Indiana University
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Energy: Science, Policy, and the Pursuit of Sustainability
Course No. L330 Sec. No. 9643
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Lecture #1
Overview of the Course

Introduction

I would like to start off by explaining how I got interested in energy and environmental issues and why I decided to offer this course.

My rising awareness and interest in these issues dates back to 1983 when I first began teaching undergraduate courses in the physics department on Energy & the Environment, Energy & Technology, and finally, three times in collaboration with professors in the School for Public and Environmental Affairs (SPEA) at Indiana University, Energy and Policy.

By 1995, when I officially retired from IU, I was deeply disturbed by what was happening to the planet and the lack of a sensible U.S. energy policy, as were most of my students.

What I was concerned about was nicely summed up by Bruce Babbitt (Secretary of the Interior in the Clinton administration) as the keynote speaker at a conference on Energy and the Environment that I went to at Ohio University in Athens Ohio in the spring of 2003. He said that he believed the Energy/Environment problem was the

No. 1 problem facing the world in the 21st century.

As John Peet puts it in his book *Energy and the Ecological Economics of Sustainability,*

The environment is the playing field on which all other social concerns compete.

The purpose of our text, and the purpose of this course, is to help raise the level of public understanding of how serious these problems are and what we should be doing about them.

We can do this in only a small way in this class, and you might ask: what difference does it make what the fifteen of us think when they're 30,000 other students on campus who don't care.

It's probably not true that people *don't care* – it's that they *don't know.*

So, our task in this course is to first educate ourselves, and then to go out into the world and have some impact on how others think about energy and environmental issues. This is how public opinion is changed in a free society, and how changes in public policy, which reflect the aspirations, values, and desires of the people, come about.

Lee Hamilton, former U.S. Congressman from Indiana, puts it this way in his foreword to our book:

> *"Despite the oil shocks of the 1970s, the Persian Gulf war, and numerous other energy-related problems that have faced the country, America has failed to develop a comprehensive, effective, and sustainable energy policy. . . .*
>
> *"The insatiable American appetite for fossil fuels creates numerous problems: it increases pollution, contributes to global warming, subjects us to major price fluctuations, and makes us dependent on imports from other countries. . . .*
>
> *"Our dependence on imported oil complicates U.S. foreign policy. For instance, it has a major influence on American policy in the Middle East. Since we do not have nearly enough oil within our borders to meet our demand, we rely heavily on imported oil from the Middle East, which is home to roughly two-thirds of the world's proven oil reserves. This is why every U.S. president refers to the American interest in access to Middle Eastern oil as vital. That vital interest forces us to look at issues that are difficult enough on their own – such as the Israeli-Palestinian conflict, our policy toward Iraq, and our complex relationship with Saudi Arabia – through the lens of our oil needs."*

A provocative idea, related to what Lee Hamilton says, what was presented at the Athens, Ohio conference last summer by Michael Klare, who holds a joint appointment as Professor of Peace and World Security Studies at Amherst, Hampshire, Mount Holyoke, and Smith Colleges and the University of Massachusetts at Amherst. He pointed out that present U.S. energy policy is not designed to decrease U.S. dependence on foreign oil but to *increase* it – by ~40% by the year 2020. In other words, present U.S. energy policy is designed to *sustain* the U.S. addiction to oil and dependence on imported oil. This has immense foreign policy implications, because we don't have nearly enough oil within our borders to meet our needs, and much of foreign oil is in unfriendly countries.

An Overview of the Course

Fig. 2 – Table of Contents

Our basic text, *Energy: Science, Policy, and the Pursuit of Sustainability*, is divided into two parts:

- Part I defines the energy problem – the challenges the world faces in trying to meet its future energy needs in environmentally acceptable ways.
- Part II is about how society is responding to these challenges.

PART I.

Chapter 1
Rules of the Game

Fig. 3 – Crowded planet and Candle

- Root cause of world energy problems is growing world population and energy consumption per capita.
- World population

today?	6 billion
when you were born?	4.8 billion
when I was born?	2 billion

- How many people can the earth support? Experts don't agree.
  - ✓ Some think the world is overpopulated today.
  - ✓ Most experts put the earth's long-term carrying capacity somewhere between 4 and 16 billion.
  - ✓ World population is currently a little over 6 billion, and will almost certainly grow to 8-9 billion, and possibly to 11-12 billion, by the end of the 21st century.
  - ✓ The current world population growth rate is 1.5%/yr corresponding to a doubling time of 47 years. [Rule of 70] If this growth rate continues, we will reach 12 billion by the year 2050 (when you're my age).

Fig. 4a – Work = Force x Distance

- To understand the "Energy Problem," the first thing we need to know is *what energy is and what the basic laws of nature that govern all energy transformations are*. This is what Chap. 1 is about.

> I'm going to skip over this for now, because this is something I would like some of you to write papers on and explain to the class. You should study this chapter carefully, because if you don't you won't know what the rest of the course is about.

Work done to lift cart. Energy from food or fossil fuels (if an electric motor is used) is required to do this work: energy used = work done.

Fig. 4b – Gravitational Potential Energy

- Gravitational energy = work done = energy used up by the attendant or electric motor.

Fig. 5 – Kinetic energy

- Transformation of potential → kinetic energy

Fig. 6 – Conservation of energy

- Neglecting friction, the cart oscillates back and forth indefinitely with Total Energy = constant.

- This is the First Law of Thermodynamics. Energy can be transformed from one form to another but is not created or destroyed: the total energy remains the same – is conserved. First Law = principle of conservation of energy.
- The first of two operating principles that constrains how we use energy.

Fig. 7 – The degradation of energy

- In real life there is friction.
- Which produces heat (and sound that ends up as heat) which is dissipated into the air, never to be recovered.

Fig. 8 – Irreversibility of energy degradation

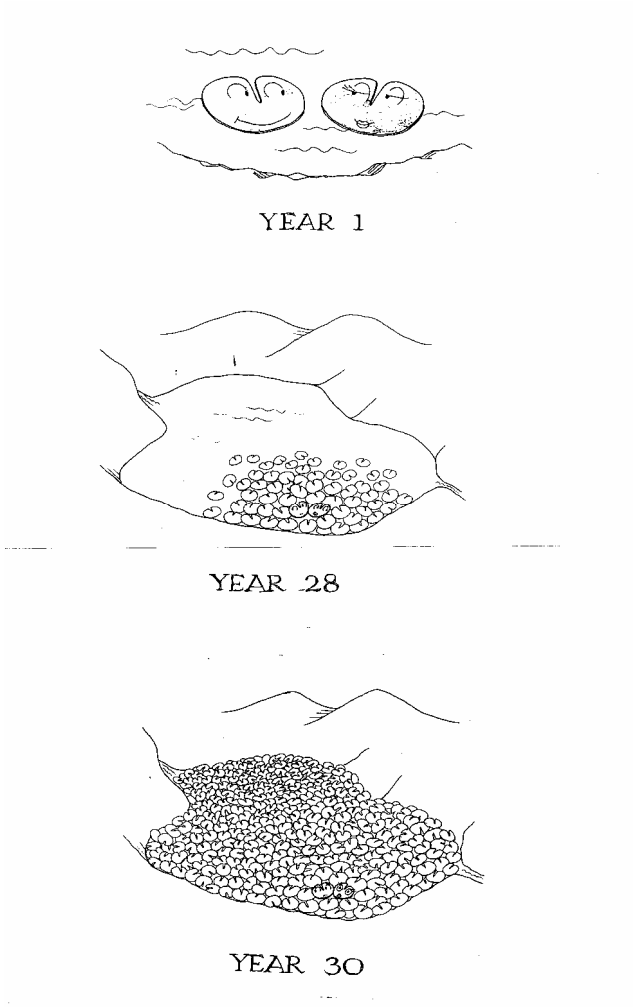
- The cart finally comes to rest at the bottom of the track with all its initial potential and kinetic energy transformed into heat.
- Irreversibly. The dissipated heat energy can never be recovered to do useful work.
- The only way to get the cart going again is for the attendant (or the electric motor) to do more work, and that requires more energy input from food (or coal).
- This an illustration of the second operating principle that governs energy transformations, which is known in phyiscs as Second Law of Thermodynamics. It says that in all physical processes such as this, **useful** energy (energy stored in food or fossil fuels) is transformed into **useless** energy (heat), **irreversibly.**
- When you drive your car, chemical energy stored in gasoline $\rightarrow$ KE $\rightarrow$PE $\rightarrow$ Heat when you put on the brakes and stop. Then, more gasoline has to be used up to get started again. You cannot reuse the heat energy that's generated when you put on the brakes to move the car. The usefulness of that energy is irreversibly lost when you put on the brakes.
- What the industrialized world is doing, in general, is rapidly converting energy stored in fossil fuels (useful energy) that took millions of years to form, into heat (useless energy) in a matter of a few centuries. We're not using up energy (the total energy including heat is conserved), but we're using up **useful** energy.
- So, now you know the 1^{st} and 2^{nd} laws of thermodynamics (**thermogodamnics** as they're often referred to by freshman physics and chemistry students) and needn't be afraid of those words anymore.

Fig. 9 – Exponential growth

- The rest of the Chap 1 is about so-called **exponential growth,** which is the same thing as growth at a **constant percentage rate**.
- Growth of a few percent per year doesn't sound like much – it sounds like a reasonable goal for a business or community. But *continual* growth of this kind of **population** or **non-renewable resource** consumption is *not sustainable* and can lead with surprising quickness to serious problems.
- It's the kind of growth one typically has when resources are abundant and demand is high, but it can never be sustained indefinitely.
- It's important to understand the nature of **exponential growth** in order to anticipate and adjust to the limits of growth, which can occur with surprising suddenness.

I'd like someone to report on exponential growth and why this is such an important thing to understand, so I won't say more about now.

Fig. 10 – Lily Pads



- This cartoon illustrates a feature of exponential growth for the case of **lily pads** growing on a lake.
- Suppose we start with one lily pad and that the number doubles every year: 2, 4, 8, 16, . . . The number of lily pads on the lake reaches 2^{30} after 30 years, which is a little over 1 billion and enough to cover a lake with an area of several square miles.
- Notice how exponential **sneaks up** on you – going unnoticed for more than a quarter of a century, and then overwhelming the lake in just two more years.
- A visual aid to remembering the nature of exponential growth: two happy lily pads with the whole lake to themselves, unaware of any population problem for 28 years, and then suddenly trapped in an overgrown lake with not enough nutrients to live on and no space to expand into. This is a very common biological phenomenon (e.g., bacterial growth in a bottle or the body).

Policy makers, and the general public in a free society, must understand the key ideas in Chap. 1:

1. the **first and second law of thermodynamics,** and
2. **exponential** growth

Understanding them is vital to developing sound energy policy and ways of life consistent with long-term energy sustainability.

Chapter 2
World Energy Needs and Resources

Fig. 11 – 10% of oil moves the car

- Chap. 2 is on World Energy Needs and Resources. I'm often asked what are the most important things that you and I can do **personally** to conserve energy and protect the environment.
- My answer is to first think about your car – its gas mileage and how you use it, because this is the single most wasteful way most of us use energy.
- Only 10% of the energy in oil removed from the earth goes into moving the car. The rest is lost along the way in transportation, refining, friction and engine inefficiencies.
- The second thing to think about is how you use energy in your home:
  - ✓ how well insulated the house is, and
  - ✓ the major electrical appliances that you use, which are (in terms of energy consumption) the refrigerator, hot water heater, air conditioner, and clothes drier.

> There's lots of good stuff in Chap. 2. This is where you'll find the *numbers* on future world energy needs and resources that you need to know in order to defend you position on energy and environmental issues. This chapter could be a good starting point for some of your papers.

Chapter 3
Environmental Impacts of Energy Use

Fig. 12a – The fossil fuel energy cycle.

- An important thing to remember, which is the main point of Chap. 3 on the Environmental Impacts of Energy Use, is that there is no such thing as a "clean" energy source. All energy sources have environmental impacts of one kind or another. This illustration shows what some of them are for the **fossil fuel cycle**: strip mining, spills during fuel transportation (illustrated here for coal but more serious for the case of oil tankers), air pollution, acid rain, CO_2 production, and global warming.
- For **nuclear** energy the environmental impacts are different.
- Even **renewables**, such as solar and wind power, have problems resulting from the relative diluteness of these energy sources. Large areas are required to collect substantial amounts of solar and wind energy.

Fig. 12b – Switching on a Light

- One thing I hope you'll remember from this course is the fact that every time you switch on a light bulb or an electrical appliance in your home, some extra coal has to be shoveled into a power plant somewhere to generate the electricity.
- Or a nuclear power plant has to be cranked up a little; currently about 20% of our electricity comes from nuclear power – the rest mainly from coal.

This is an example of the importance of increasing public awareness of energy issues.

Fig. 13 – Mix of world energy sources

- **To sum up Part I of our book**, this figure shows a possible scenario for how the world might meet its energy needs during the 21st century.
- Currently, the world gets about 85% of its energy from fossil fuels.
- Fossil fuel resources will decline substantially in coming decades while the demand for energy continues to climb due to increasing world population and energy consumption per capita.
- Making up the difference between energy demand and what fossil fuels will be able to supply will require extensive development of alternative energy resources, the most important of which are shown here.
- We're entering a **multi-energy** era.

Meeting world energy needs over the present century is a daunting challenge in itself, but is only **half** of the energy problem.

The other half of the problem is how to do this without doing *intolerable and irreparable damage to the environment*.

The technological challenges are enormous, and it's perfectly clear that there is *no purely technological solution* to the world energy problem.

Truly *long-term* energy and environmental sustainability will require world-wide social, cultural, and institutional changes as well.

These are the problems that are addressed in Part II of our text: chapters 4 – 7.

PART II.

Chapter 4
Culture and Energy Consumption

Understanding the social, economic, and political determinants of energy consumption is essential for the development of effective energy policy. Policies that don't take into account cultural customs and experiences are likely to fail.

Those of you interested primarily in the environmental consequences of excessive consumerism may find this chapter a good starting point for papers.

One of the interesting ideas in this chapter has to do with how **wants** get converted into **needs**.

Fig. 14 – Wants → Needs

- For example: When I was growing up, home air conditioning was uncommon, even in the south.

> I went to graduate school at Rice University in Houston, TX where it is hot and humid. During WWII, soldiers in training got hardship pay for being stationed there. The only two buildings on the Rice campus at that time (1950-54) that were air conditioned were the main library and the lab where I worked. All the classrooms and dormitories were not, and air conditioning in cars was uncommon.

- Now, air conditioning is viewed by most people, even in the mid-west, as a **necessity** and tends to be overused by people who don't think about where electricity comes from and the environmental impacts of generating it.
- When you're looking for ways to save energy at home, think about
  - ✓ turning up the thermostat in the summer;
  - ✓ using electric fans, which use $1/10^{th}$ as much energy as a window air conditioner;
  - ✓ air conditioning only the rooms where you spend the most time – not the whole house, if you're a small family living in a large house.

Chapter 5
Energy Policy – The Problem of Public Perception

This chapter is about the role of public perception in the development of energy policies.

- The unfortunate need for the perception of a **crisis** in order to get meaningful change in public policy.
- This is unfortunate because if you wait until there is a crisis, it may be too late for optimal solutions, and in some cases hopeless.

> I'm sure that in your reading you'll come across examples of this – historical examples of societies that got caught in a downward spiral that became irreversible. Species extinction is an example of an irreversible ecological change, and E.O. Wilson (a renowned biologist at Harvard) has said this is likely what future generations will least forgive us for.

Fig. 15 – Short- and long-term views

A major problem discussed in this chapter is

- the difference between the politician's and the environmentalist's *time horizons*.
- Science tells us that the most serious environmental problems – such as global warming and species extinction – are **long-term** problems, whose solutions, in time to avoid catastrophe, require looking far ahead, which politicians (and to a lesser extent economists) tend not to do.

> I would love to see some papers on what to do about this problem.

Chapter 6
Economic Growth and Sustainability

This is the most technical of the chapters in the second half of the book on the human dimension of energy and environmental problems, and I hope some of you will be interesting in looking into them in some depth, using this chapter as a starting point.
This chapter was written by a neo-classical economist, who believes in *changing* existing economic policies in the U.S., and other capitalist countries, to make them work better – rather than abandoning capitalism.

One of the main points made in this chapter is that the prices we pay for things we buy over the counter don't include the full social and environmental costs (so-called **externalities**) of producing the goods and services we enjoy.

Prof. Orr discusses in this chapter ways of **internalizing** the full social costs of energy, material, and environmental resources basically through the gradual implementation of **incentive taxes –** as **substitutes** for other kinds of taxation so as not to increase the total tax burden on society.

Fig. 17 – Wealth is whatever people value

A major point Prof. Orr makes has to do with how to reconcile the economic and scientific world views.

The business world likes *growth* – the more the better. At first glance, steady economic growth on a planet with finite resources sounds like an **oxymoron**.

The KEY IDEA in Chap. 6 (perhaps the most important idea in the whole book) is that economic growth is sustainable only if

> *the historic connection between economic growth and growth in resource consumption and environmental pollution is broken.*

The extent to which this connection can be broken is the **sustainability question.** At the present time, there is little indication that the world is making any headway toward breaking this connection.

The U.S. is one of the main culprits. Just walk into K-Mart and look at all the stuff, most of which is what people *want* but don't *need*.

Chapter 7
Protecting Future People – The Motivation Problem

The final chapter on moral issues underlies the whole book and in some ways should come first, because if you don't *care* about our legacy to future generations, why worry about what we're doing to the planet. Things probably won't get so bad during your lifetime that you won't be able to survive.

There are two moral questions:

1. Why should we care about future generations?
2. What in human nature can be drawn upon to motivate people to do what morality requires?

Prof. Care addresses in this chapter the second of these two questions: what in human nature can be drawn upon to motivate people to place burdens on themselves in order to enhance the welfare of others who are remote in place or time?

Some philosophers are not very optimistic. For example, Robert Heilbroner in *An inquiry into the Human Prospect* (Norton Press, 1975) says:

> There seems to be no hope for rapid changes in the human character traits that would have to be modified to bring about a peaceful, organized reorientation of life styles. . . . Therefore the outlook is for what we may call "convulsive change" – change forced upon us by external events rather than by conscious choice, by catastrophe rather than by calculation. . . Nature will provide the checks, if foresight and "morality" do not. . . . Nor is it easy to foresee a willing acquiescence of humankind, individually or through its existing social organizations, in the alterations of lifeways that foresight would dictate. If then, by the question "Is there hope for man?" we ask whether it is possible to meet the challenges of the future without the payment of a fearful price, the answer must be: No there is no such hope.

This is a troubling view, to say the least. Prof. Care is somewhat less pessimistic. After analyzing the usual motivations that come to mind, such as love and concern for other people, a sense of community, and a sense of extended shared fate, and concluding that these types of motivation are unlikely to work well for people distant in time and place whom we can never know, Care turns to an analysis of what he calls the *motivational power of novel ideas.*

Fig. 18 – The power of novel ideas

He gives two examples of what he means by novel ideas – ideas that were once novel but are now common place.

1. The first is the **egalitarian** moral idea – the idea that all persons have certain "natural rights" or "basic rights" and are thus morally on a par with one another. At one time, this idea was novel, but over time it caught on and became

motivating. Now, to us, it is not novel at all; we are used to it and it has a profound effect on how most people conduct their lives.

2. The second example is the idea that **poverty** is not a natural state that some members of society must be in but is instead a function of economic, political, and legal systems. The idea of poverty as a conventional rather than natural state was novel at one time, but over time it "took" – that is, it caught on and became motivating – and now is not novel at all to most people. When we see poverty, we are troubled by it.

Prof. Care suggests then that the solution to the *future-generation motivation problem* may be an idea that's familiar to theorists in environmental ethics but that is not yet operative among people generally.

Care's view is that the environmental crisis we face today calls into question our sense of the relationship of human beings to the rest of nature. The kind of environmentalism that's needed, he suggests, is not just a general prudence regarding the environment that permits us to continue to think of our relationship to the rest of nature in anthropocentric terms.

What's required, Care believes, is something more – a new and widely accepted "environmental ethic" or "ecological conscience," which he suggests may be the next step in the social evolution of humankind required for long-term environmental sustainability.

> I hope some of you have a philosophical bent and will be willing to tackle these moral and ethical issues. Why should we worry about future generations? If what is needed to save the planet is a new "environmental ethic," what will bring this about?

Figure 19 – Ignored Alarms

Lee Hamilton points out in his foreword that the U.S. lacks a comprehensive energy policy that will "maintain our way of life, preserve the environment, and provide security for future generations."

> Are these three conditions self consistent? Would it be possible, or environmentally acceptable, for everyone in the whole world to live the way we do, and simultaneously preserve the environment and provide security for future generations throughout the world?

If changes in American lifestyles are going to be required, what will bring them about?

I've discussed our book before a number of civic groups, both in Bloomington and elsewhere, and this is what I find people least willing to talk about – the personal changes, or sacrifices, that may be required to get the world on a more sustainable path. There is an organization in Bloomington called "Sustainable Living" that some of you may want to look up. I can give you the contact person, if you're interested

M**ajor crises** may be inevitable, as Prof. Baker points out in Chap. 5. I hope not, and that's my motivation for teaching this course.

The problem is that the signals of an impending **energy crisis** aren't currently loud enough to generate the necessary public concern.

One of the aims of this course is do something about this – through the exponential growth of new *ideas*.

Sustainability

I would like to end by going back to the title of our book, "Energy: Science, Policy and the Pursuit of Sustainability," and explaining what "sustainability" means – what it is that we're pursuing.

Sustainability is a somewhat vague term, and its definition is not always clear.

The most widely accepted general definition of sustainable development is that given by the United Nations' World Commission on Environmental Development:

> *Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*

The physicist Nobel Laureate Murray Gell-Mann offers the following definition of sustainability:

> *The achievement of quality of human life and of the state of the biosphere that is not purchased mainly at the expense of the future. It encompasses survival of a measure of human cultural diversity and also of many of the organisms with which we share the planet, as well as the ecological communities that they form.*

An economist's definition of sustainability is given in Chapter 7:

> *The preservation for future generations of a set of economic and social opportunities that are at least as rich and diverse as our own. It is not a goal so much as a process of continuous change and adaptation.*

Working toward a sustainable future is best viewed as a continuous process of adaptation to changing circumstances. Sustainability is an elusive goal that we pursue but never fully achieve – like many other things in life, such as the pursuit of happiness.

It's up to each generation, therefore, to head in the right direction and then to *pass the baton* to the next generation.

What is the right direction? Some general goals for the world in the 21st century are clear. They include

- vast improvements in the efficiency with which we use energy;
- accelerated development of alternative energy resources to replace fossil fuels – including the technology required for them to meet acceptable environmental standards;
- reduction in energy use per capita – especially in the developed world;
- stabilization of world population with smaller per capita energy use than has been required historically in developed countries.

Are we headed in the right direction?

- Gas mileage of automobiles (including SUVs and trucks) has gone **down**, not up, in recent decades.

> What about hybrids and hydrogen fuel-cell automobiles? These would be a great paper topics.

- The United States is trying to solve its oil problems by more drilling in the U.S. and greater control of foreign oil supplies – rather than by promoting greater energy efficiency, conservation, and the development of renewable energy resources such as solar and wind energy.

> This is a great topic for papers. To what extent can more drilling in the U.S. meet our oil needs? How much oil is there in the Alaskan National Wildlife Reserve (ANWR), and how long would it last if we were to tap this resource? Would the environmental costs be worth it? To what extent is the Iraq war motivated my U.S. oil interests in the Middle East?

- World population is still growing at the rate of 1.5% per year, corresponding to a doubling time of 47 years.

> What can and should be done about this. Another good topic for papers.

It seems the world is seriously **off course**.

Finding the right course is a complex interdisciplinary problem requiring a basic understanding of both the *laws of nature* that constrain our options and the *fundamental moral, cultural, economic, and political principles* that determine how humans behave.

> These are the two things we'll be studying in this course.

The End

In writing the text for this course, we focused on these basic laws and principles, in the belief that a broader understanding of these principles by policy makers and the general public is needed in a democratic society to move us toward a sustainable future.