

# SUSTAINABLE ENGINEERING

PROFESSIONAL ENGINEERING PRACTICE ELG2911 / SEG2911

Dr. Joan Haysom

Solar Project Manager

SUNLAB Solar Research Group

School of Electrical Eng. and Comp. Science

University of Ottawa



uOttawa



uOttawa

# INTRODUCTIONS

---

- About me
- About SUNLAB
- About this talk

# ABOUT ME AND ENGINEERING

Engineering Physics degree (Queens)

Ph.D. Physics (uOttawa) Opto-electronics

Work primarily in industry R&D (14years)

Chipworks - reverse engineering of computer chips

National Research Council - integration of opto-electronic devices

Nortel & Bookham - design and manufacture of lasers and modulators

Group IV Semiconductor - high efficiency solid state lighting on silicon

Presently SUNLAB at Elec. Eng, uOttawa (2.5 yrs)

Management of research team and collaborations

- project with Morgan Solar Inc. on concentrated solar
- project with Hydro Ottawa on standard solar



# ABOUT ME AND SUSTAINABILITY

- 5kW solar installation on my house and a plug-in EV/hybrid car
- Board member of the Ottawa Renewable Energy Cooperative
- Studied Sustainable Development (Royal Roads U, 2008)
- Taught ELG4126 - Sustainable Electric Power Systems
- Lots of outreach:
  - university students
  - high school students visits to uO, mini-courses on solar
  - environmental programs at my children's school
  - community seminars



# UOTTAWA SUNLAB RESEARCH ON CPV

## Current photovoltaic technology

Silicon - has efficiency of 15-20%  
potential maximum ~ 25%

## Our research is on Concentrated Photovoltaics (CPV)

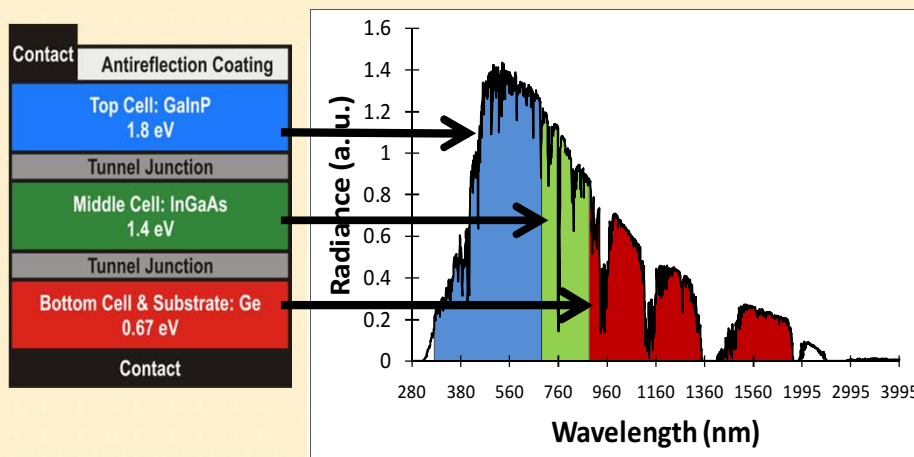
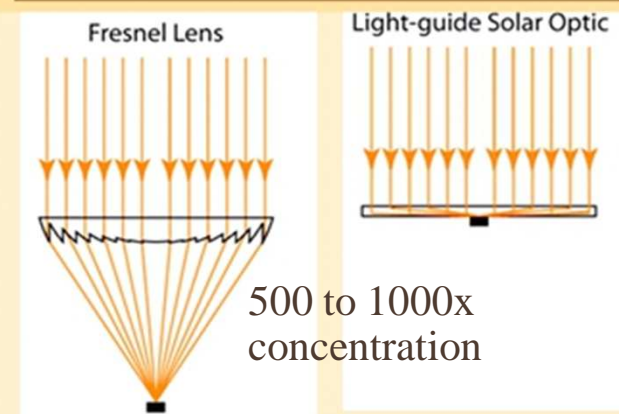
Younger industry, presently achieving ~30% efficiency

Potential to reach 45-50%

### 3. CPV panels on tracker



### 2. Concentration optics



# ABOUT THIS TALK

---

Engineering Ethics

Concepts

Sustainable Development

Industrial Ecology

Tools

Materials Flow and Life Cycle Analysis, Footprints

Complete pricing

Corporate Change

Case Study of Renewable Energies

# ENGINEERING PRACTICE

ENGINEERING PRACTICE

Engineering practice is comprised of a number of important considerations.

- Can we do it?

Technology



- Can we do it at an acceptable price?

Economics



- Can we do it in safe conditions, and will it be safe in the end?

Society



- Can we do it without harming the environment?

Environment



# ENGINEERING PROFESSION

Ontario Professional Engineers Act (2010)

“safeguarding of life, health, property,  
public welfare”<sup>^</sup> or the environment.<sup>^</sup> economic interests,

Can. Eng. Accreditation Board

- expects graduates to understand the impact of engineering on society and the environment, and to demonstrate an ability to analyze social and environmental aspects of engineering activities.

# EVOLVING RECOGNITION OF SUSTAINABILITY

---

Many organizations are going further, e.g.:

- Engineers Canada – 2006 National Guideline on Environment and Sustainability
- American Society of Civil Engineers - Code of Ethics:

“Engineers shall hold paramount the safety, the health and welfare of the public and shall strive to comply with the principals of sustainable development.”

# MOTIVATIONS

---

The industrial products, processes and services that are being developed today will dictate a large fraction of the industry-environment interactions of the next few decades.

Engineers play a major role in these developments.

# CONCEPTS

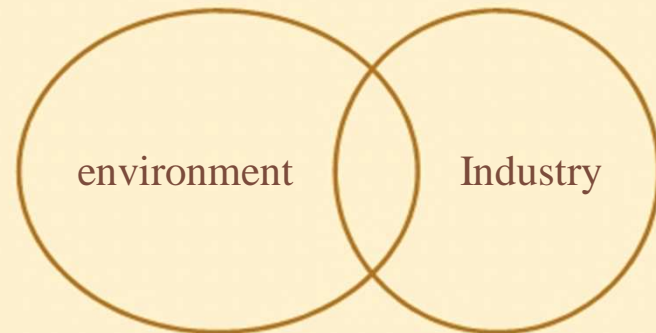
# ENVIRONMENT-INDUSTRY CONNECTION

ENVIRONMENT-INDUSTRY CONNECTION

## Our past view

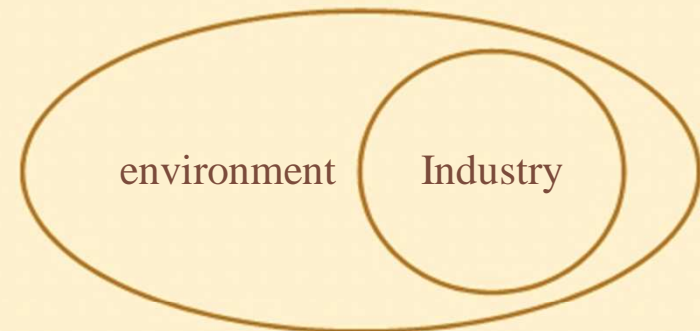
Environment serves industry

It is an infinite source and infinite sink



## Our needed view

Industry must fit within the bounds given by the environment



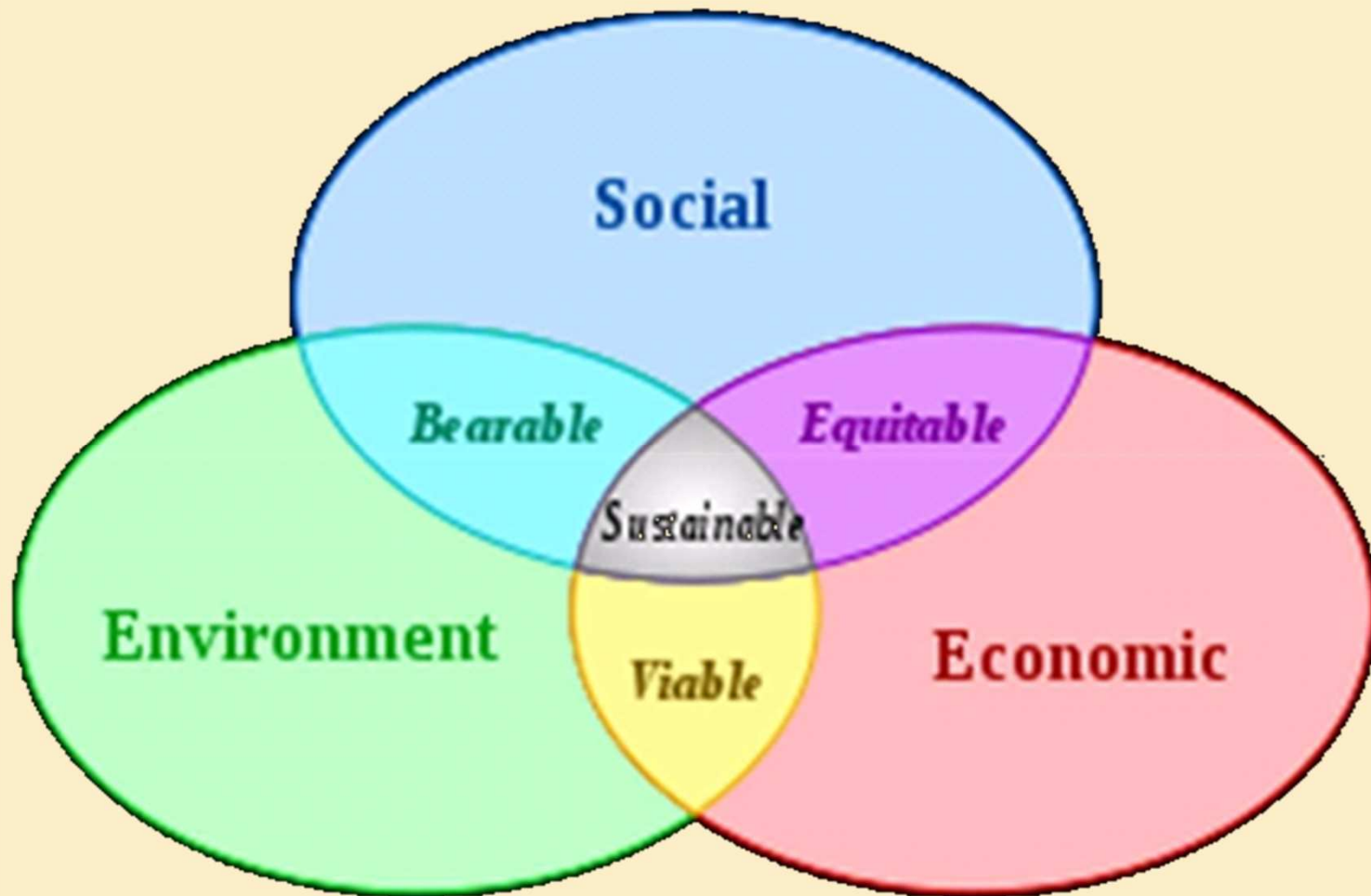
# SUSTAINABLE DEVELOPMENT

as defined in 1987 by the United Nations Brundtland Report,  
"Sustainable development is development that meets the needs  
of the present without compromising the ability of future  
generations to meet their own needs."

---

At United Nations 2005 World Summit further scope wrt the  
"interdependent and mutually reinforcing pillars" of sustainable  
development as economic development, social development, and  
environmental protection.

# The 3 Pillars of Sustainable Development



# WHAT IS TO BE SUSTAINED?

---

Availability of inexpensive stuff?

“good” jobs?

No. Even more fundamental things:

Life support systems (human centered, but includes most facets of our natural world)

For how long?

Now and in the future? forever?

Too vague. Typically 25-50 yrs is used

# WHAT IS TO BE DEVELOPED?

- Economic development - The process by which a country increases its ability to produce goods and services. Traditional figure of merit is growth in the gross domestic product (GDP).
- But now we want to distinguish between
  - Growth = quantitative increase in economic output, and
  - Development = qualitative improvement of the quality of life, now and in the future
- Does Growth produce Development? Not universally.
  - *Economic* growth over the past 50 yrs has not led to the end of inequity.
  - An oil spill, a divorce, and cancer therapy all result in an increase in GDP!

# SUSTAINABLE DEVELOPMENT CAN INCLUDE:

---

- New buildings, infrastructure
- New institutions, organizations
- New services or products
- New processes with improved outcomes
  - (including higher efficiency)

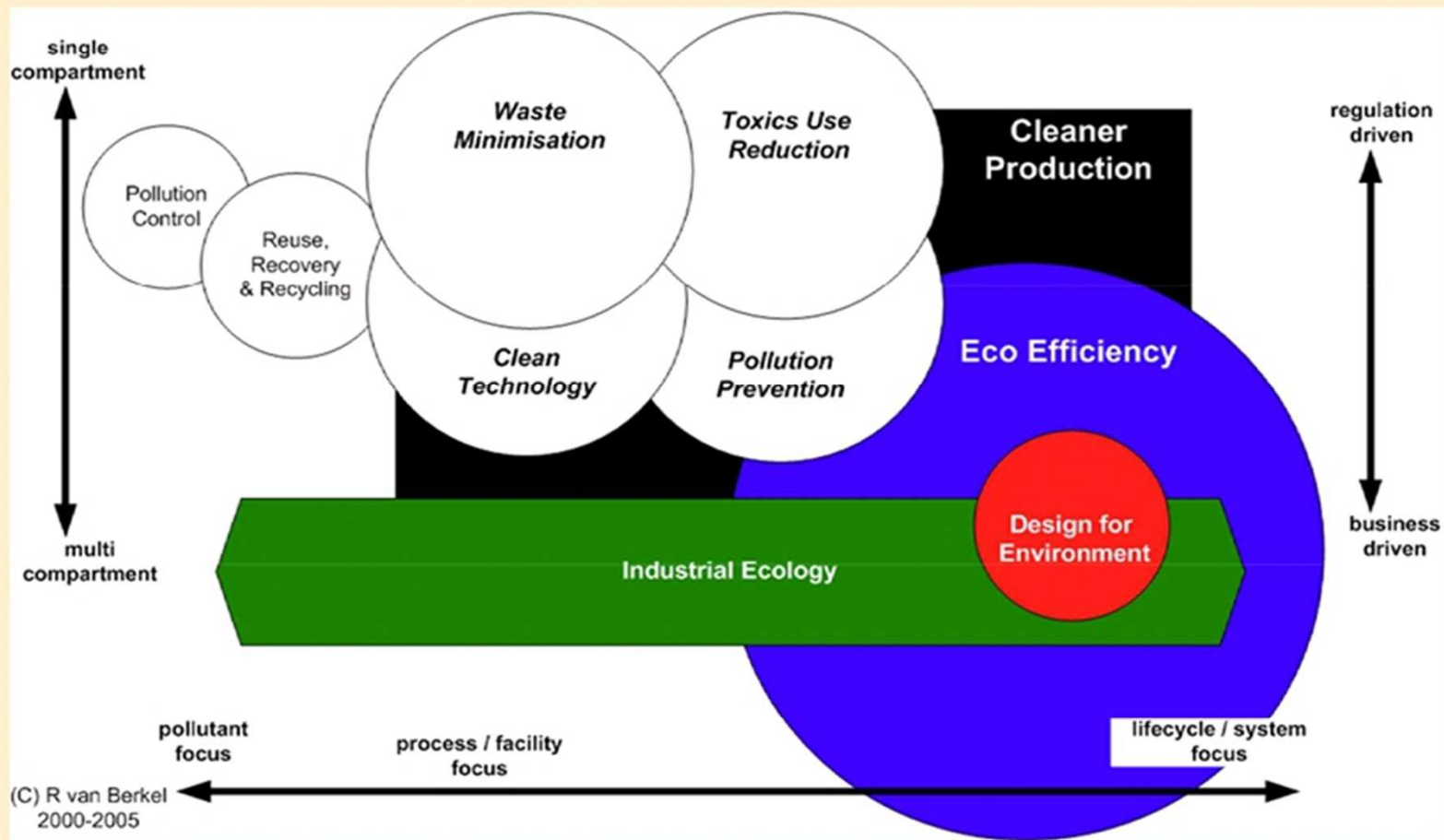
As long as the three pillars are achieved  
Careful though...

# SHIFTING TEMPORAL APPROACH

Activity	Time	Focus	Goal	Corporate View
Remediation (removing toxins from soil)	Past	Local	Reduce human risk	Overhead
Treatment, disposal (proper handling of waste)	Present	Local	Reduce human risk	Overhead (satisfy regulations, avoid lawsuits)
Industrial Ecology	Future	Global	Sustainability	Strategic

From T.E. Graedel, B.R. Allenby Industrial Ecology and Sustainable Engineering, Pearson/Prentice Hall, 2010

# THE REALM OF SUSTAINABLE ENG



# INDUSTRIAL ECOLOGY

Biological ecology is the study of the distribution and abundance of organisms and their interaction with the physical world.

Industrial Ecology is the branch of science that is developing the concepts of the industrial- environment interaction,

Industrial - broad definition here - any human action involving the transformation of materials or energy

Ecology - includes: resource flow, energy use, evolution of entities and markets, growth and decay, production of wastes

Thus Industrial Ecology: is the study of technological organisms, their use of resources, their potential impacts, and the ways in which their interactions with the natural world could be restructured to enable global sustainability.

Engineers are a primary actor that can implement the tenants developed by Industry Ecology

# DESIGNING PRODUCTS

---

## MFA, LCA, Footprints

---

# THE STORY OF STUFF

20 min video outlining the many problems with our linear, consumerism approach

[www.thestoryofstuff.org](http://www.thestoryofstuff.org)

“What percentage of total material flow through this system is still in functional use six months after the product sale?”



- 
- What are some roles that Engineers have in the system of “*stuff*”?

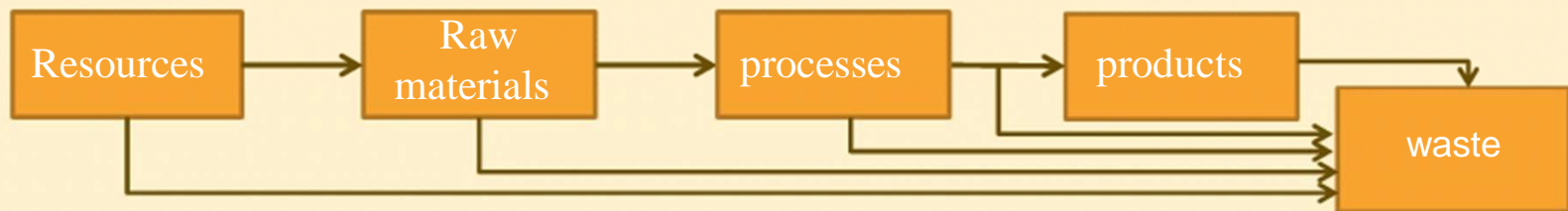
# MATERIALS FLOW ANALYSIS

an analytical method of quantifying flows and stocks of materials or substances in a well-defined system

based on two fundamental and well-established scientific principles:

system approach AND mass balance

Essentially an augmented, accurate version of



# LIFE-CYCLE COST ANALYSIS

Assess environmental impacts associated with all the stages of a product's life from **cradle-to-grave** (i.e., from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling)

Result is a tabulation of inputs and outputs: energy used, tons material used, GHG emission, pollutants...

LCA's can help avoid a narrow outlook on environmental concerns by:

- Compiling an inventory of relevant energy and material inputs and environmental releases;

- Evaluating the potential impacts associated with identified inputs and releases;

- Interpreting the results to help you make a more informed decision

# FOOTPRINTS

Environmental footprint: It is a standardized measure of demand for natural capital that may be contrasted with the planet's ecological capacity to regenerate (generally in terms of area)

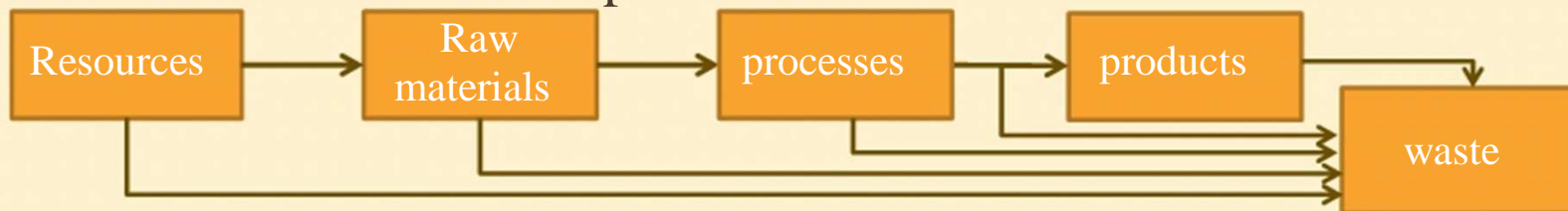
Carbon footprint

Water footprint



# FROM LINEAR TO CYCLIC

Linear: Each step of processing and use creates wastes, which must be disposed of somehow



Cyclic: Waste of one organism becomes the inputs of another



# SHIFTING SCOPE OF ENGINEERING DESIGN

Improved Sustainability



Engineering design

Problem to solve => limited science and/or data to => predict solution using best assumptions => prototypes => refine => product

Calculate wastes and impacts (LCA)

Redesign for lower impact

Develop materials flow cycles within company, industry; turn wastes into products

# COMPLETE PRICING

The price we pay for an item quite often does not reflect the full price to society:

Eg.1 - coal is “cheap” electricity, but results in high environmental damage due to mining and smog-based health care costs

Eg.2 - disposable plastic items don't include environmental pollution effect (man & transpo) and costs of disposal

Examples of how to add *Externalities* into the price

- Carbon Taxes
- Polluter Pays (e.g. Eco-fees on electronics)

---

# OTHER KEY ACTORS

---

Besides Engineers

---

# THE SYSTEMS WE WORK IN

---

Engineers execute in the framework of corporations and economies => we need those players on board too!

# RECENT ADVANCES IN ECONOMICS

- **Ecological Economics**

aims to address the interdependence and coevolution of human economies and natural ecosystems

- **Natural Capital** i.e. value and finite nature of natural resources

- **Human Capital** is the stock of competencies, knowledge, social and personality attributes, including creativity, embodied in the ability to perform labor so as to produce economic value.

⇒ These can be added to the ledger of capital asset analysis of land, labor, and financial capital, and can develop a 'price' of the services

- **Replacements to GDP**

- Happiness index - attempts to measure how well countries use their resources to deliver longer lives, greater physical well-being and satisfaction

# CORPORATIONS

## Recent Advances Corporately:

Corporate Social Responsibility (CSR) weakest: some form of contribution to society

Corporate Sustainability - taking into consideration every dimension of how a business operates in the social, cultural, and economic environment; have Chief Sustainability Officer.

Triple Bottom Line - **people, planet, profit** - business goals are inseparable from the societies and environments within which they operate

Business Ethics - discussion of a professional code of conduct for business people (MBAs)

# THE SYSTEMS WE WORK IN

---

- Concerning Trends
  - Free Trade Agreements dictating control over resources and regulations
  - Corporations that are larger than countries
  - Global companies that come and go at their whim
- One alternative to business as usual...
  - Cooperatives are corporations with a different value set  
=> owned by workers, growth for the workers' benefit

# A LOCAL EXAMPLE...

Allows local Ottawa citizens to invest in clean energy in their city

- 6 solar projects = 330kW = \$1M installed, more projects under development
- 3 of 9 board members are engineers
- Our work is a blend of:
  - Technical
  - Business partnership
  - Investment decisions
  - Community engagement
  - Project development
  - Advocacy

**OREC**  
Ottawa Renewable  
Energy Cooperative Inc.

Home About OREC Projects Membership How to Invest in OREC Why Solar? Contact OREC

### Welcome to OREC - Making Community Power a Reality in Ottawa

The Ottawa Renewable Energy Cooperative provides an opportunity for any resident of the City of Ottawa to jointly own and invest in renewable power generation projects in their community, while at the same time earning a reasonable return on this investment.

If you do not have the ability to own your own solar power system, then OREC provides you with an alternative. OREC pools investment from its members allowing them to invest in renewable energy projects larger than those they could individually own.

As well as providing you with a reasonable return for up to 20 years, your OREC investment puts clean local power into onto the grid and creates local jobs and community development.

For more on how it all works see [About OREC](#) and see [Membership](#) to learn more about the Benefits of Investing with OREC.

[Download the OREC Brochure.](#)

search...  
Search

#### Related Links

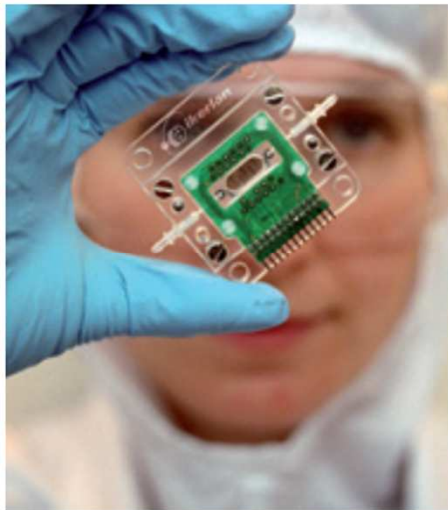
- [OREC on Facebook](#)
- [OREC on Twitter](#)
- [Clean Energy Ontario](#)
- [Stand Up for Solar](#)
- [CanSIA Solar Television](#)
- [1000 Solar Rooftops](#)
- [3i Summit](#)
- [Sustainable Ottawa](#)
- [Ecology Ottawa](#)
- [SLOE](#)
- [SLOWest](#)
- [Sustainable Eastern Ontario](#)
- [OSEA](#)
- [Canadian Renewable Energy Alliance](#)
- [Promising Practices](#)

Provides a opportunity for long term investment in the community  
Earns members a reasonable return on their investment  
RRSP eligible  
Earns revenue from solar projects through 20 year "Feed-in Tariff" power supply contracts  
Puts clean local power into onto the grid and creates local jobs and community development

# MONDRAGON COOPERATIVE GROUP

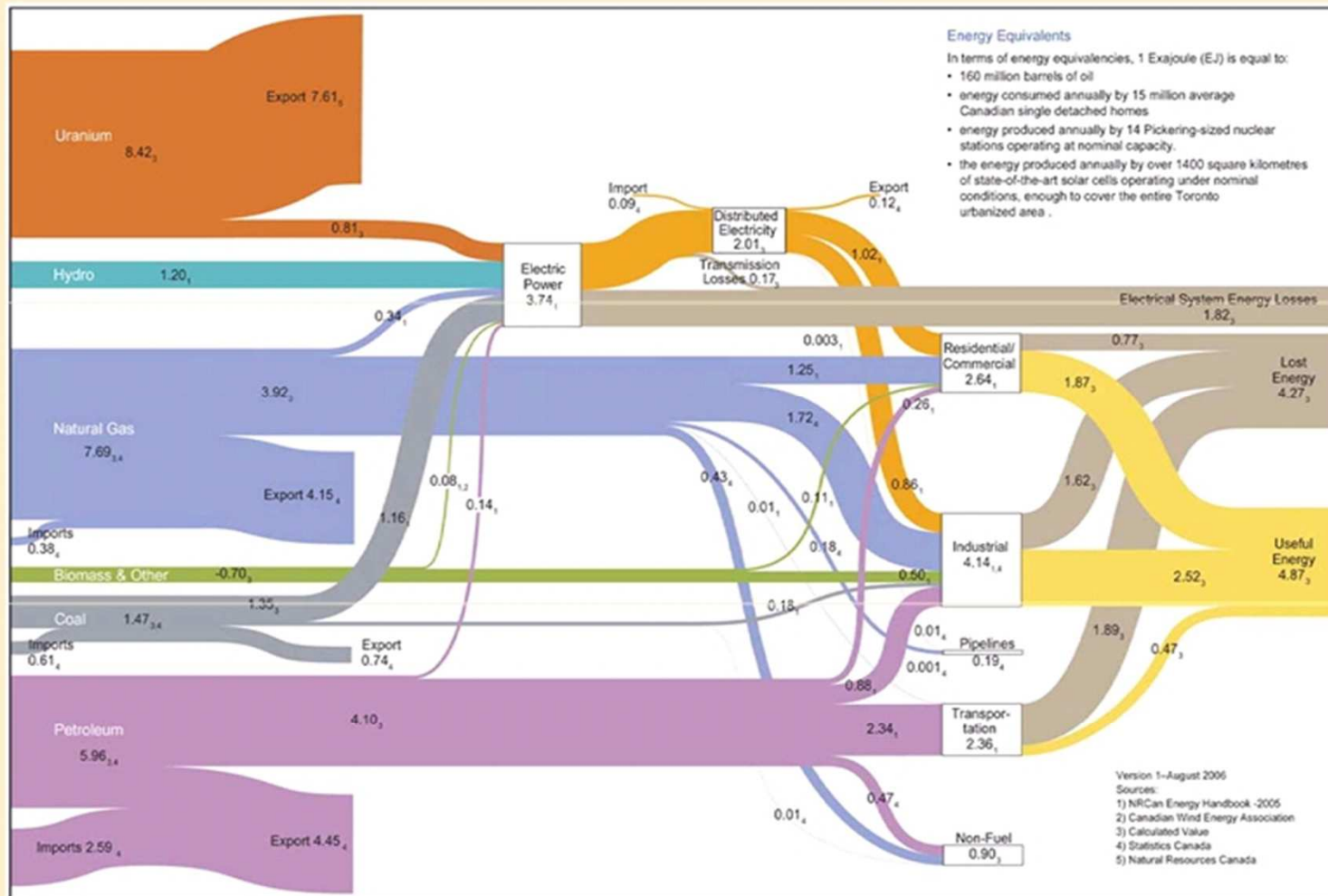
“We are committed to people development and to generating wealth for society through job creation.”

- 56 years old, from Basque region Spain
- Group of 258 companies globally, 14B Euro/yr revenue
- One of most profitable spanish companies, 55% of profit re-invested in cooperative, highest labour productivity, etc
- 5% interest rate paid on member capital



# CASE STUDY: ENERGY

# MFA EXAMPLE 2: CANADIAN FUEL USE BY SECTOR ~2006

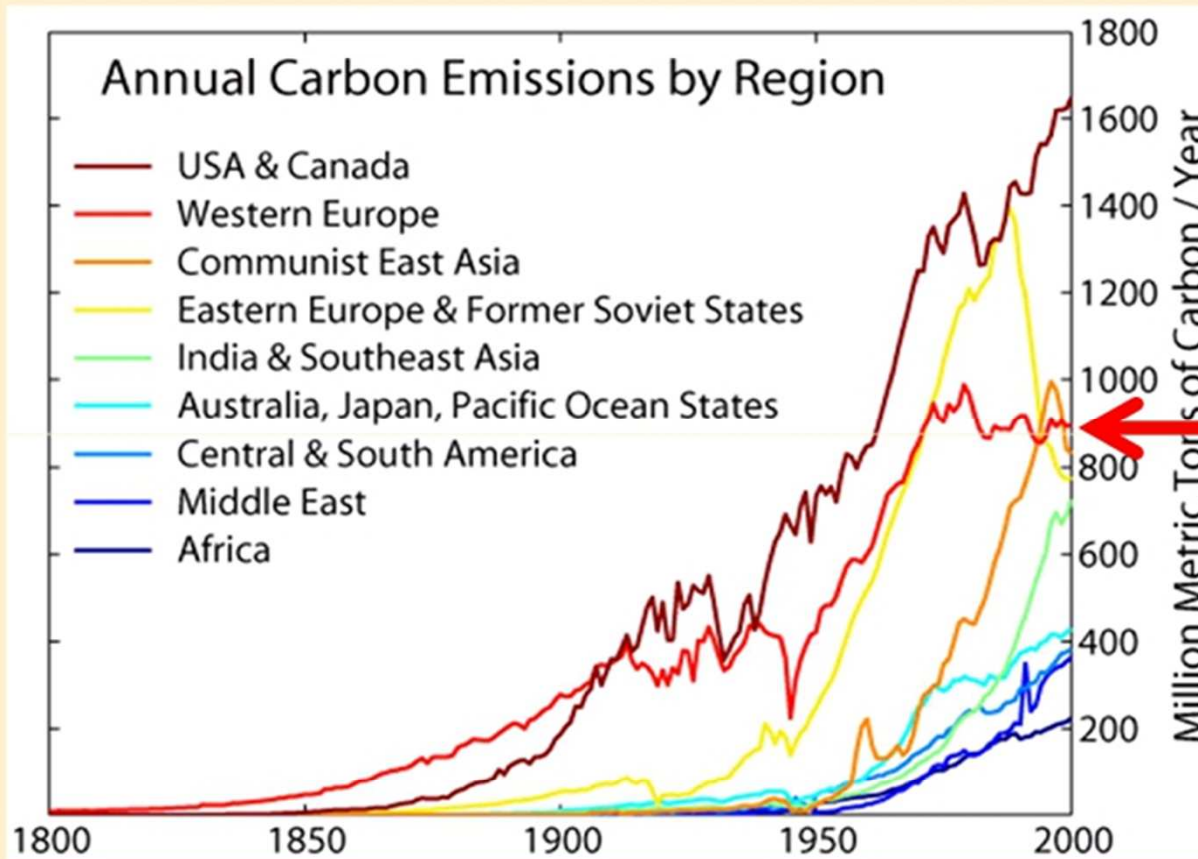


Source: Powerful Connections: Priorities and Directions in Energy Science and Technology in Canada, Natural Resources Canada, 2006.

# CARBON FOOTPRINT

---

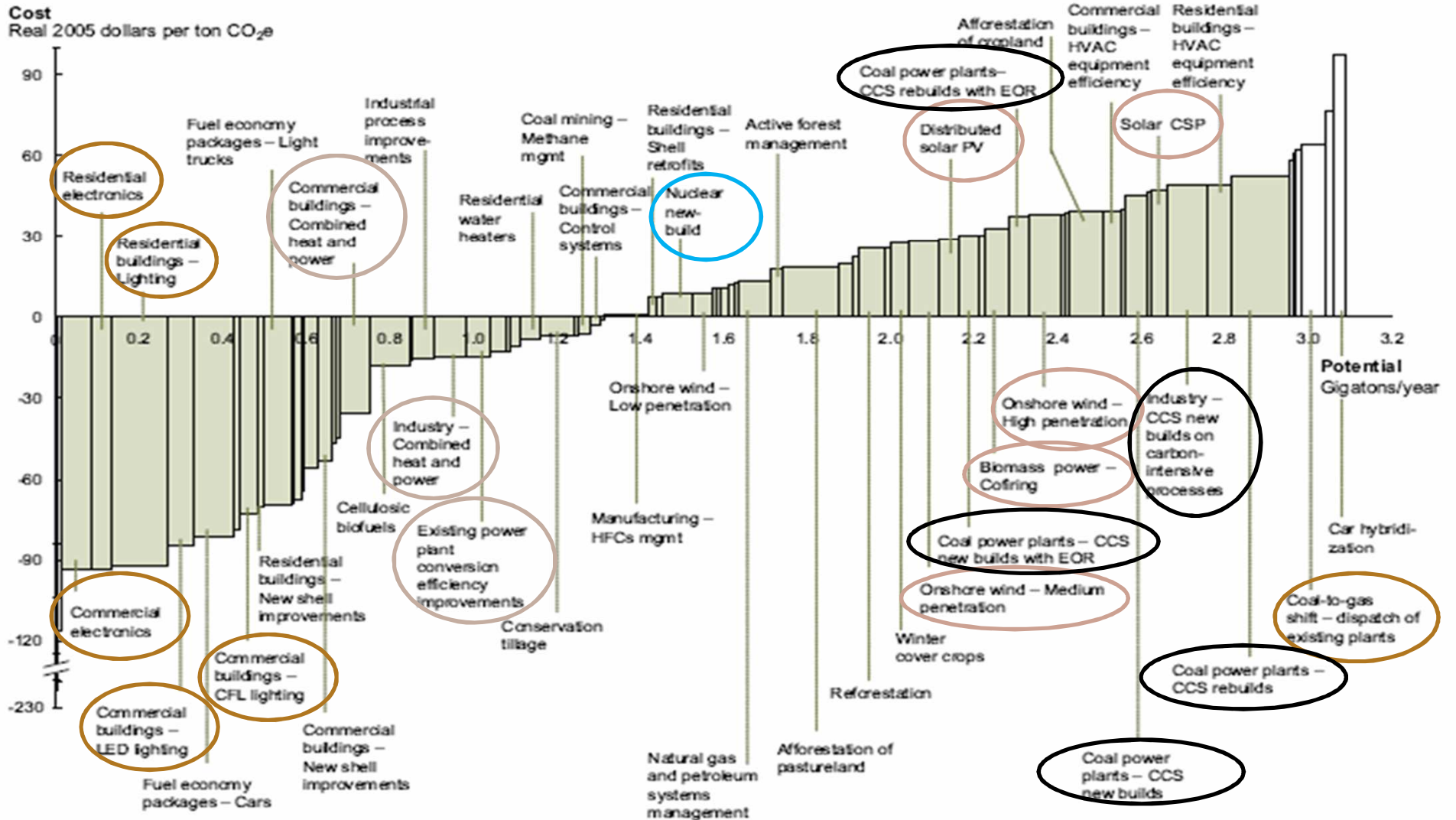
# ANNUAL CARBON EMISSIONS BY REGION



Europe has at least capped its emissions, primarily through energy efficiency

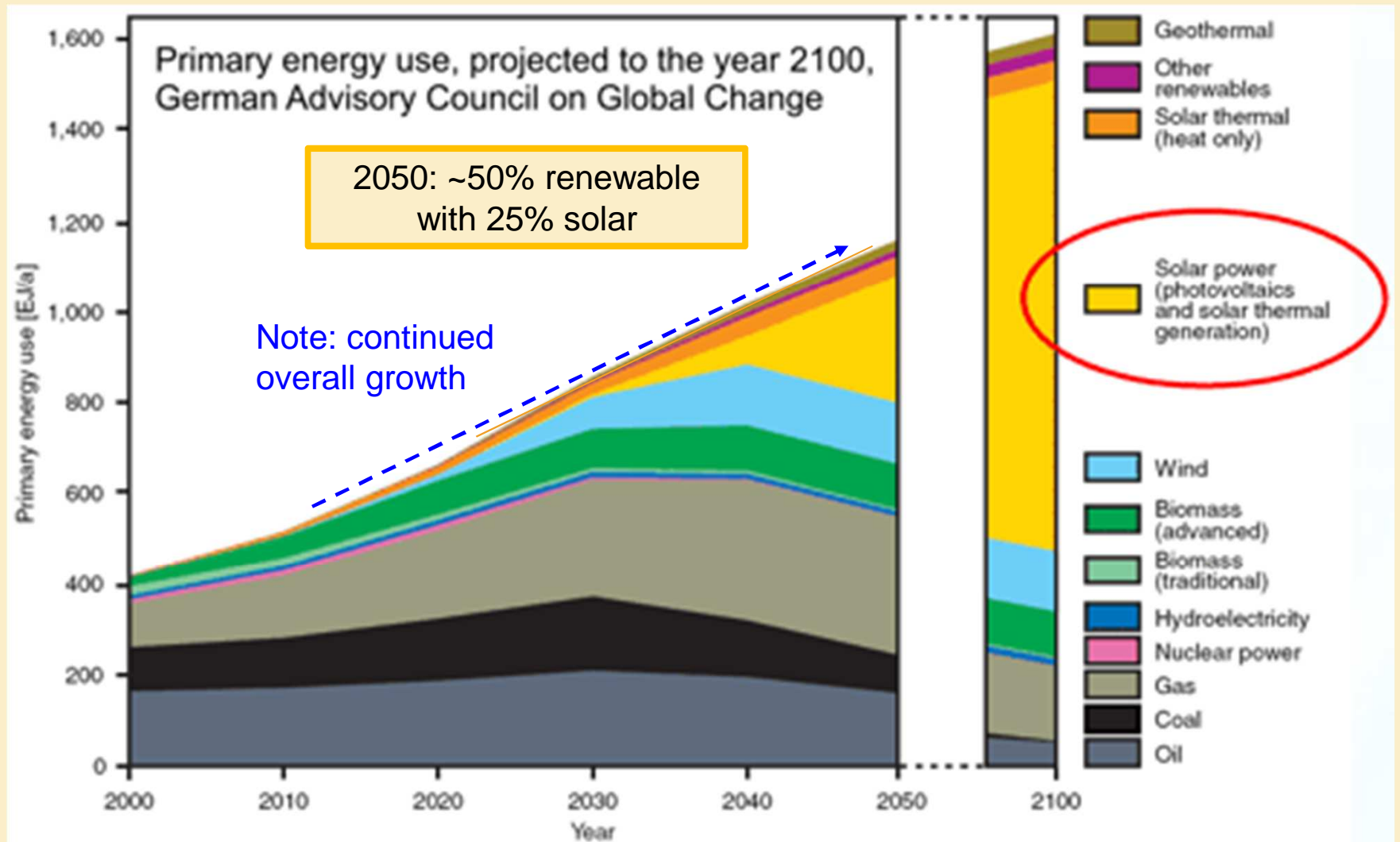
# CARBON ABATEMENT CHOICES

## U.S. MID-RANGE ABATEMENT CURVE – 2030

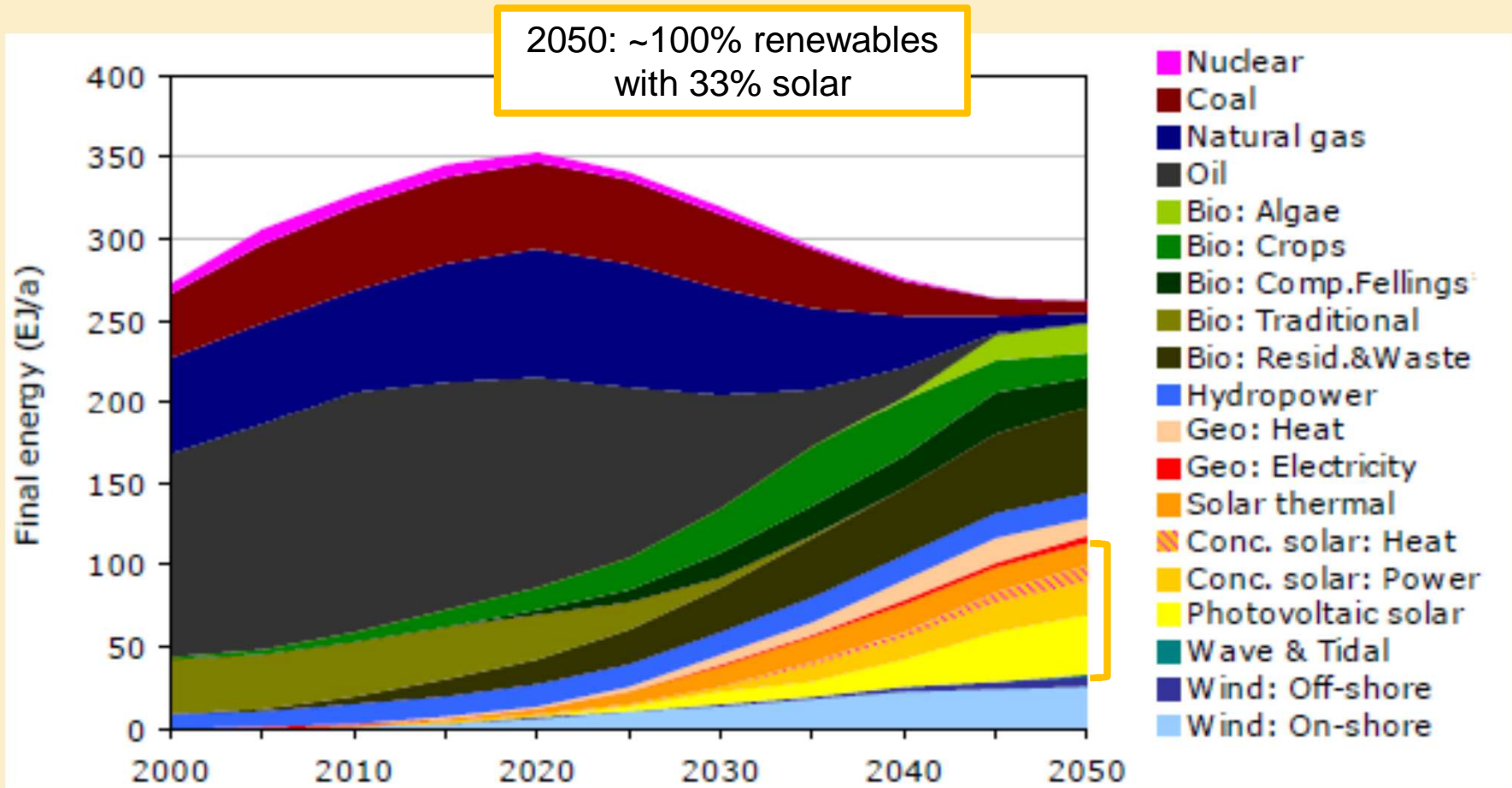


Source: McKinsey analysis

# ADOPTION OF RENEWABLES - MODERATE VIEW



# ADOPTION OF RENEWABLES - AGGRESSIVE VIEW



# DOES RENEWABLE ENERGY = SUSTAINABLE DEVELOPMENT?

---

## Economic

- Installation prices continue to fall, systems currently have a 5-15 year payback (dependent on sun, wind resource) and have a 30+ yr lifetime

## Environmental

- Reduced carbon emission
- Reduce fossil fuel use
- Minor environmental implications (land use)

## Social

- Small, distributed => local engagement, local ownership, local profit

# RENEWABLE ENERGY

---

Can renewable energy technologies be dependable and affordable?

YES, many are today when doing complete cost analysis

Which technology is best?

A integrated combination of them all is required!

Can we build a whole energy system on them?

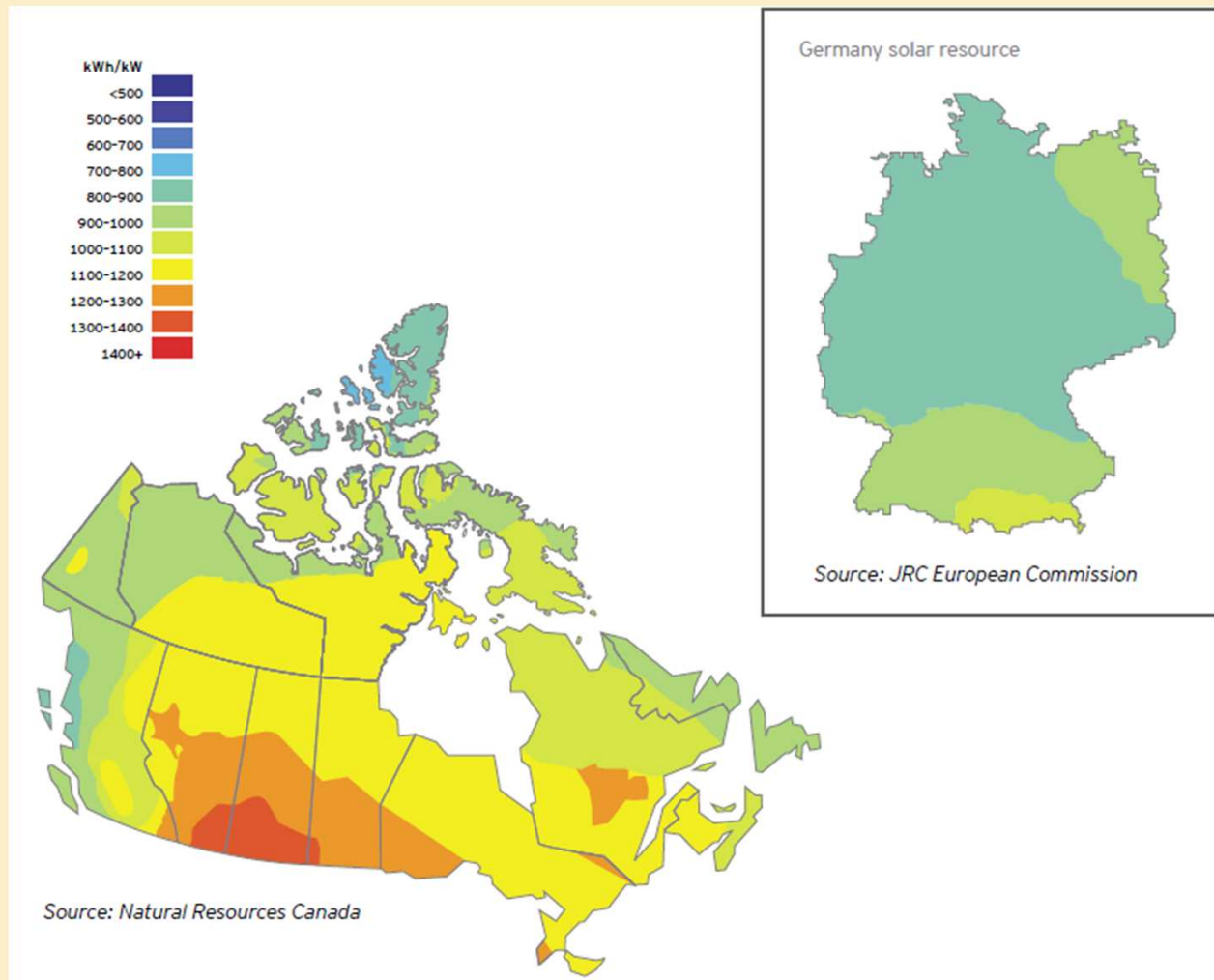
YES - several countries have roadmaps; it's a question of mindset

Germany considers it a task, not an obstacle to move to 0% fossil fuels.

Some innovation in technology required

Significant innovation in policy, implementation

# SOLAR POTENTIAL IN CANADA



- Most of Canada has more sun than Germany (the #1 world leader in PV)
- Ottawa valley very sunny!
- Cooler climate can be a benefit to panel performance

# FEED-IN-TARIFFS (FIT)

Ontario is a North American leader in policy to promote Green Energy Production

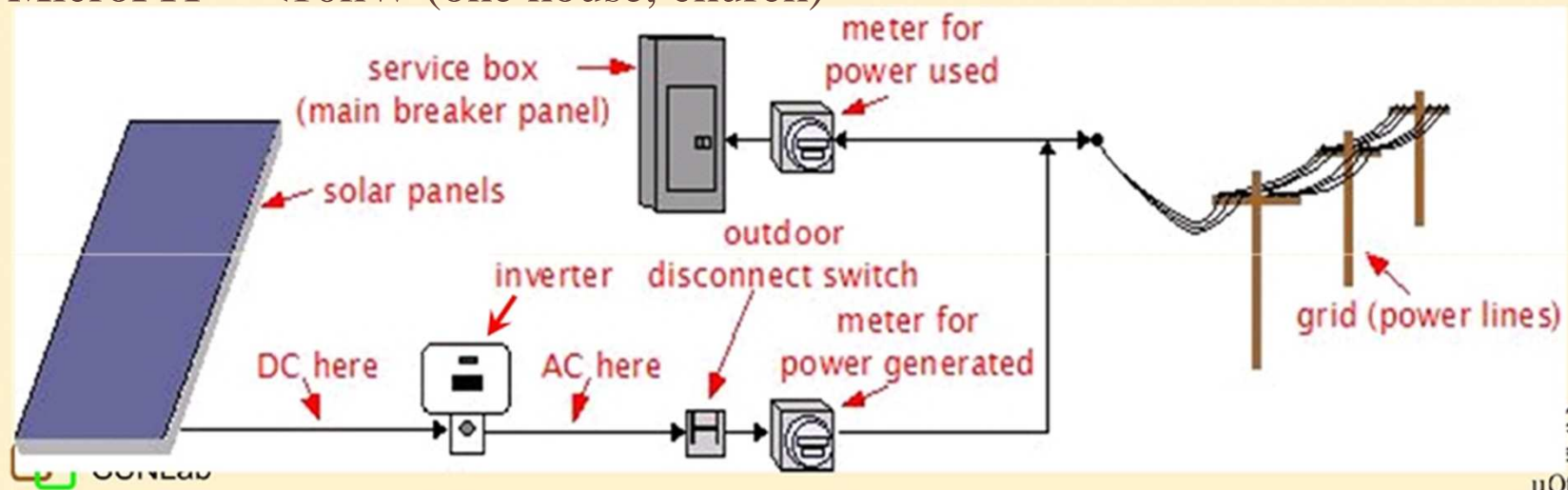
FIT contract gives guaranteed rate paid for energy supplied to the grid over a 20 year term

Large FIT = up to MWs (wind farm, solar farm)

Small FIT = 10-500kW (solar on a sizeable building)

MicroFIT = <10kW (one house, church)

2012 MicroFIT prices		¢/kW hr
Roof-mount solar	54.9	<del>80.2</del>
Ground-mount solar	44.5	<del>64.2</del>
Wind	11.5	<del>13.5</del>
Waterpower		13.1
Biomass		13.8
Biogas		16.0
Landfill gas		11.1



---

# SUMMARY

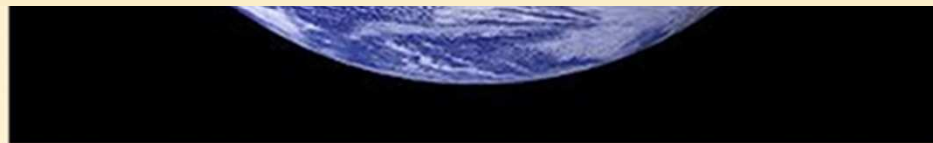
---

# ONE EARTH IS ALL WE HAVE

---



The most unrealistic thing we can do is  
**IGNORE** the **FINITE** nature of our  
resources and the profound effect we  
have on our Earth.



# YOU => SD

---

- What changes will you as an Engineer make happen?
- What are the challenges you might face in your career?
- What changes can you make personally?

# SUMMARY

---

- Sustainability is becoming an integral part of engineering
  - There are many tools developed to quantify impact of products and processes on the environment
  - Efforts required on both small scale (improved products) and big scale (better systems of operating and better economics) to truly get to a sustainable future
  - Understanding the global context and valuing the multidisciplinary nature of the solutions are important
  - Change can happen very quickly when we all move in the same direction

# SUGGESTED READING/WATCHING

“A Short History of Progress”, Ronald Wright - about societal collapses in history (Easter Island, Mesopotamia,...)

“Our Choice: A Plan to Solve the Climate Crisis”, Al Gore - lots of detailed data on large number of technologies

“Powerful - Energy for Everyone”, a film by David Chernushenko - politics of renewable energy and community ownership

“The Story of Stuff”, on-line videos and podcasts

*Anything that inspires you to make change happen, in yourself and in others*

# QUESTIONS?



Dr. Joan Haysom

Solar Project Manager  
SUNLAB Solar Research Group  
School of Electrical Eng. and Comp. Science  
University of Ottawa



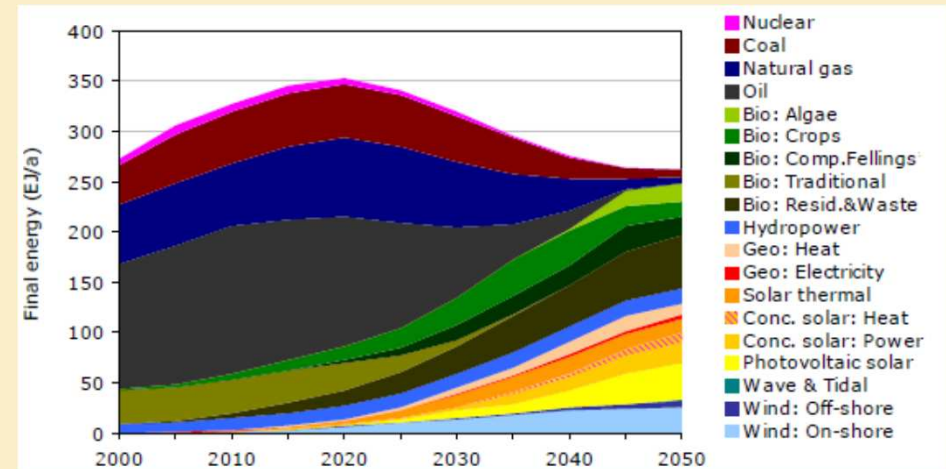
# BACK-UP SLIDES

# CHANGE IS UNDERWAY

1983 – \$4000, just voice, 1 hr talk



2013 - \$400, ...



## Tools at our disposal include:

- data analytics, Terabit PCs, Cloud computing
- Bluetooth, wireless, cell, fiber, cable communication networks
- 60 years of advanced manufacturing
- 50 years of semiconductor development
- Highly educated people who care!

# FEED-IN-TARIFFS (FIT)

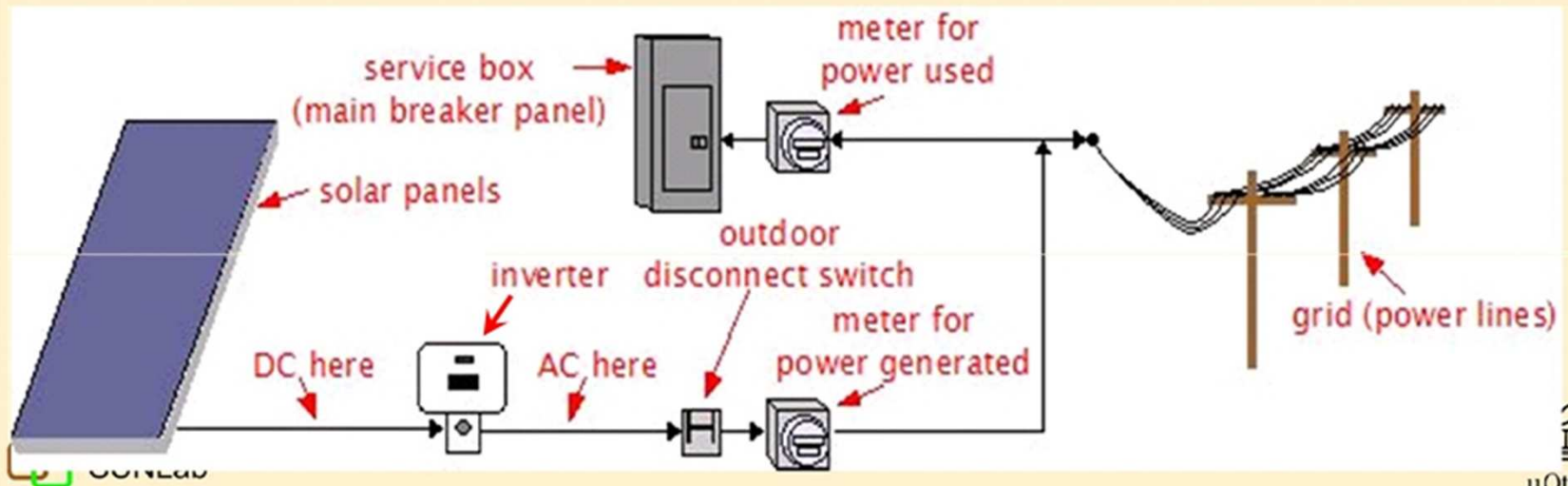
Ontario is now a North American leader in policy to promote Green Energy Production

FIT = guaranteed rates paid for energy produced

MicroFIT are <10kW (one house=2-5kW)

Become a micro-producer: production metered separately from your consumption

Microfit technology	¢/kW hr
Roof-mount solar	80.2
Ground-mount solar	64.2
Wind	13.5
Waterpower	13.1
Biomass	13.8
Biogas	16.0
Landfill gas	11.1



# WHY ARE SOLAR FEED-IN TARIFFS GOOD FOR ALL?

## Because of WHEN

Peak production of solar is on sunny summer days which match nicely our Peak usage (A/C use)

Ont pays >\$1/kW to import electricity on the hottest days

Scalable, quick build times compared with large energy plants  
More predictable than wind

## Because of WHO

Distributed local job creation and modest profitability compared with mega-energy projects where 75% profits leave the country

Ont Green Energy Act set to create 50,000 jobs by 2012

## Because of WHERE

Energy produced where is it used = no transmission system costs or liabilities

## Because of WHAT \$ are saved

Zero capital risk to taxpayers => \$ are for kW generated

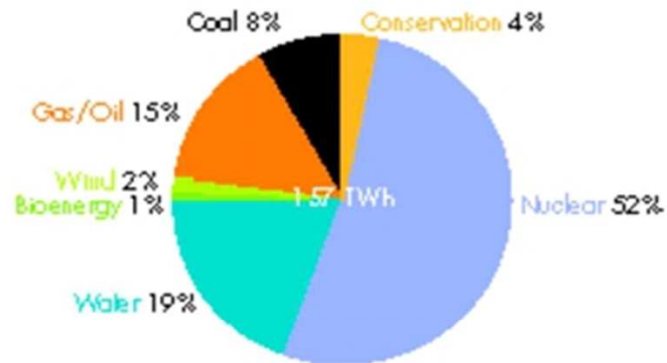
We are still paying debt retirement charges for nuclear plant cost overruns

Zero pollution = lower health care costs

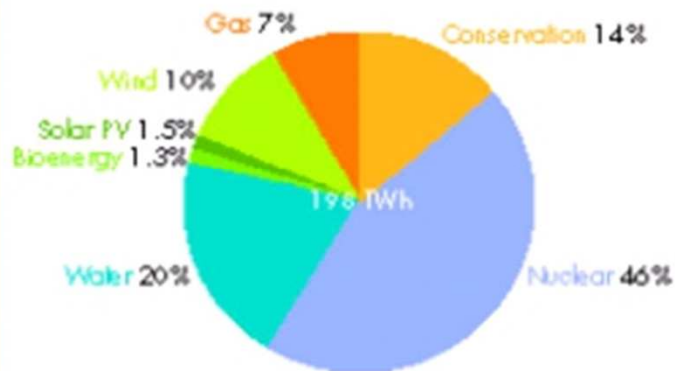
A 2005 study found that the average annual health-related damages due to coal could top \$3 billion for Ontario. Coal will now be phased out by 2014.

# ONTARIO ENERGY SUPPLY

2010 Projected Generation (TWh)



2030 Projected Generation (TWh)



Ontario is moving forward:

No coal by 2014

13% renewables in 2030

Still only 1.5% solar in 2030

1st two year of FIT program had enough applications for 1.5% solar NOW

Compare this with Germany (less sun, more aggressive FIT)

10% renewable now

29% renewables by 2020, with 14% solar