is oxidised to produce non-conducting regions, then other elements are added in order to allow the chip to conduct electricity.

14 Si Silicon · 8 O Oxygen · 51 Sb Antimony · 33 As Arsenic · 15 P Phosphorus · 31 Ga Gallium

Tin & lead are used to solder electronics in the phone. Newer lead-free solders use a mix of tin, copper and silver.

50 Sn Tin · 82 Pb Lead



BATTERY

3 Li Lithium · 27 Co Cobalt · 8 O Oxygen · 6 C Carbon · 13 Al Aluminium

The majority of phones use lithium ion batteries, which are composed of lithium cobalt oxide as a positive electrode and graphite (carbon) as the negative electrode. Some batteries use other metals, such as manganese, in place of cobalt. The battery's casing is made of aluminium.

CASING

Magnesium compounds are alloyed to make some phone cases, whilst many are made of plastics. Plastics will also include flame retardant compounds, some of which contain bromine, whilst nickel can be included to reduce electromagnetic interference.

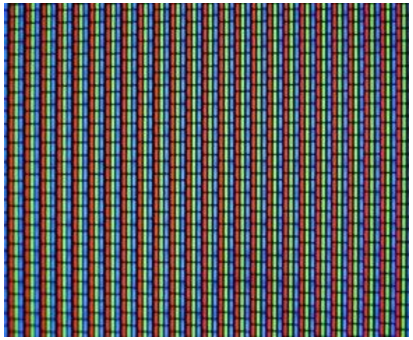
6 C Carbon · 12 Mg Magnesium · 35 Br Bromine · 28 Ni Nickel

❑Nanotechnology

- Creation of many materials and devices with applications in nanomedicine (drug delivery), nanoelectronics (computer processors), biomaterials, and personal products (sunscreens)

❑Displays

- LCD (TV, watches, calculators)



Display device magnified showing a nano structure

Image source: Wikicommons

CHEMICALS IN THE ECONOMY

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❑Chemical industry sector

- Total pharmaceutical revenue had reached $1 trillion in 2014

❑Petrochemicals

- Global market is estimated to reach $791 billion by 2018

❑Consumer products

- Most products that we see, touch, and feel are petroleum based

❑Job creation

- Robust selection of consumer/personal care products leads to job creation and increase in GDP
  - Approximately 1 million direct jobs from chemicals industry
  - Approximately 6 million indirect jobs

Chemicals can also negatively impact the society.

HOW?

UNINTENDED CONSEQUENCES

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Biofuels made from corn that compete with food, feed, and land use.

Biofuels made from corn.

Image source: Adobe Stock

UNINTENDED CONSEQUENCES

Purifying water with acutely lethal substances.

Chlorine transported in Washington D.C.

UNINTENDED CONSEQUENCES

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Renewable energy through the use of precious, rare, toxic metals in photovoltaics.

Solar panel installed on the roof of the building

Image source: Wikipedia

OTHER ENVIRONMENTAL CHALLENGES

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- Population
- Energy
- Global Change
- Resource Depletion
- Food Supply
- Toxics in the Environment

POPULATION TRENDS

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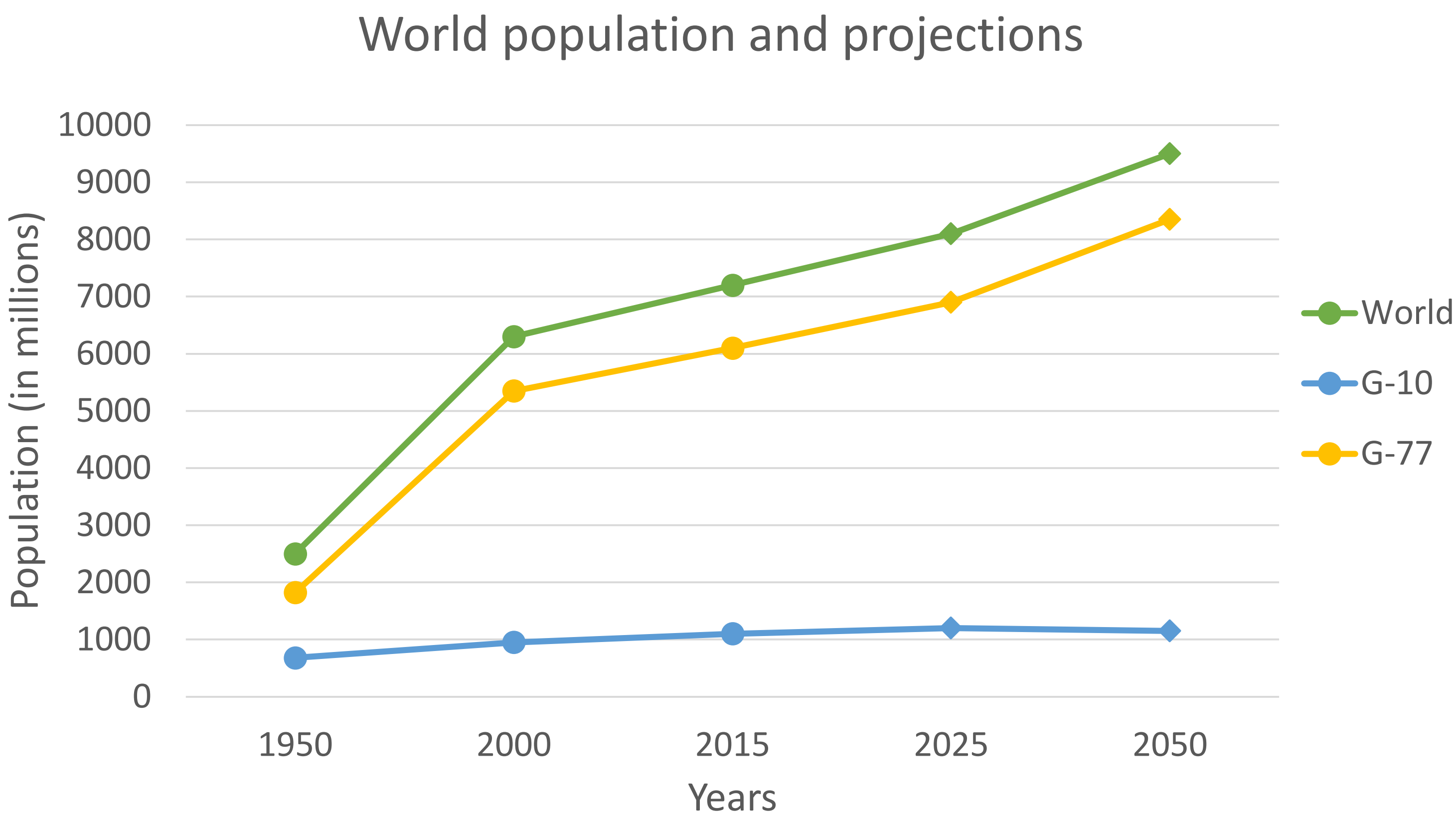

Source: U.N. World Population Prospects, *2000 Revision*

Population growth in developing countries is predicted to reach 7.8 billion by 2050. G-10 countries remain the same.

QUALITY OF LIFE DILEMMA

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- Empirical data shows that increased quality of life correlates with sustainable population control
- Increased quality of life, however, has historically resulted in increased damage to the biosphere and the earth's ability to sustain life

IMPACT OF DEVELOPMENT ON THE ENVIRONMENT

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Humanity and the Environment

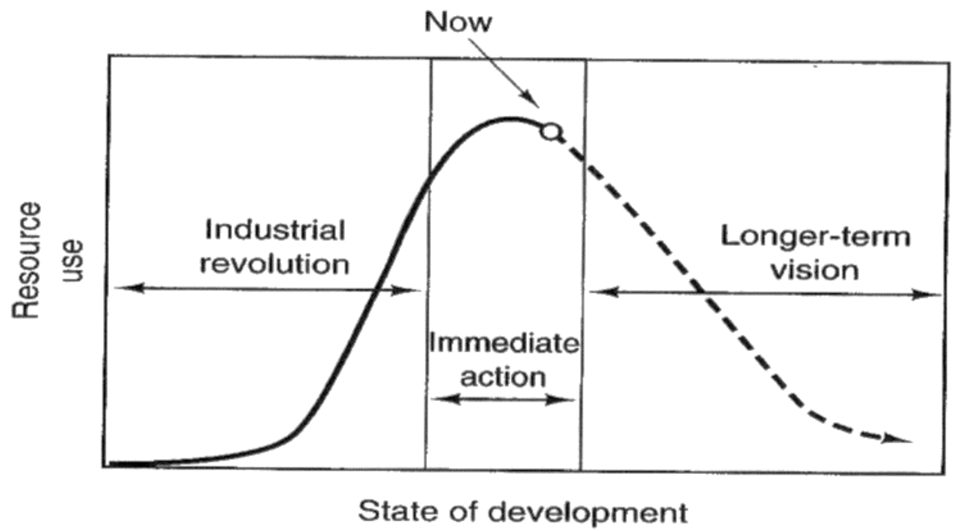

Figure 1.5 The typical life cycle of the relationship between the state of technological development of society and its resulting environmental impact.

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- **The challenge:** How to increase quality of life while minimizing detrimental effects to human health, the environment, and the biosphere
- **The solution:** Green Chemistry and Green Engineering provide a mechanism to address this challenge in very real terms

EFFICIENCY THROUGH SCIENCE AND TECHNOLOGY

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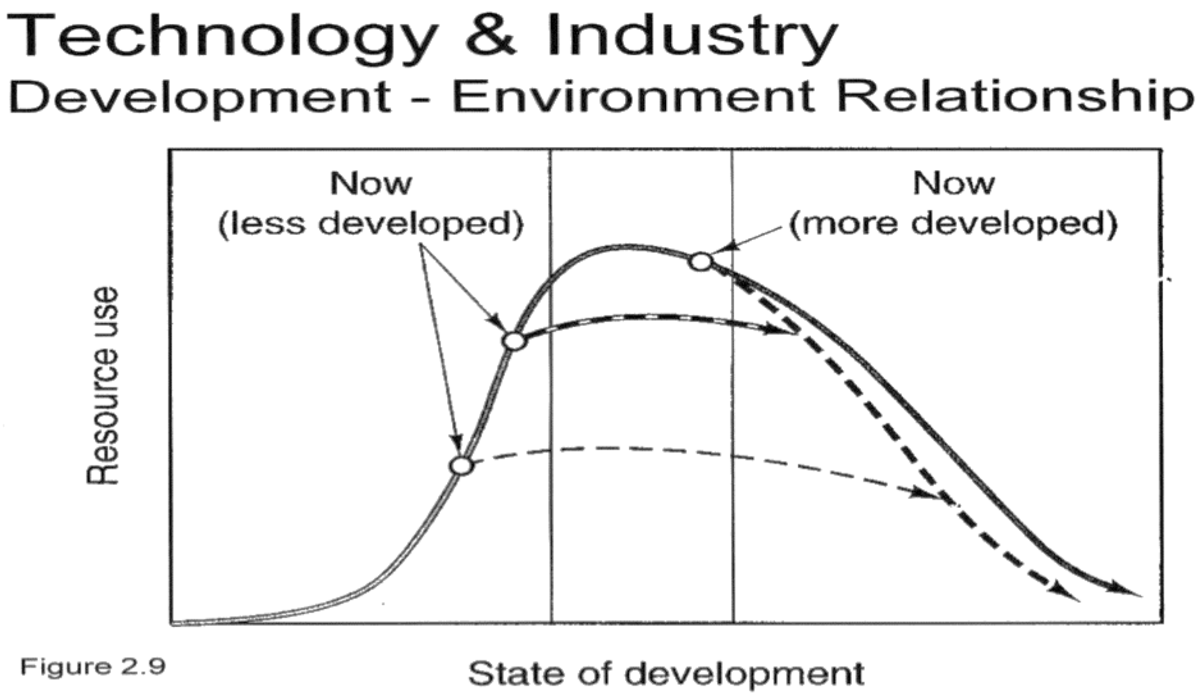

Figure 2.9

"The great enemy of the truth is very often not the *lie* -- deliberate, contrived and dishonest

but the *myth* -- persistent, persuasive and realistic."

John F. Kennedy

OTHER ENVIRONMENTAL CHALLENGES

- Population
- Energy
- Global Change
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- Food Supply
- Toxics in the Environment

The vast majority of the energy generated in the world today is from non-renewable sources that damage the environment:

- Carbon dioxide and greenhouse gases
- Depletion of resources
  - Rare earth metals, fossil fuels
- Effects of mining, drilling
  - Contamination of streams, lakes and ground water by fracking fluid or Sulphur ores
- Toxics
  - Separation agents like benzene, toluene and xylene (BTX) which are shown to be carcinogenic.

GROWING ENERGY CONSUMPTION

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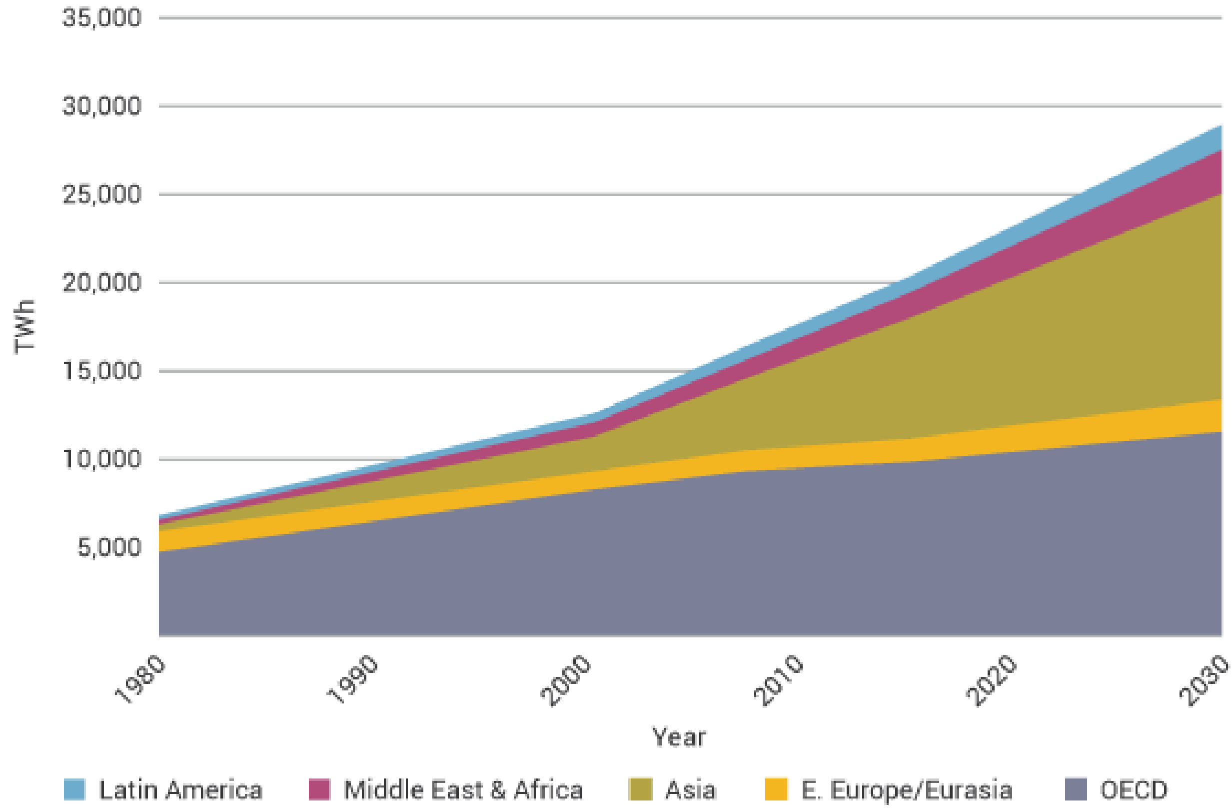
Energy use has approximately doubled in the past 30 years



Source: OECD/IEA World Energy Outlook 2009 - Reference Scenario

WHAT TYPE OF ENERGY FUTURE?

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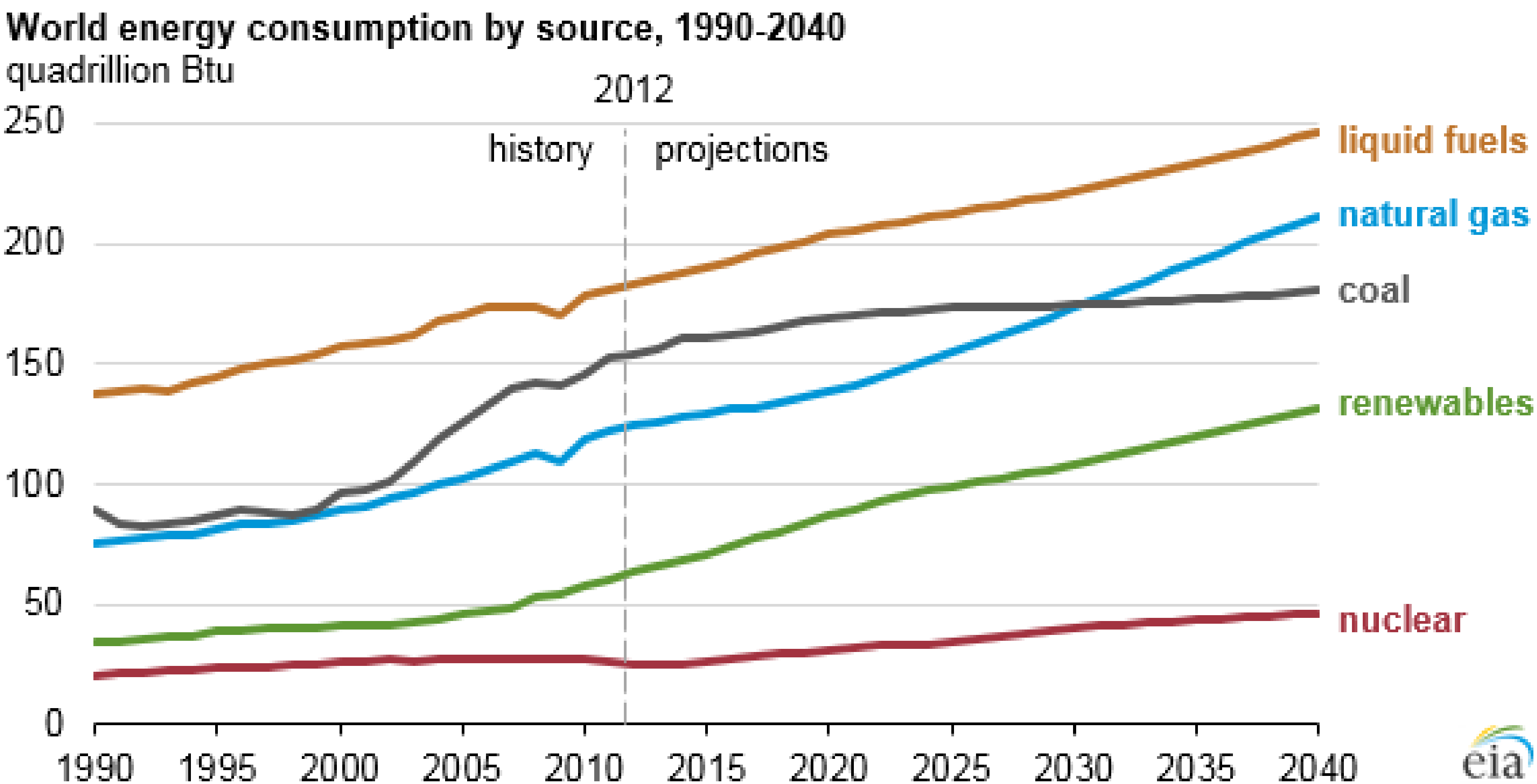

Sources: DOE/EIA-Word energy projection system

Green Chemistry will be essential in both:

- Developing the alternatives for energy generation (photovoltaics, hydrogen, fuel cells, biobased fuels, etc.)
- Continuing the path toward energy efficiency with catalysis and product design at the forefront

OTHER ENVIRONMENTAL CHALLENGES

- Population
- Energy
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Concerns for climate chaos, oceanic temperature, stratospheric chemistry, and global distillation can be addressed through the development and implementation of green chemistry technologies

TEMPERATURE CHANGE

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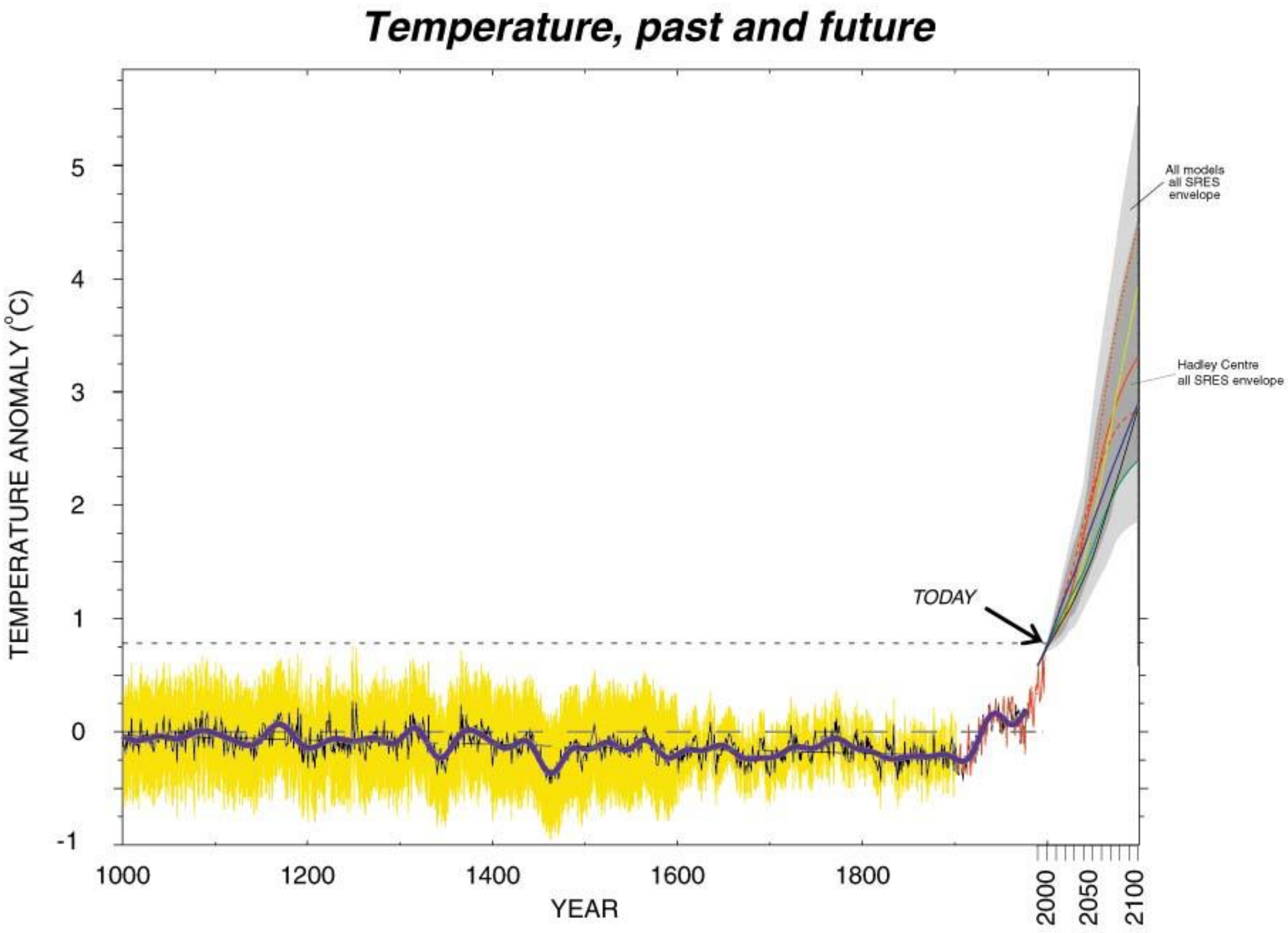

Source: http://www.sustainablescale.org/

CARBON DIOXIDE, METHANE AND NITROUS OXIDE CONCENTRATIONS OVER THE PAST 1,000 YEARS

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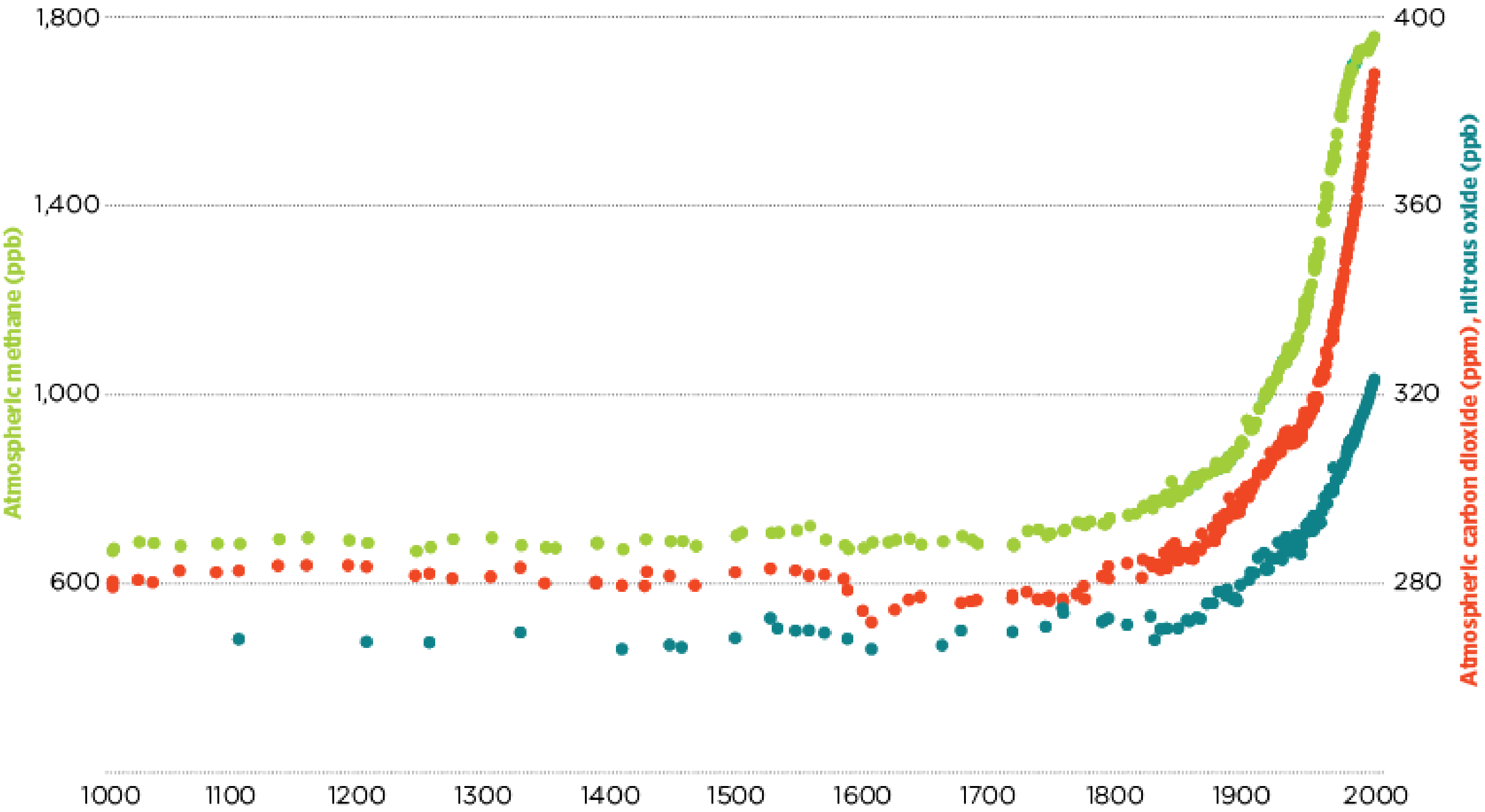

OTHER ENVIRONMENTAL CHALLENGES

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RESOURCE DEPLETION

Due to the over utilization of non-renewable resources, natural resources are being depleted at an unsustainable rate.

- Examples of depleting resources: precious metals, fossil fuels
- These are used to support of our current life style, economy, etc

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Renewable resources can be made increasingly viable technologically and economically through green chemistry:

- Biomass
  - Algae for fuel, lignin for platform chemicals
- Nanoscience & technology
- Transformations with visible light
  - Light rather than solvents
- Carbon dioxide as feedstock
  - In plastics
- Chitin as feedstock
  - In packaging
- Waste utilization
  - By biodegradation

OTHER ENVIRONMENTAL CHALLENGES

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FOOD SUPPLY

- While current food levels are sufficient, distribution is inadequate
- Agricultural methods are unsustainable
- Advances in future food production intensity is needed

INCREASE IN GRAIN PRODUCTION

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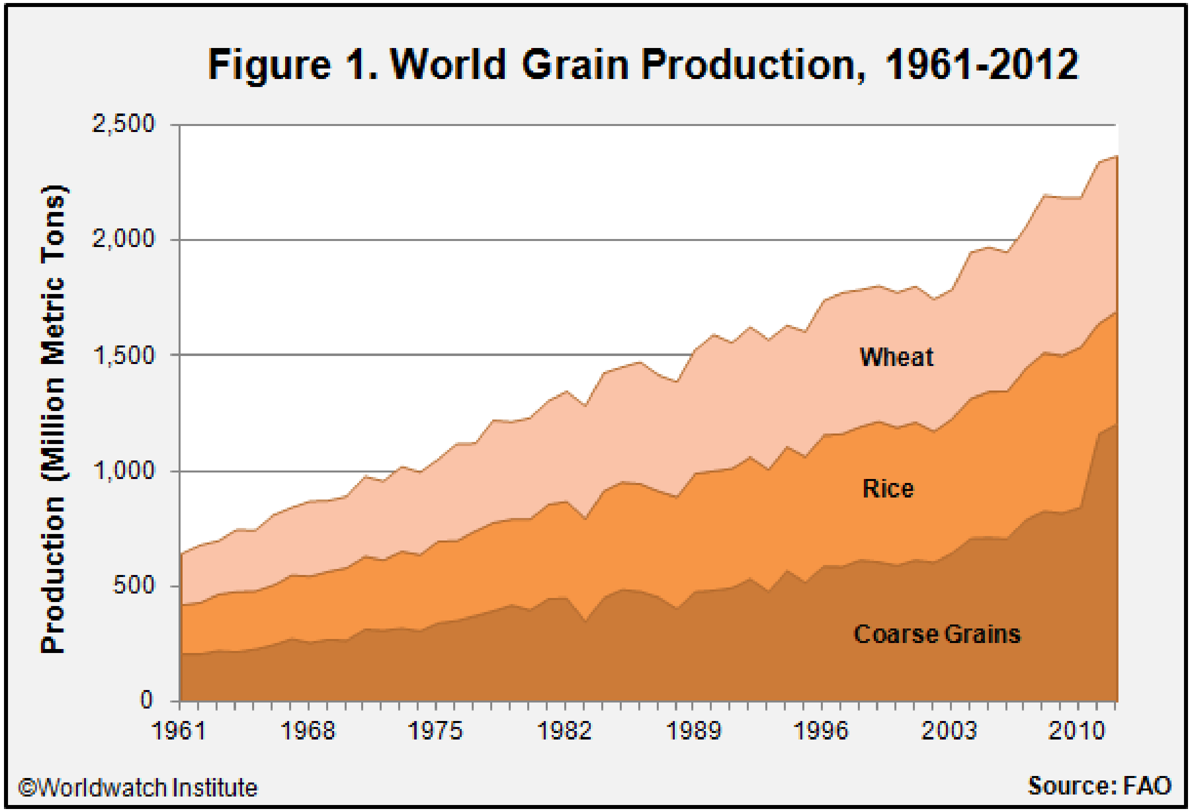
There is a growing demand in grain production in developing, industrialized and transition countries.



Source: FAO 1989-2000

USE OF PESTICIDES

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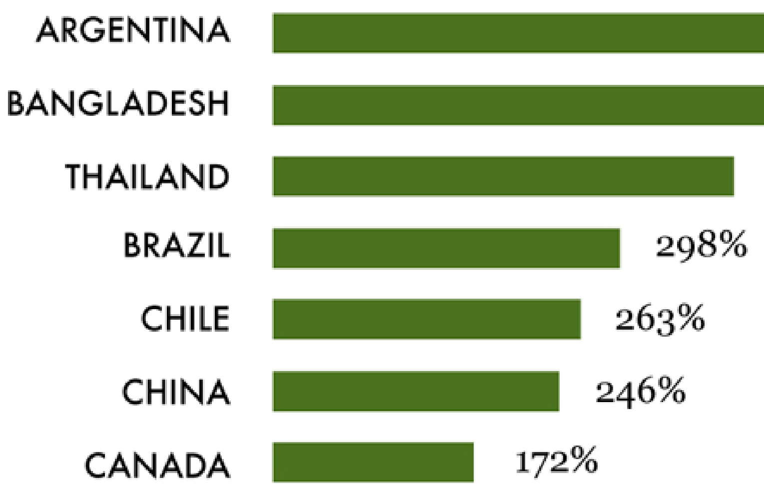
INCREASE IN PESTICIDE USE

FROM 1990 TO LATEST DATA (2007–12)



Only showing countries that use over 20 million kilograms of pesticides annually. Though Burkina Faso, Ethiopia and Ghana have seen exponential growth in pesticide use, those countries start from a much lower base.

Source: Pretty and Bharucha, *Insects*, 2015.

GREEN CHEMISTRY

Green chemistry is developing:

- Pesticides which only effect target organisms and degrade to innocuous by-products
- Fertilizers and fertilizer adjutants that are designed to minimize usage while maximizing effectiveness
- Methods of using agricultural wastes for beneficial and profitable uses

OTHER ENVIRONMENTAL CHALLENGES

GREEN CHEMISTRY

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Substances that are toxic to humans, the biosphere and all that sustains it, are currently still being released at a cost of life, health and sustainability.

BODY BURDEN

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- In 2000-2001 the study showed that human body includes 148 xenobiotic.
- Of the chemicals found:
  - 76 suspect carcinogens in humans or animals,
  - 94 are identified neurotoxins, and
  - 79 are linked to reproductive/developmental toxicity.
- The synergistic effects of these chemicals in combination has not been studied.

One of Green Chemistry's greatest strengths is the ability to design for reduced hazard.

THANK YOU!

QUESTIONS?

This training material was developed in close collaboration with the Center for Green Chemistry and Green Engineering at Yale University.

www.greenchemistry-toolkit.org