Grid-Connected Solar Electricity

– How to get Started –

Trimline Training Centre

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Questions…?

Next

- Course Contents
  1. Introduction to course
  2. Context to solar electricity
  3. Energy, solar energy – the resources, the technology, how it works
  4. Mounting angles – how important are they
  5. Solar equipment
  6. Costs, economics, rules of thumb sizing
  7. Electricity efficiency
  8. Connecting to the grid
  9. Local examples of solar PV systems
  10. Getting your own PV system, how to find contractors, how to buy

Every great movement must experience three stages:
…ridicule, discussion, adoption.

John Stuart Mill

Intro: My Goals…

- To empower you to get ready
  for the energy and environmental issues coming upon us

- To help you understand
  how solar electricity be used to energise your whole house

- To help you take next steps in using solar electricity
  - to reduce your electricity bills,
  - to reduce your environmental footprint,
  - to increase your energy security,
  - to leave a legacy… so you can look your grandkids in the eye!

- We have done a lot of research for you and have assembled it into one place.

I'd put my money on the sun and solar energy. What a source of power!
I hope we don't have to wait 'til oil and coal run out before we tackle that.

Thomas Edison
(1847–1931)

Intro: Me! ––

- I am a solar system project developer
- I am not an equipment supplier
- I have no vested interest in any technology

- My interest is that you choose wisely
  - with your eyes wide open
  - based on the facts and whether it is right for you or not.

Intro: Your Goals?

- What are your goals?
- What do you want to get out of the course?
- What do you want to achieve by using solar electricity?

The Earth provides enough to satisfy every man's need,
…but not every man's greed.

Mohandas Karamchand Gandhi
(*Mahatma*) India

Intro: What the Course Does…

- NOT a design course… This is an introductory course
- Gives you familiarity with the technology and its terms, concepts, components and costs
- Gives you space to ask questions and get answers right away
- Dispels mis-understanding and myths about solar energy
- Helps you understand how to buy a solar electricity system with confidence

FAST – GOOD – CHEAP

… you are only allowed to choose two of them!

Grid-Connect Solar Electricity – What is it?

- Solar electricity produces electricity from the energy in sunlight.
- This can provide electricity for any use and application.
- Grid-connected solar electricity:
  - when the solar-electric generating system feeds a building at the same time as the utility grid

Intro: Course Focus

- How does it work?
  What equipment do you need?
- What can you expect from it?
- How much does it cost?
  What is the price of its electricity?
  How does this compare with other prices?
- How to put it on your house?
  - Location, tilt, orientation
  - Finding a contractor
  - Connecting to the grid

- Electric utility companies:
  - This course is not about being against them.
  - They have had a critically important role in helping society grow, by providing affordable energy and by showing us how to use it in a very safe way.

2 kW solar power system
Edmonton

Be the change you want to see in the world.
Mahatma Gandhi, India

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The future does not belong to those who are content with today, fearful in the face of new ideas and bold projects. It will belong to those with a personal commitment.

Robert Kennedy
1966

Context: Energy Efficiency *vs.* Adding Energy…

- Solar energy, wind energy, and geothermal heat pump energy option:
  - Does NOT reduce your electricity consumption!
  - Instead it substitutes your electricity source from coal and natural gas over to the sun…
- Energy efficiency option:
  - This is the cheapest, most important, highest return on investment and shortest payback option…
  - …but it is emotionally boring
- Solar, wind and geothermal all have much higher costs and longer paybacks than energy efficiency
  - It is exciting and something you can brag about to your friends…

Context: Why Use Solar Electricity?

Utility Costs

- Reduce electricity bills – you pay for solar electricity equipment up front
- Reduce vulnerability to up and down electricity prices

Environmental Footprint

- Reduce how much air pollution you cause from electricity generators to emit on your behalf
- Increase the reserve of coal and natural gas you leave for the next generation

Political will arises from personal momentum

We need to be the leaders to our governments and corporations.

Context: Why Use Solar Electricity?

Social Opportunity

- Provide the leadership that we need
- Encourage the government to facilitate it instead of blocking it

Business Opportunity

- Serve the growing public interest
- Serve the multi-billion $ world markets

The superior man seeks what is right;
the inferior one, what is profitable.

Confucius

Context: Benefits of Solar Energy…

- Proven technology
  - thousands of systems across Canada
- Can provide energy security and independence
- Inflation-proof
- Political-proof
- No noise
- No emissions
- Low or zero maintenance costs

When one tugs at a single thing in nature,
you find it attached to the rest of the world.

John Muir
Conservationist

Context: Challenges with Solar Energy…

- Purchase costs are very high…
  - though typically decreasing by 10% per year
- Not a lot of broad-based experience in Canada
  - supply and installation chain is growing in its experience and depth
- Has to compete with highly subsidized coal- and natural gas-fired utility electricity
- Little interest by governments in developing policies and technology assistance programmes
- Regulatory barriers – slowly being resolved

Solar Myth:

Solar takes up too much land area!


2000 kW PV, Sacramento

- Lots of land available on which to install solar:
  - Unused land
  - Unused walls
  - Unused roofs
  - Parking lots
  - Road meridians


100 W PV, Edmonton


15 kW PV, Sacramento

Never doubt that a small group of thoughtful and committed citizens can change the world.
Indeed, it is the only thing that ever has. +Margaret Mead, Anthropologist

Integration into Infrastructure…

rights-of way,
highways,
railways

The right to access every building in the city by private car, in an age when everyone possesses such a vehicle, is actually the right to destroy the city.

Lewis Mumford, 1981

2.9 kW, Alberta Legislature

120 kW, Berlin

Placed on Roof-Tops

85 kW, Germany

1.3 MW, Netherlands

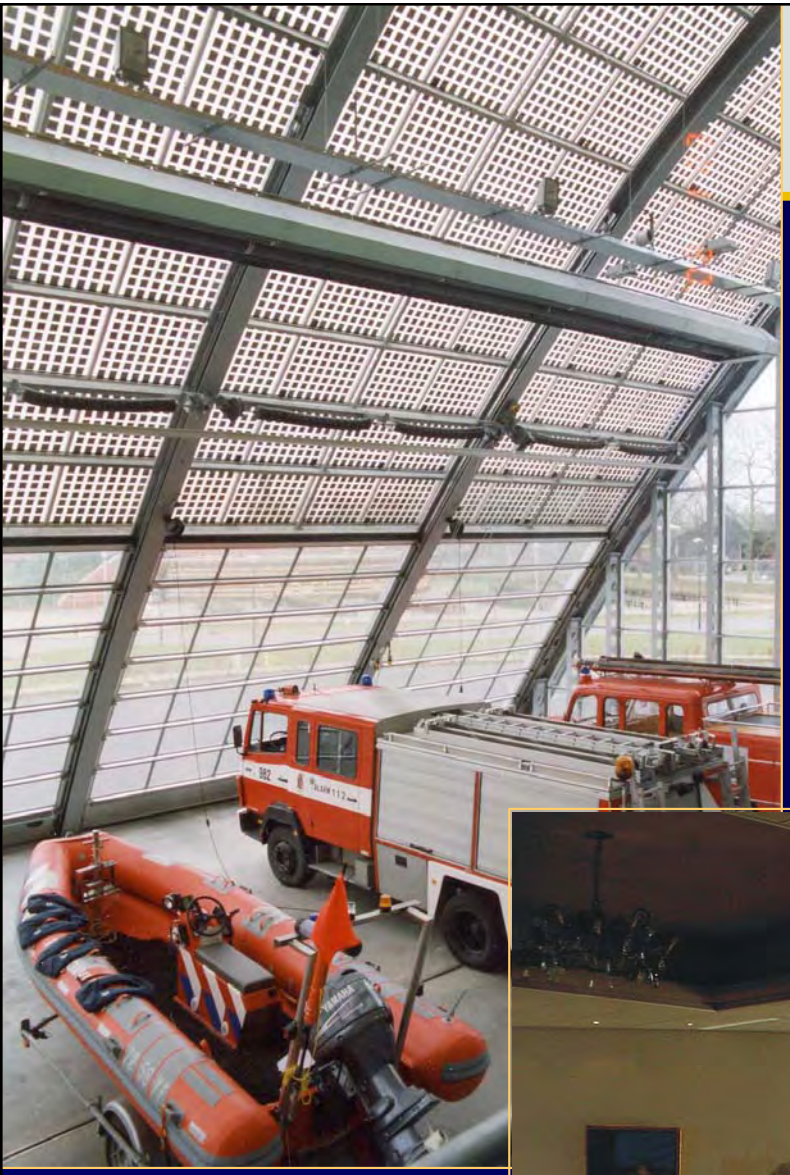
If you're not in favour of zero waste …

how much waste are you in favour of?

Opportunities – Building-Integrated PV (BIPV)

- It is now an architectural feature, which draws interest.
- It is now a building cladding and is sold on an area cost basis ($/m^2) rather than energy price basis (¢/kWh).
- Gives structure, environmental protection, PR, image, sizzle, and pollution reductions… as well as electricity.

It is the small group of friends that changes the world.
+C.S. Lewis, England



30 kW,
Netherlands

45 kW (340 m²), Netherlands.
©Saint-Gobain Glass Solar.

Integrated into Glazing for Natural Lighting

If you're in a hole
…stop digging.

Classroom space

Photo Credit
Gerry Kopelow

Photo Credit:
Corbett Cibinel Architects

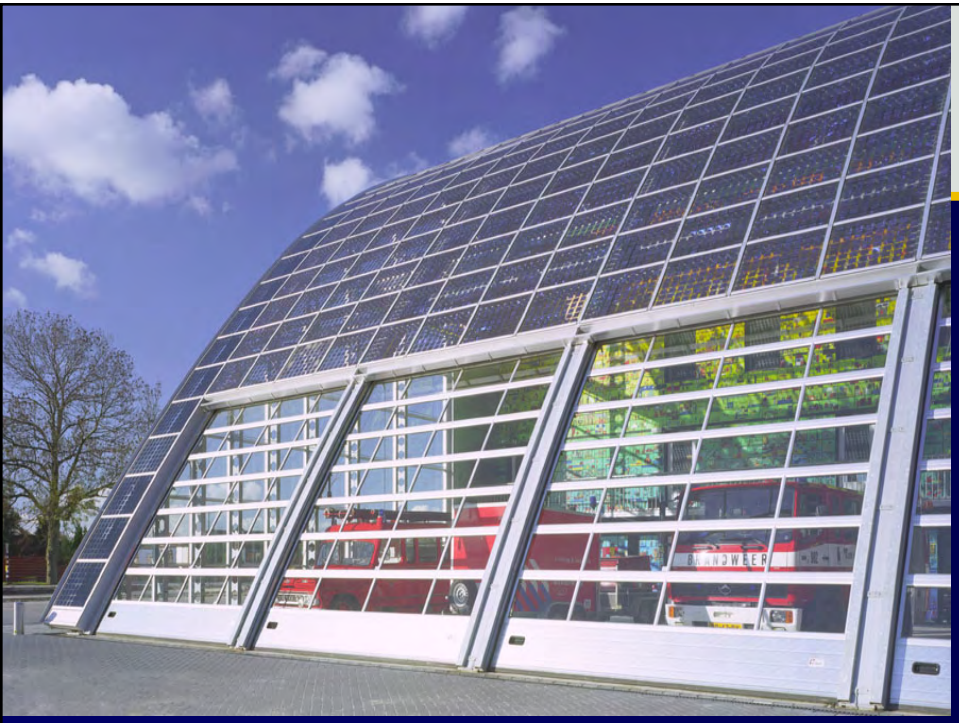
Red River College,
13 kW, Winnipeg

Integrated into Curtain Walls

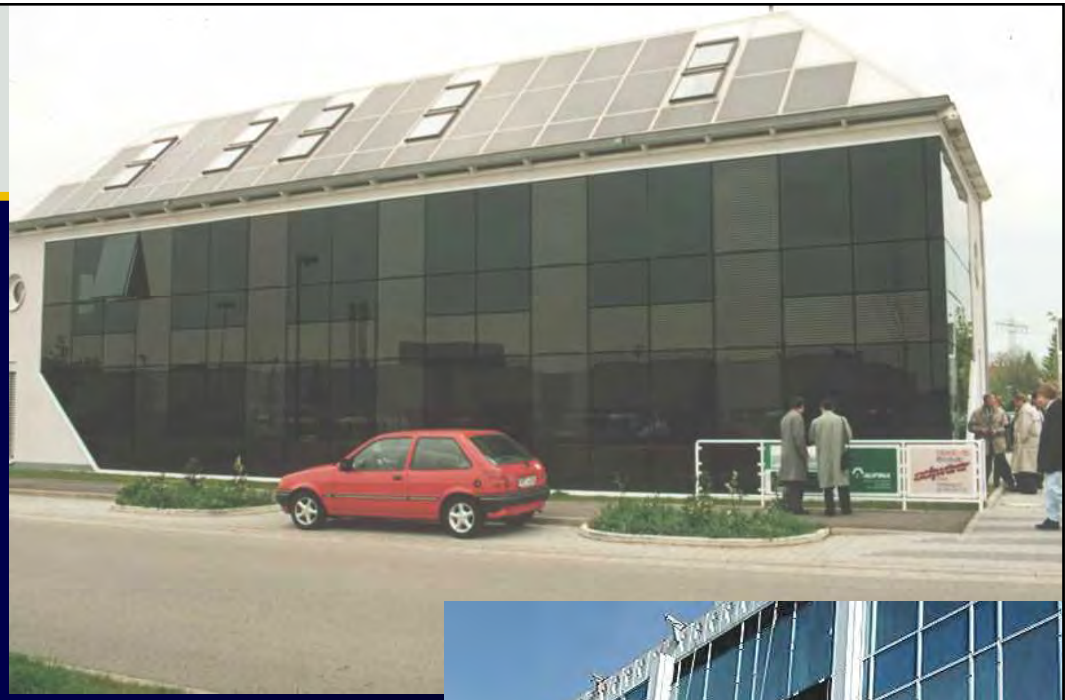
Inside of PV curtain wall

Photo Credit:
Corbett Cibinel Architects

Photo Credit:
Corbett Cibinel Architects



Netherlands



Germany

Victoria

Integrated into Façades

Treat the Earth well. It was not given to you by your parents.
It was loaned to you by your children.

Kenyan Proverb

Photo Credit:
Per Drewes

Photo Credit:
Anton Driesse

Queens University, Kingston

Integrated into Shading Structures

15 kW sunshades, America.
© Kawneer Company Inc.

Railway station Canopy, Switzerland. © EPEL-LESO

Integrated into Roofing Materials

With concrete roof tiles

With metal roofs

As shingles

With slate tiles

2.8 kW,
BCIT
Technology
Place,
Burnaby, BC

Integrated into Window Films

30% transparency

RWE Solar
Frankfurt

Service to others…
is the rent you pay for your room here on earth.

Muhammad
Ali

Buildings are becoming Solar Power Plants!

1 MW, Munich

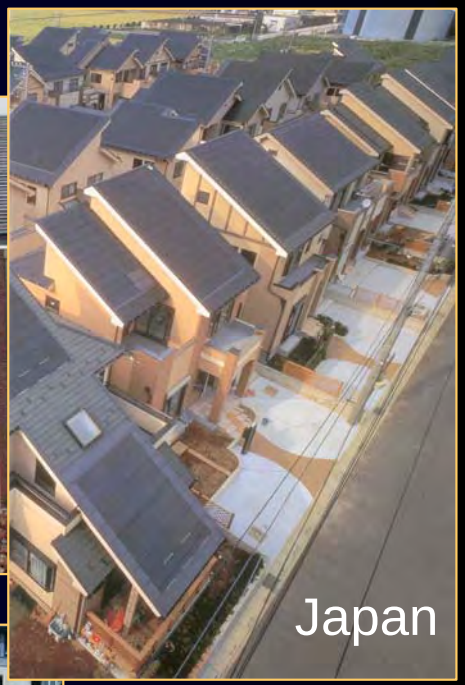
Aachen, Germany

5 kW, Waterloo

6 000 kW, Germany

Neighbourhoods are becoming Solar Power Plants!

1000 kW community PV project on
500 houses in the Netherlands



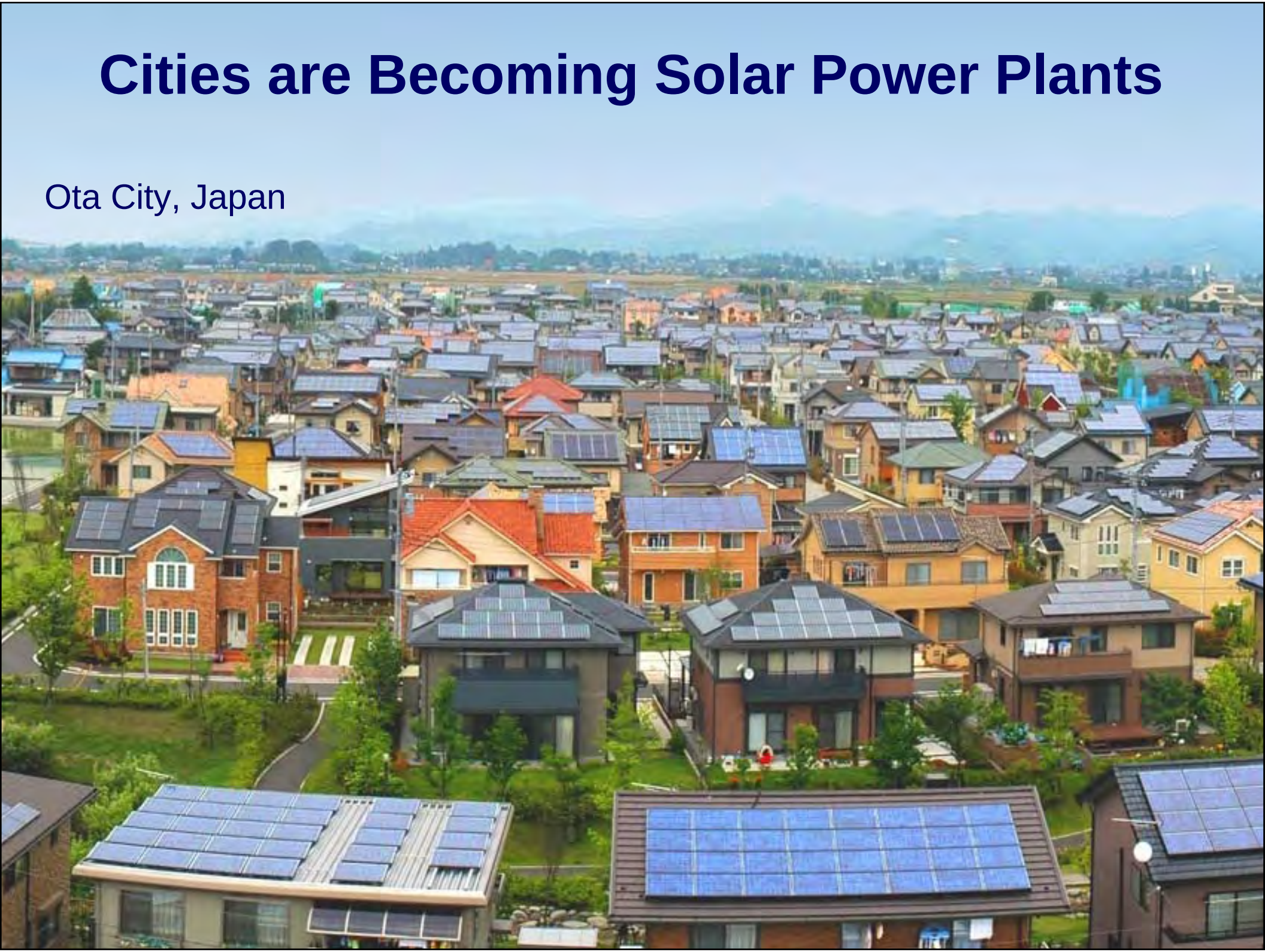
Japan

California

Every revolution is about power!

Cities are Becoming Solar Power Plants

Ota City, Japan



What is happening with solar electricity?

- Solar electricity is growing substantially around the world
  - 21% growth per year in Canada
  - 50% growth per year around the world
- More countries are getting involved:
  - Japan, Germany, Netherlands, Austria, America, Australia, Italy, Korea, Great Britain, Spain, France, Thailand, India
- Solar PV feed-in tariffs
  - Germany, Italy, France, Austria, Ontario, South Australia ++
- New innovative products
- Sometimes higher prices and shortages because of huge demand!

- World-wide
  - 16 billion $ industry in 2006
  - 50,000 employees in 2006
  - 100,000s of systems installed world-wide
  - 1,000,000 homes in 2006 were installed with PV
- Thousands of off-grid systems in Alberta.

Premier Gardens, California!

Anyone who thinks they are too small to make a difference…
has never spent the night with a mosquito.

African Proverb

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We are consuming the resources of our planet at such a rate that we are, in effect, living off credit and living on borrowed time.

Prince Charles of Windsor

Background: What is Energy? – The basics

- Energy is the ability to do work:
  - Equals a force exerted over a distance
  - Measured in "Joules" or "J".
- Heat is a form of energy.
- Electricity is NOT energy, it is free electrons
  - but the energy that is in them can be extracted and put to work
  - thus electricity is usually represented as energy.
- Light is NOT energy, it is photons
  - but the energy that is in them can also be extracted and put to work.

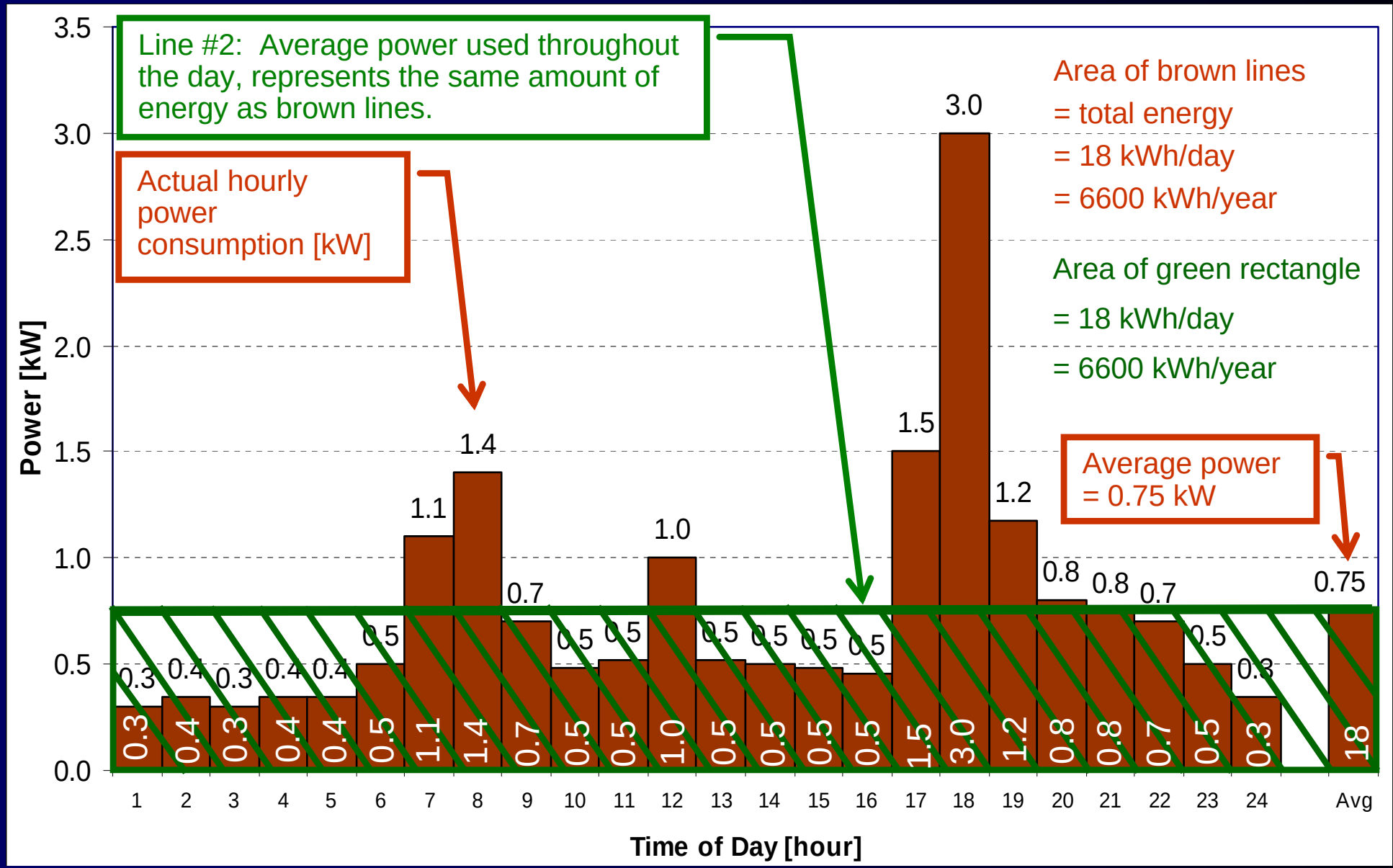
Background: What is Power? – The basics

- Power is the speed at which energy flows!!!
  - Measured in Joules per second, which we call a "watt", or "W".
- Heat flows from one place to another through:
  - Conduction – such as through a metal object
  - Convection – which causes hot air to rise
  - Radiation – which transports light energy from the sun to the earth.
- Electricity flows from one place to another:
  - Along a conductor.
- Light flows only by radiation.

Background: What causes energy to flow?

	Commodity	Driver that causes commodity to flow	Flow (or Rate)
Water	Water volume [litre] [kg]	Pressure difference [kPa, psi, metres of head or height difference]	Water current [litre per second] [kg per second]
Electricity	Electrical charge [Coulomb (C)] Electrical energy [kWh = 3.6 million J] (= 1/10 litre gasoline)	Voltage difference [Volt]	Electrical current [Ampere = 1 C/s] Electrical power [W = 1 J/s] [kW, MW]
Heat	Thermal energy [GJ = 1 billion J] (= 28 litres gasoline)	Temperature difference [C°, K]	Heat flow [MJ/h, GJ/h]

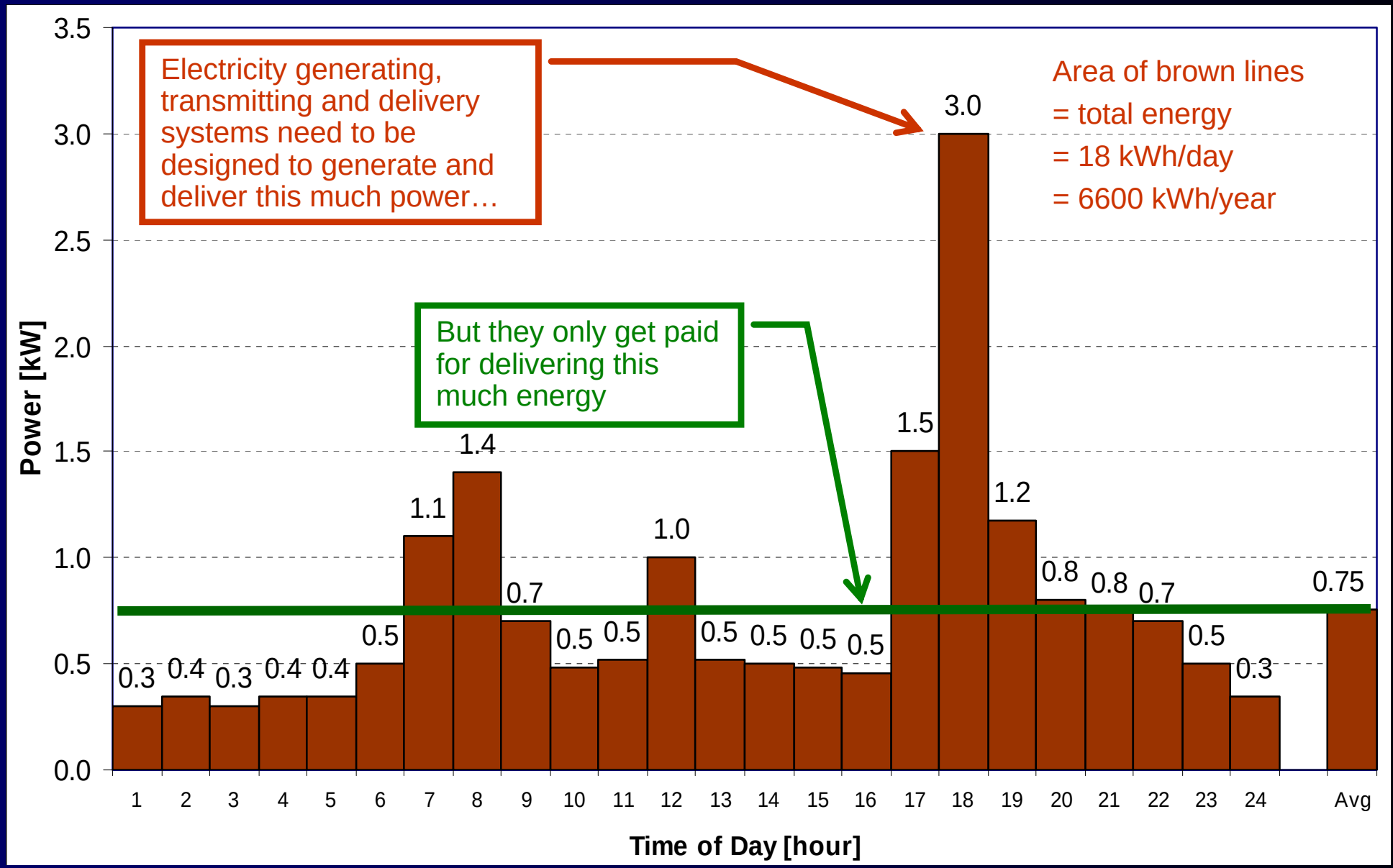
Background: Energy *vs.* Power



Energy = Power x Time
kWh = kW x h

Distance = Speed x Time
km = km/h x h

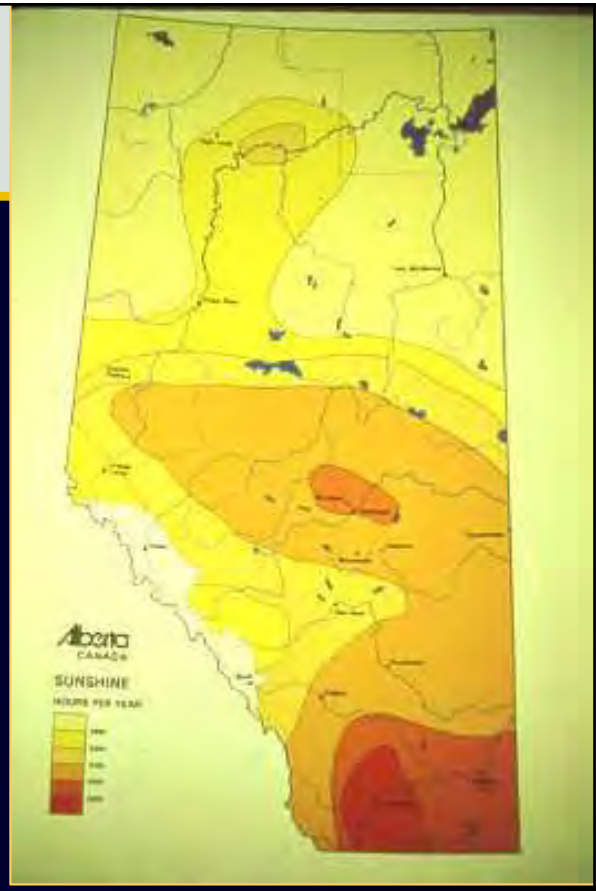
Background: Energy *vs.* Power



Question: What is Alberta's most abundant energy resource?

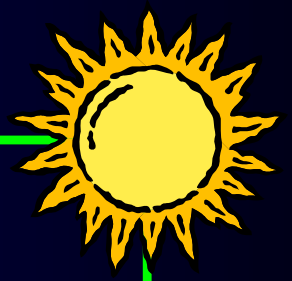
Alberta: The Solar Province

– Our Most Abundant Energy Resource



- 14 hours of sunshine = all our fossil energy resources in 2001!
- Alberta's sunshine is over 300 times more than our fossil fuel resources.

What is solar energy?



- Solar energy
  - the energy contained in the photons that comprise sunlight
- Sunlight is
  - visible light
  - electromagnetic radiation (as is all light)
  - non-ionizing radiation (as is all light)
  - short-wave light (different from radio waves or microwaves)
- All energy has come from the sun!
  - some of it has just been stored for a time!

Photo Credit:
Gordon Howell

Photo Credit:
SPS Energy

Solar Energy
– where can it be used –

Okotoks swimming pool
solar heating

Cochrane High School
solar power

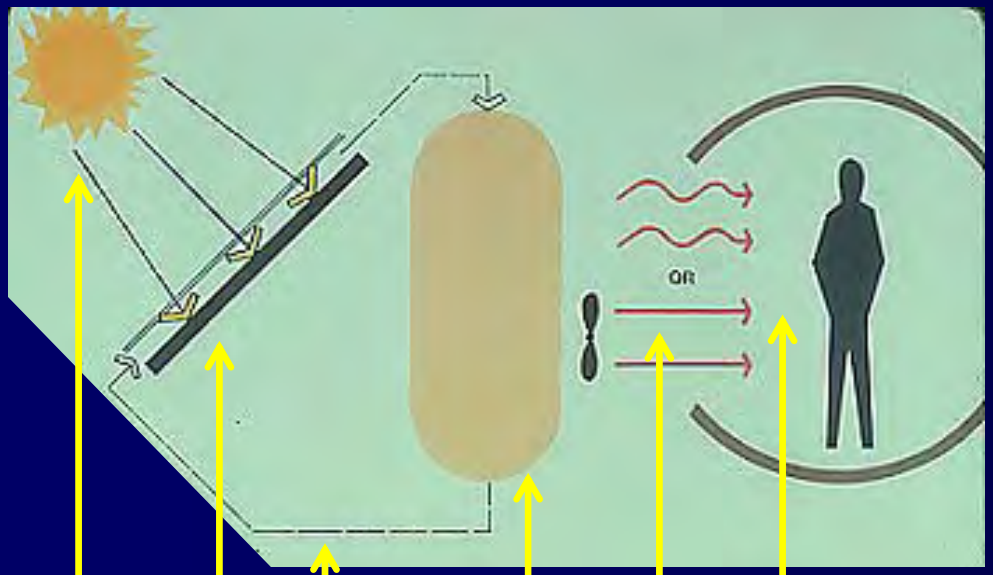
- Anything that uses electricity, any time, any where
- Space heating
- Water heating – for domestic water and pools
- Industrial and commercial process heating
- Cooking
- Daytime illumination

Okotoks 52-home
solar heated subdivision

Red Deer's
newest net zero
electricity home

Photo Credit:
Gordon Howell

How do we use solar energy?



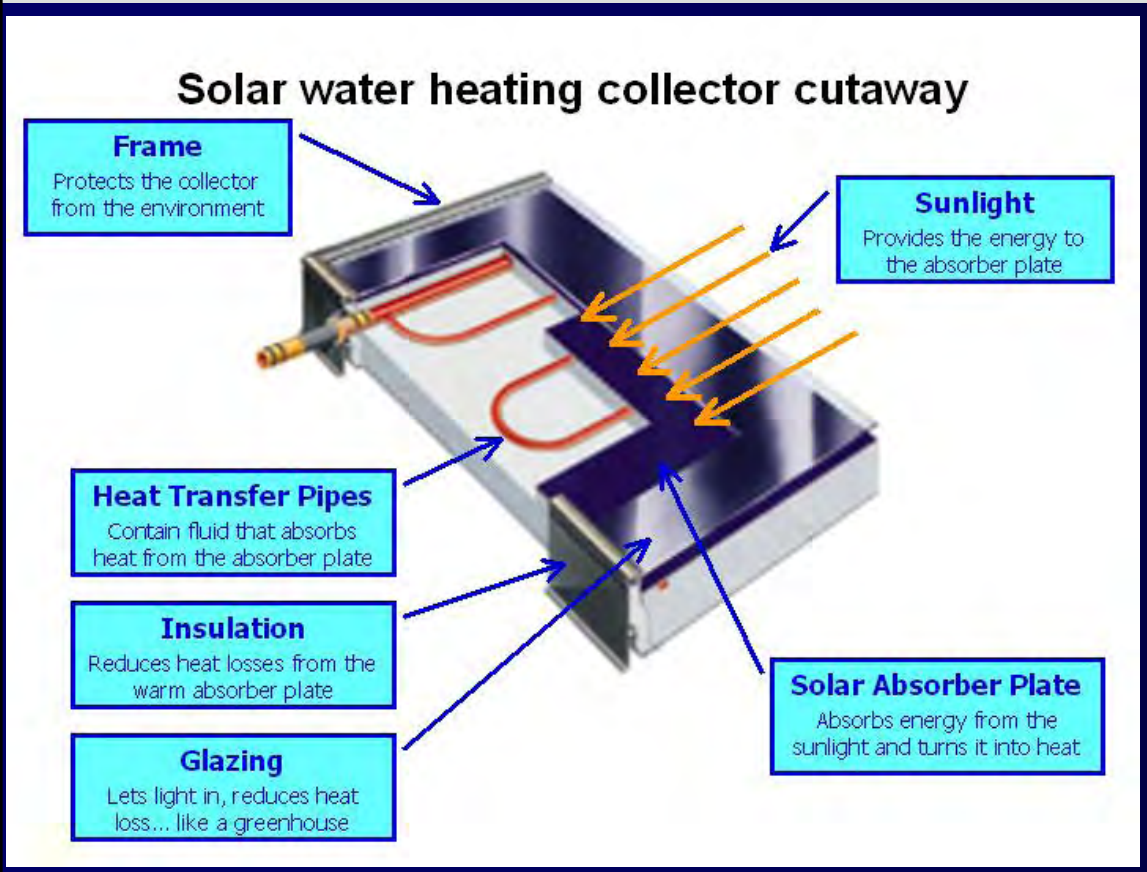
Source
Collector
Recovery
Storage
Delivery
Usage

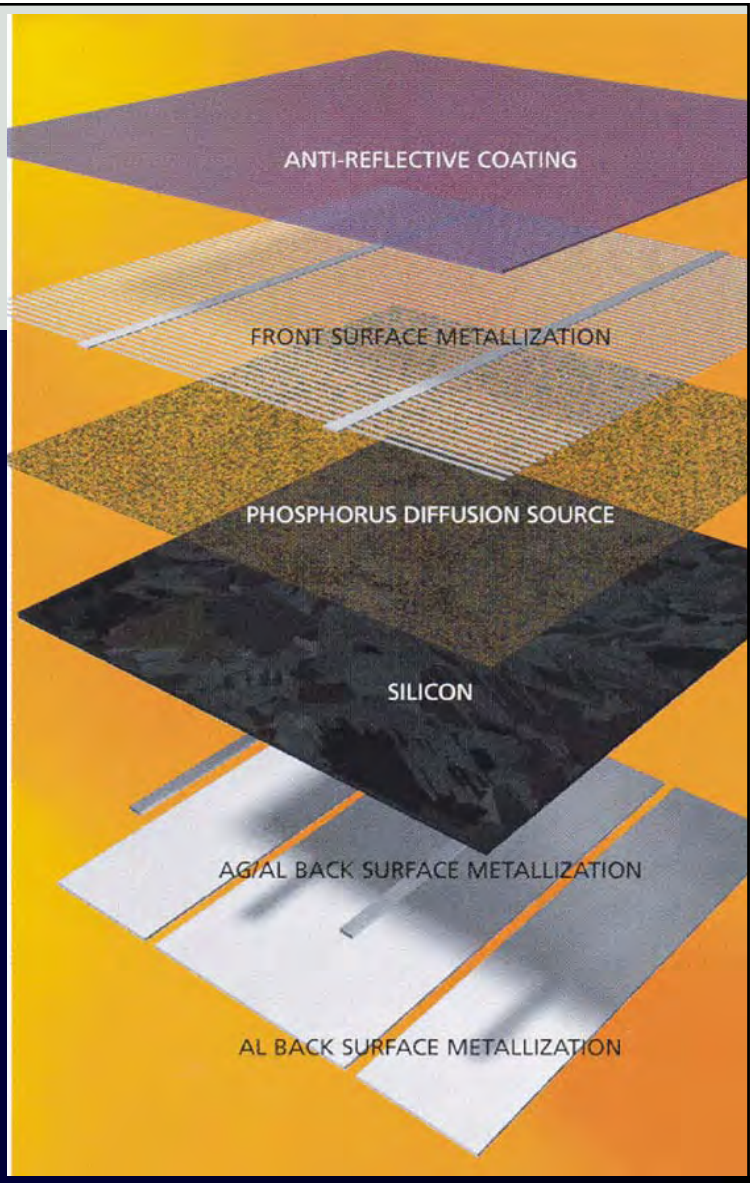
- Need to collect it (both for electricity and heating)
- Need to store it – but only if we have enough to spare for times when we need it
- Need to deliver it to the appliances and the house
- Need to protect ourselves from it! (…overheating)

You cannot teach a man anything,
You can only help him discover it within himself.

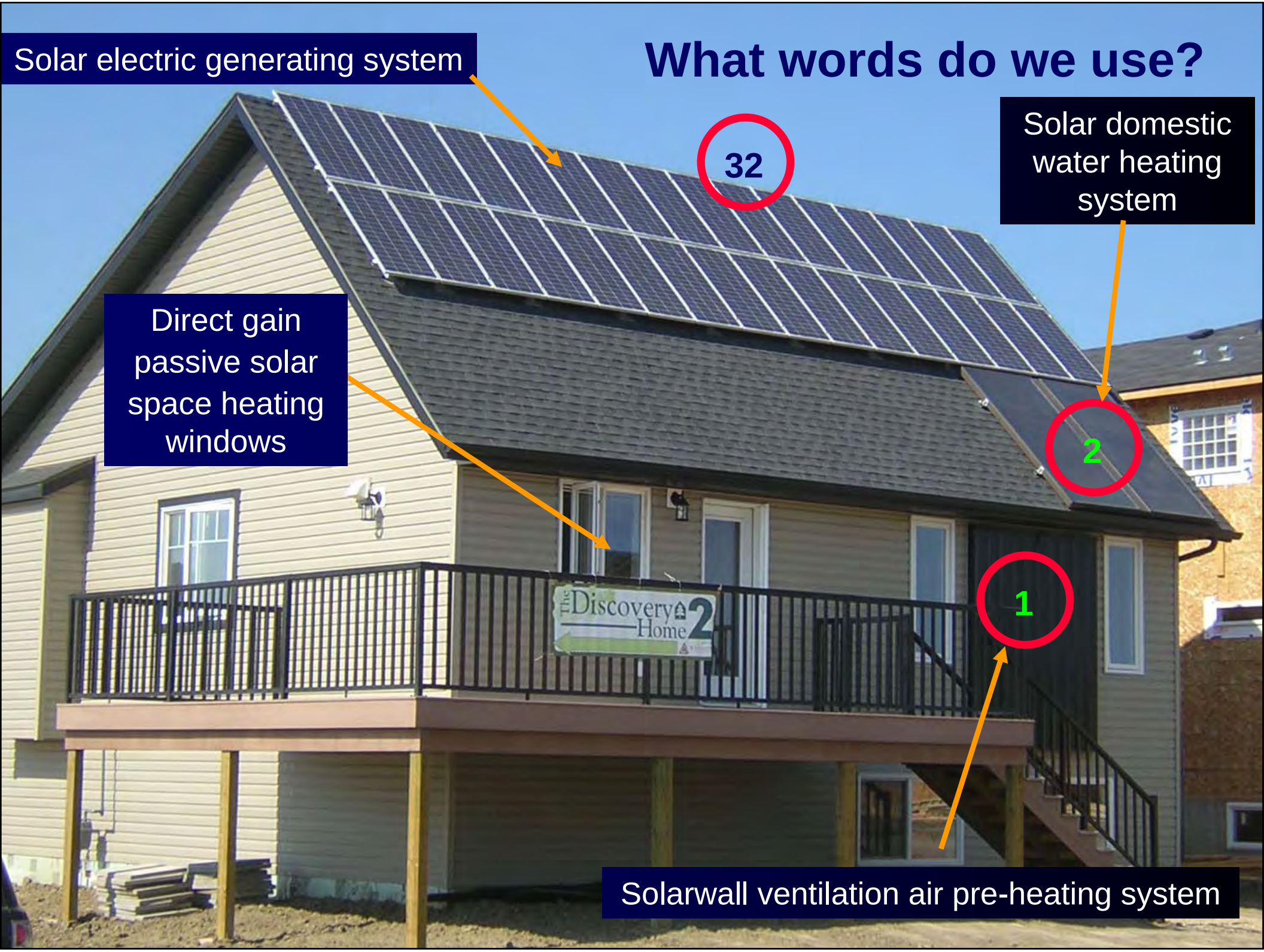
Galileo

Solar heating and solar electricity are NOT the same…





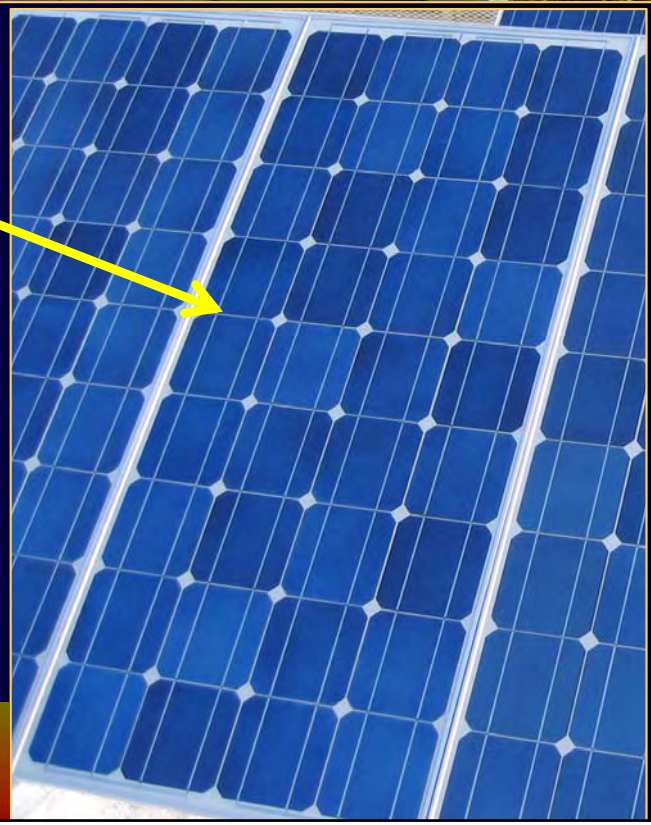
- Solar heating
  - A dark surface sitting in the sunshine
  - Water or air runs past the solar heated surface carrying heat to the building.
- Solar electricity
  - A semiconductor device like a computer chip
  - Photons bump electrons out of an atom.
  - Wires carry the electrons away.


What words do we use?
Solar electric generating system
32
Solar domestic water heating system
Direct gain passive solar space heating windows
2
1
The Discovery Home 2
Solarwall ventilation air pre-heating system

What words do we use?

- Solar heating
  - thermal **collectors**

- Solar electricity
  - photovoltaic **modules**



- Solar panel – when several PV modules are attached on a rail.

We've never lacked the means to solve our problems,
…only the will to do it.

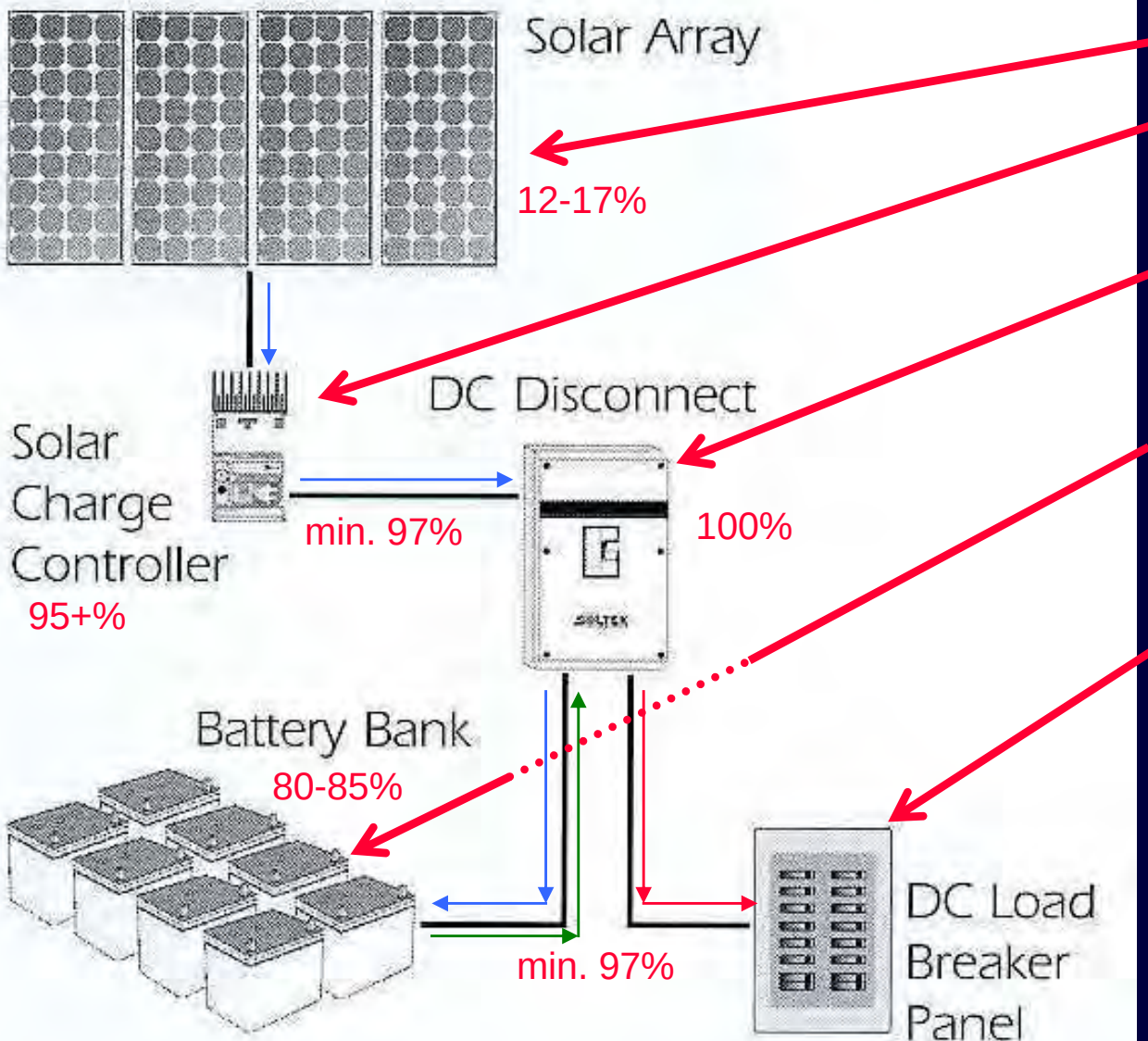
Solar Electricity – used everywhere!

Photo Credit:
Ralph Cartar

From calculators and watches to large generating stations.

1. Off-grid stand-alone
2. Hybrid: off-grid… + genset or wind
3. Grid-connected

Solar PV Stand-alone Off-grid DC System



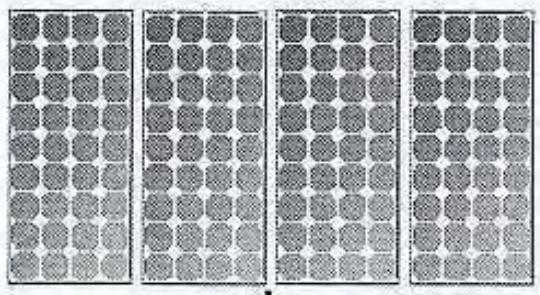
Components:

- Solar **array** generates electricity
- **Charge controller** shuts down the array when the battery is full
- **DC disconnect** is a safety switch that is used if you need to work on the system
- **Battery bank** stores electricity from day to night, and sunny to cloudy weather
- **DC breaker panel** is used to attach the DC wiring circuits in your house

Overall system efficiency:

- array to loads: 72% to 79%
- sun to loads: 8% to 13%

Solar PV Stand-alone Off-grid AC System



Solar Array

12-17%

Solar Charge Controller

95+%

DC Disconnect

min. 97%

100%

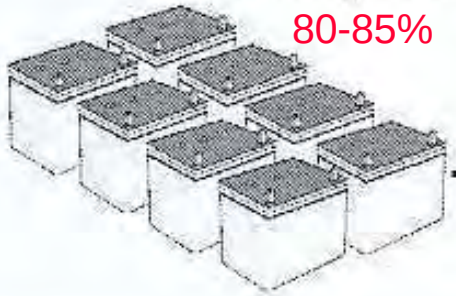
Inverter

85-94%

min. 97%

Battery Bank

80-85%



min. 97%

DC Load Breaker Panel

AC Load Breaker Panel

Additional **Components**:

- **Inverter** changes DC electricity from the solar array and the battery bank to AC electricity for your house
- **AC breaker panel** is used to attach the AC wiring circuits in your house

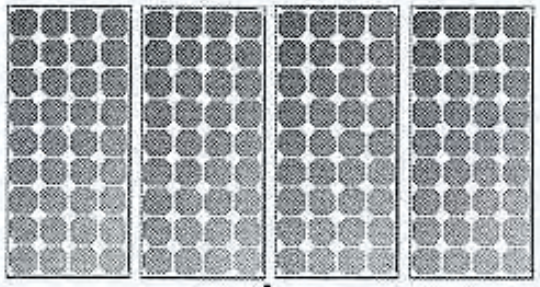
Overall system efficiency:

- array to loads: 59% to 74%
- sun to loads: 7% to 12%

Solar PV Hybrid Off-grid System

Additional **Components**:

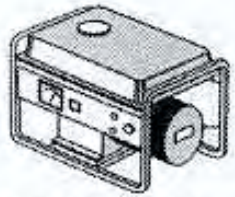
- **Inverter by-pass switch** to divert loads to generator
- **Main AC breaker panel** to attach major AC wiring
- Back-up **generator**, for heavy loads and mostly used in winter



Solar Array

12-17%

5-15%



Generator

Main AC Breaker Panel

min. 97%

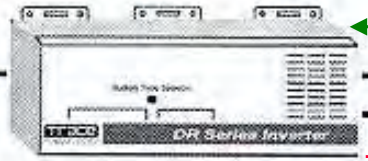
Solar Charge Controller

95+%

min. 97%

DC Disconnect

100%



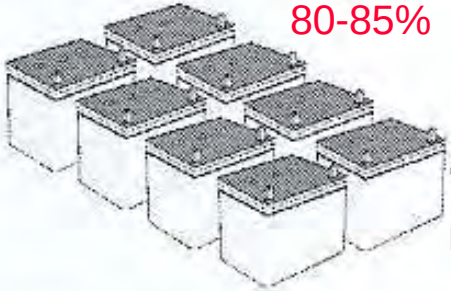
85-94% Inverter / Charger

min. 97%

Inverter By-Pass Switch

Battery Bank

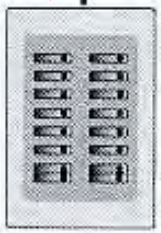
80-85%



min. 97%

Overall system efficiency:

- sun to loads: 7% to 12%
- array to loads 59% to 74%
- fuel to loads: 3% to 11%
- genset to loads: 51% to 72%



Inverter AC Sub Panel

Solar Electricity

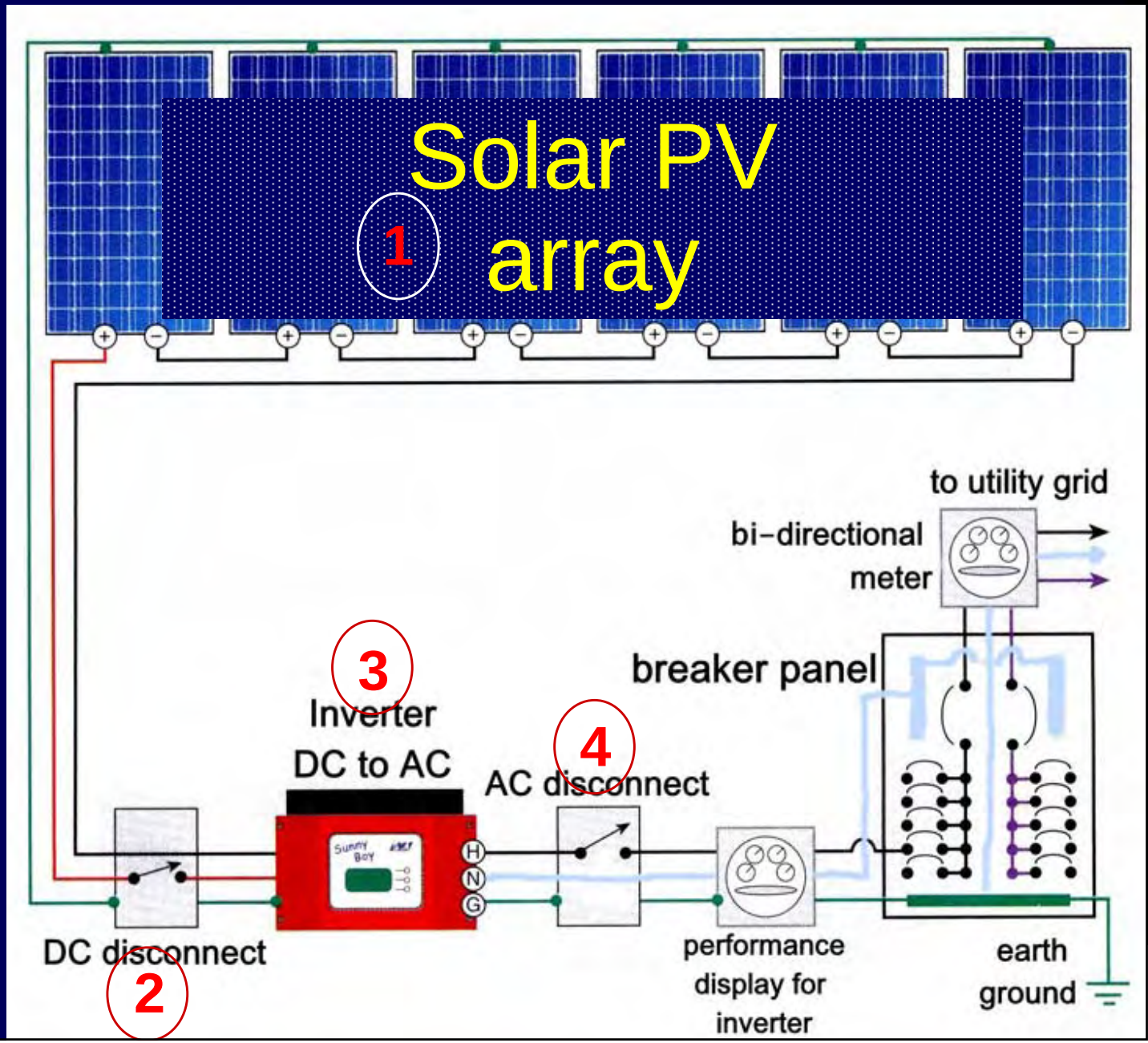
Peter Bull's home, Edmonton, 2006

Avalon Master Builder's Discovery II
Net Zero electricity home,
Red Deer, 2006

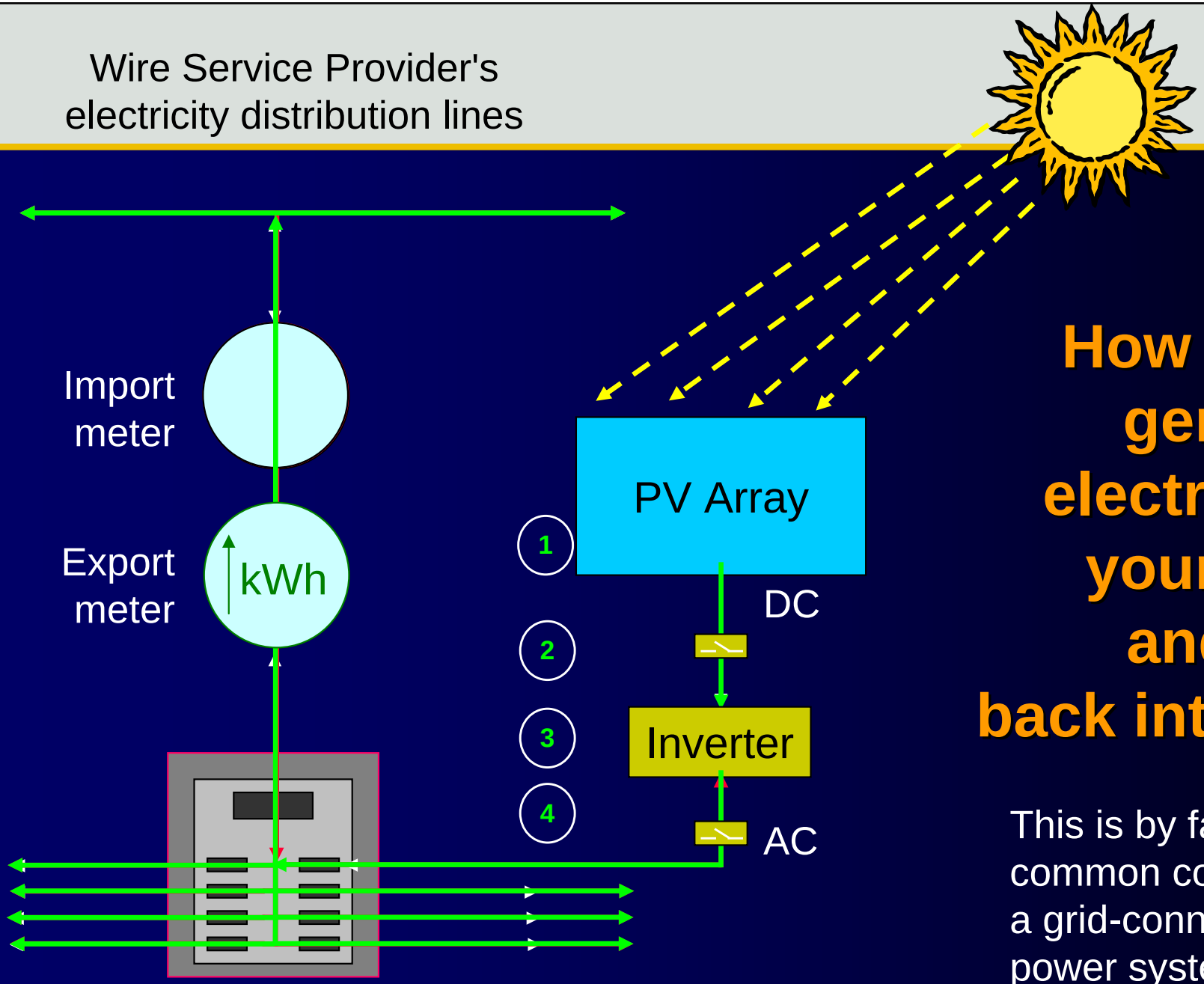
To be truly radical is to make hope possible… Raymond
…not despair convincing. Williams

Grid-Connected System – Grid-dependent

- 4 major components:
  - PV array
  - DC disconnect
  - Solar inverter
  - AC disconnect
- No energy storage
- Most common grid-connected configuration
- 300 in Canada???
- 50 in Alberta?
- 3.8 million around the world…



Wire Service Provider's
electricity distribution lines



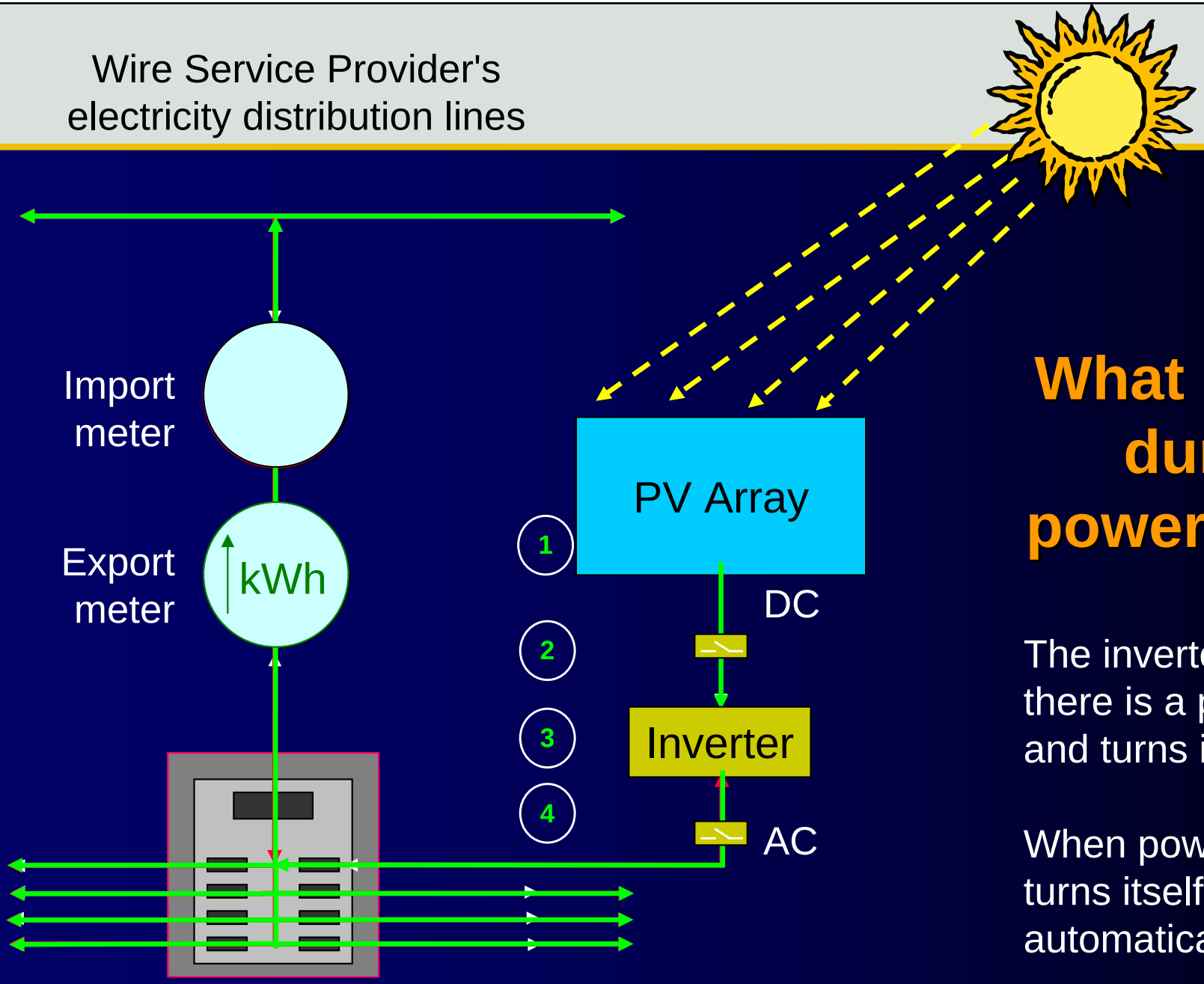
All electrical circuits in a house or building

How can you generate electricity into your house and also back into the grid?

This is by far the most common configuration for a grid-connected solar power system.
There is no battery bank.

Solar energy is the ultimate in wireless nuclear fusion
… where the fusion generator is very safely stored 150,000,000 km away!

Wire Service Provider's
electricity distribution lines



What happens during a power outage?

The inverter senses that there is a power outage and turns itself off.

When power returns it turns itself on automatically.

People who say it cannot be done
… should not interrupt those who are doing it.
George Bernard Shaw

+Eric Steeden's Solar Garden

2.5 kW Sunny Boy inverter

Installed in 2003

Cost $26,000

Electricity generation: ~$180 per year

Annual electricity export value: $100

Edmonton

2 kW solar PV

Photo Credit:
Steve Wiebe

Gives his excess to
the Alberta Electric System Operator's
Energy Trading System for free

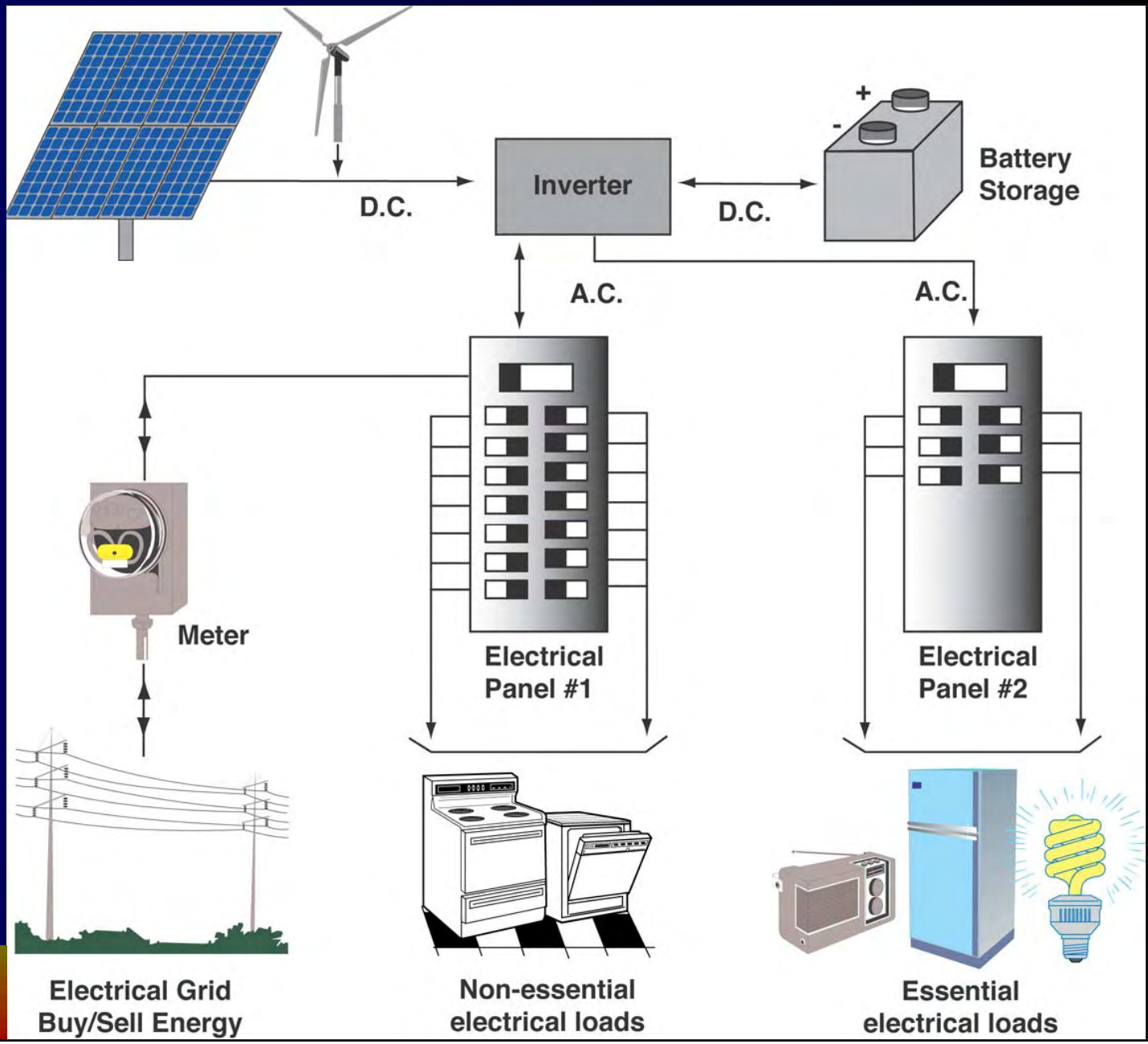
Buys from EPCOR

Solar meter

Cities grow great… when old men plant trees
in whose shade they know they will never sit in.

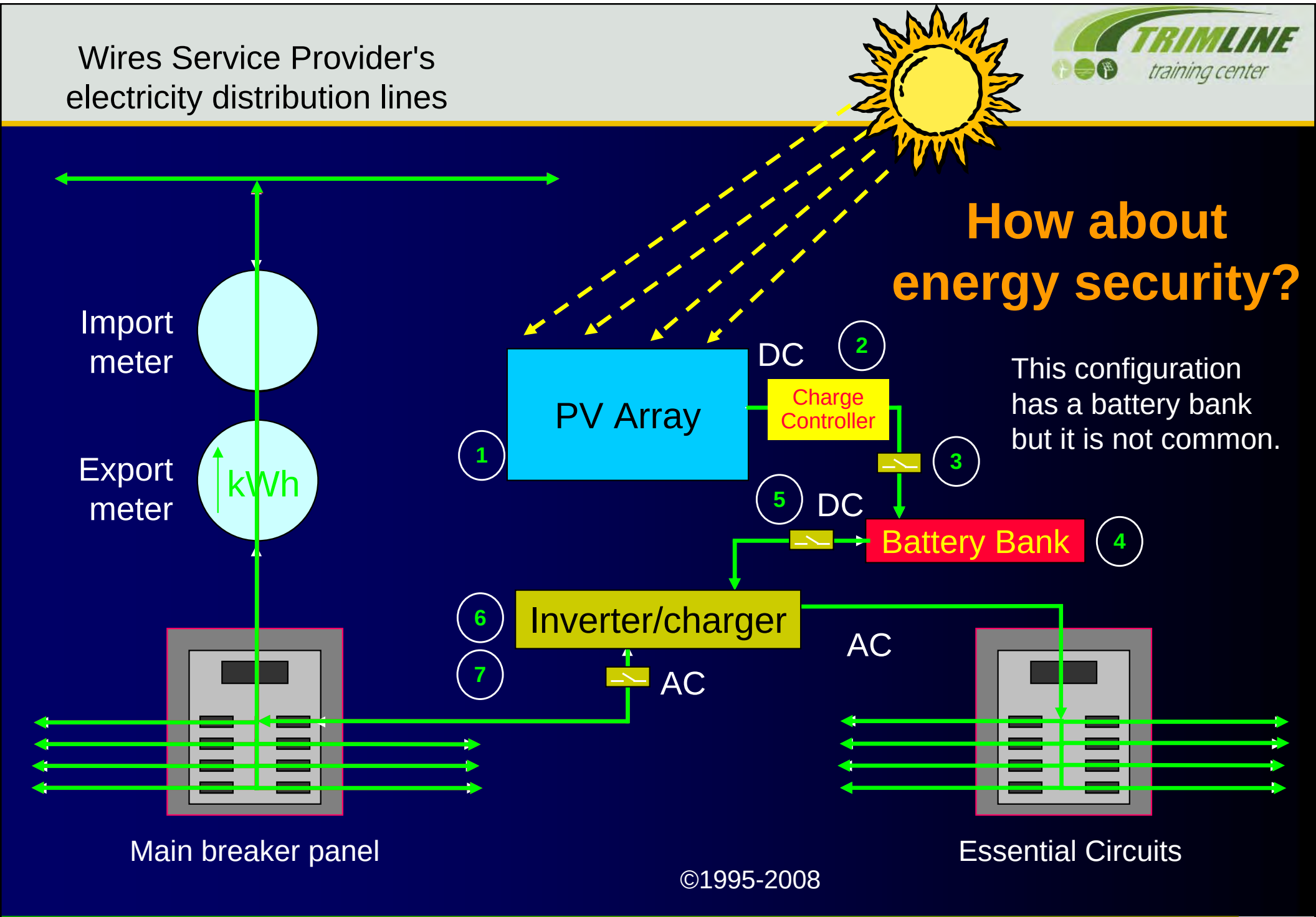
Grid-Connected System – Grid-interactive

- 7 major components
- Includes energy storage
- Not common at all
  - 15 in Canada?



Nobody is more blind, than one who does not want to see.

Wires Service Provider's
electricity distribution lines



You must skate to where the puck is going
…not to where it is now.

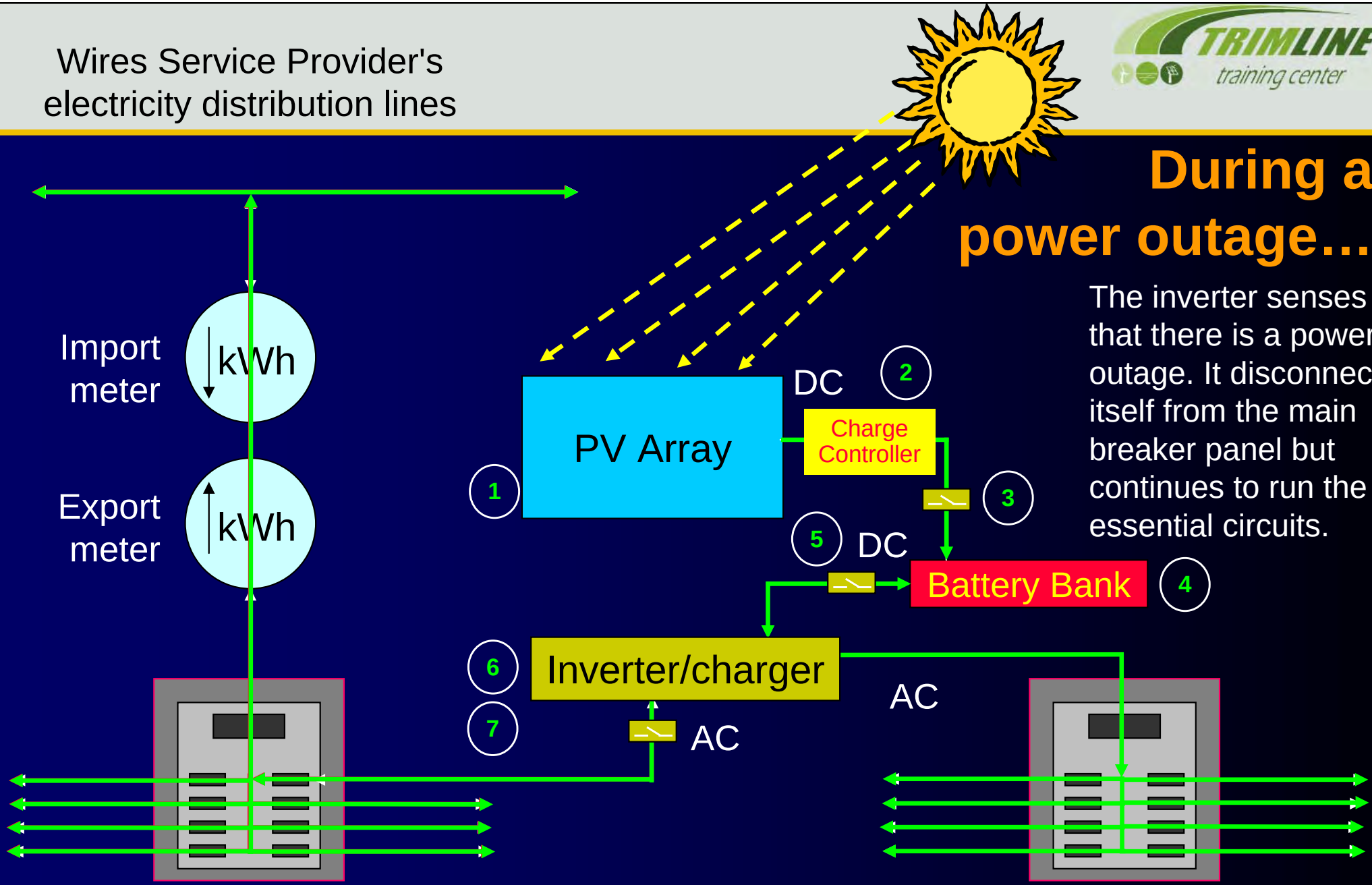
Wayne Gretzky

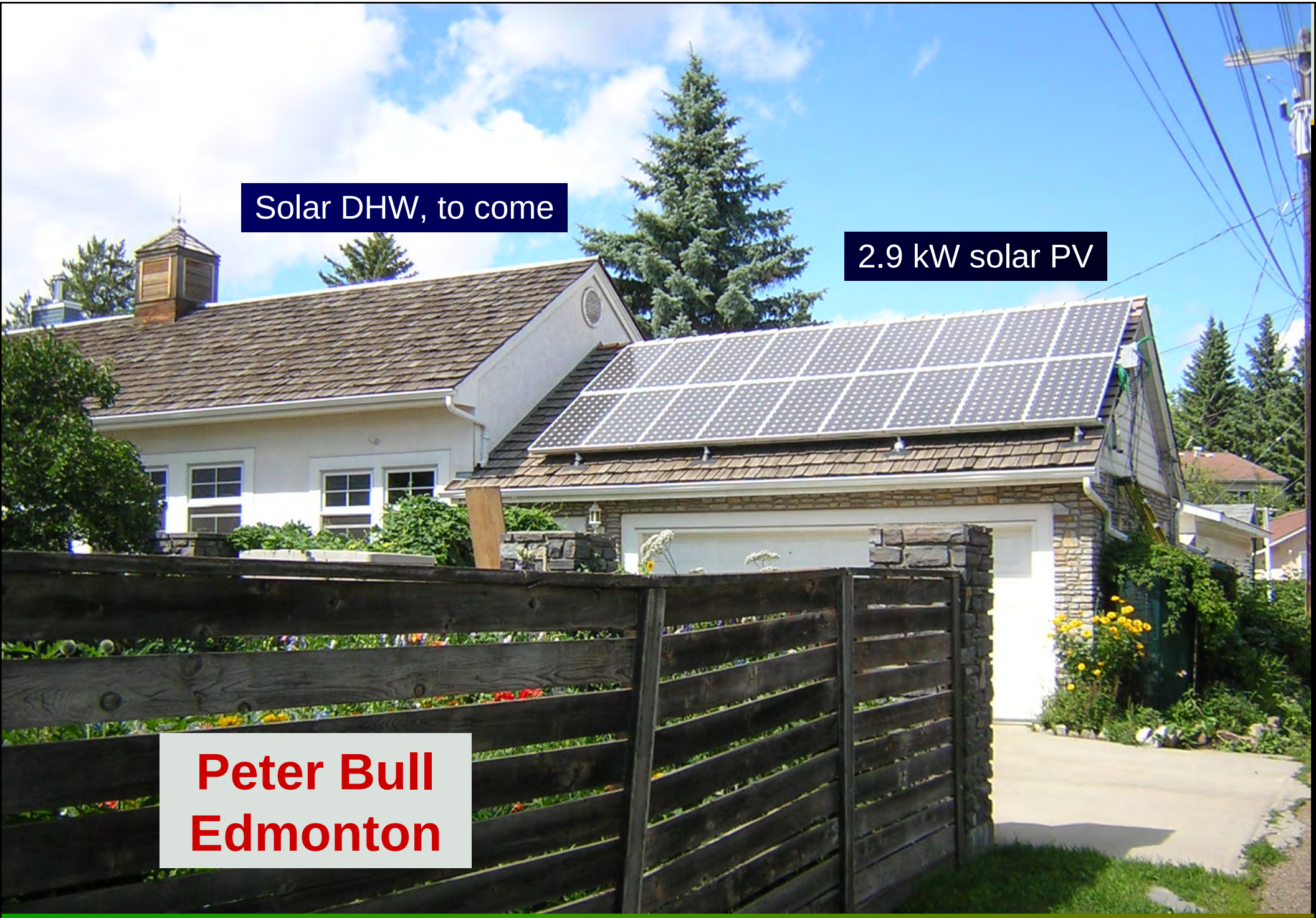
Wires Service Provider's
electricity distribution lines

TRIMLINE training center

During a power outage…

The inverter senses that there is a power outage. It disconnects itself from the main breaker panel but continues to run the essential circuits.





Let him that would move the world first move himself.

Socrates
Greece

Inverter, charge controllers, DC switches, meters

Charge controllers

Inverter /charger

DC array switches

Peter Bull Edmonton

Questions…?

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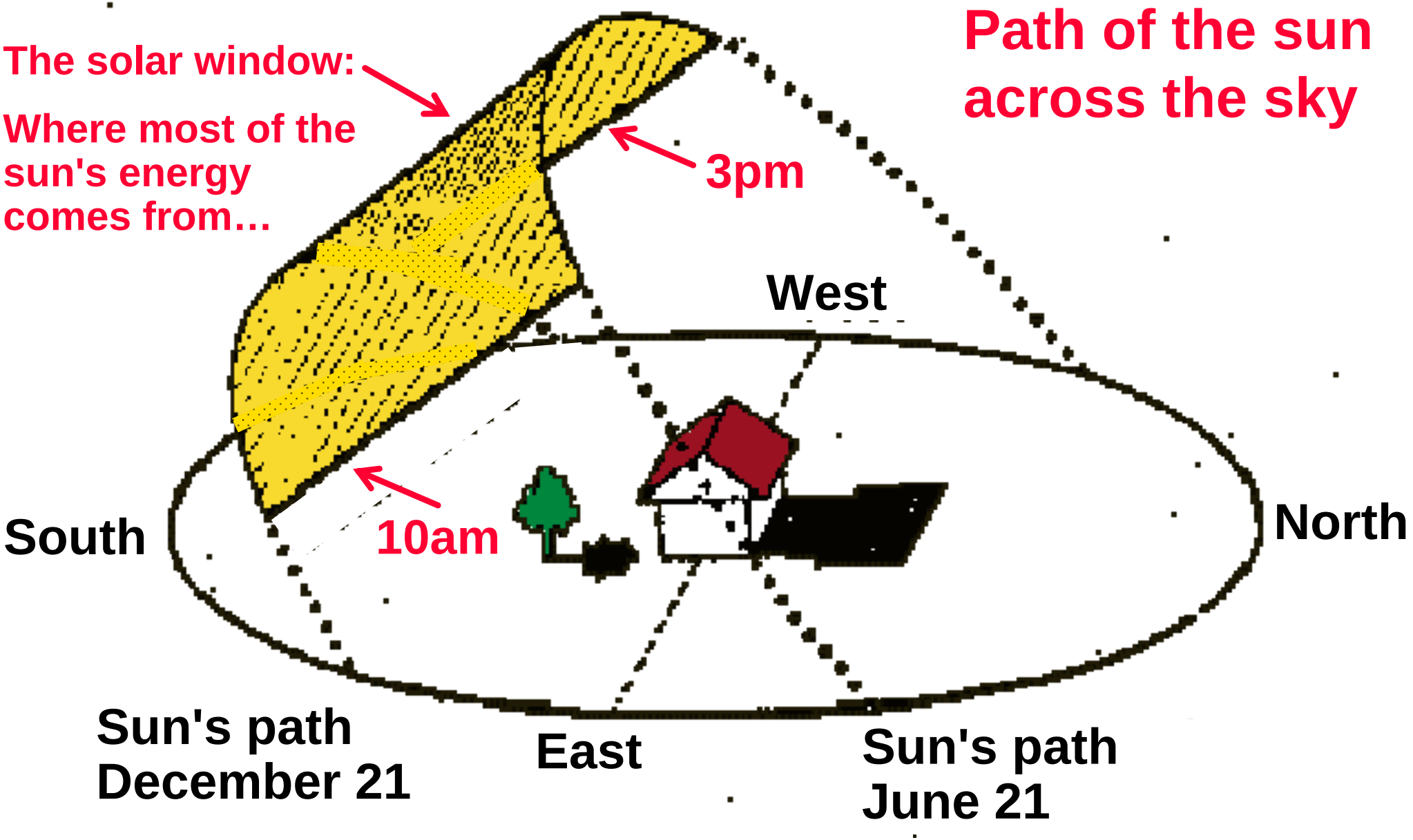
The reasonable man adapts himself to the world;
the unreasonable man persists in trying to adapt the world to himself.
Therefore, all progress depends on the unreasonable man.

George Bernard Shaw

Path of the sun across the sky

The solar window:

Where most of the sun's energy comes from…



The Energy in Solar Radiation

- = 3.6 sun-hours/day in Edmonton
- … ok, but under what conditions
  - Tilt? horizontal, 6/12 tilt, 53 tilt, vertical?
  - Orientation? north, south, east, west?
  - Conditions? maximum, average
  - When? summer, winter, yearly?

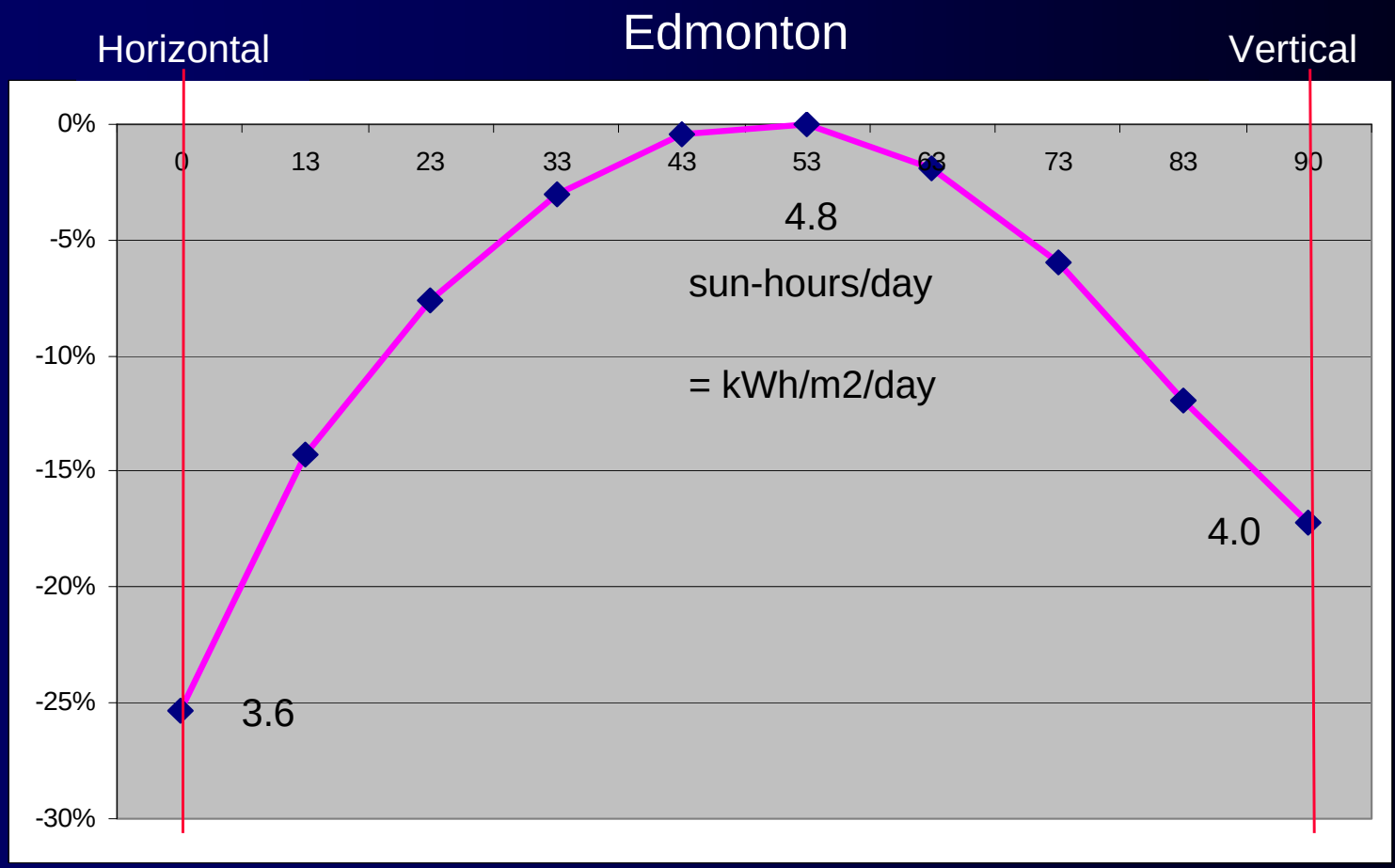
Solar Myth:

Solar needs to be perfectly orientated in order to work at all !! – NOT

- precise optimum
  tilt and orientation
  to collect maximum solar energy

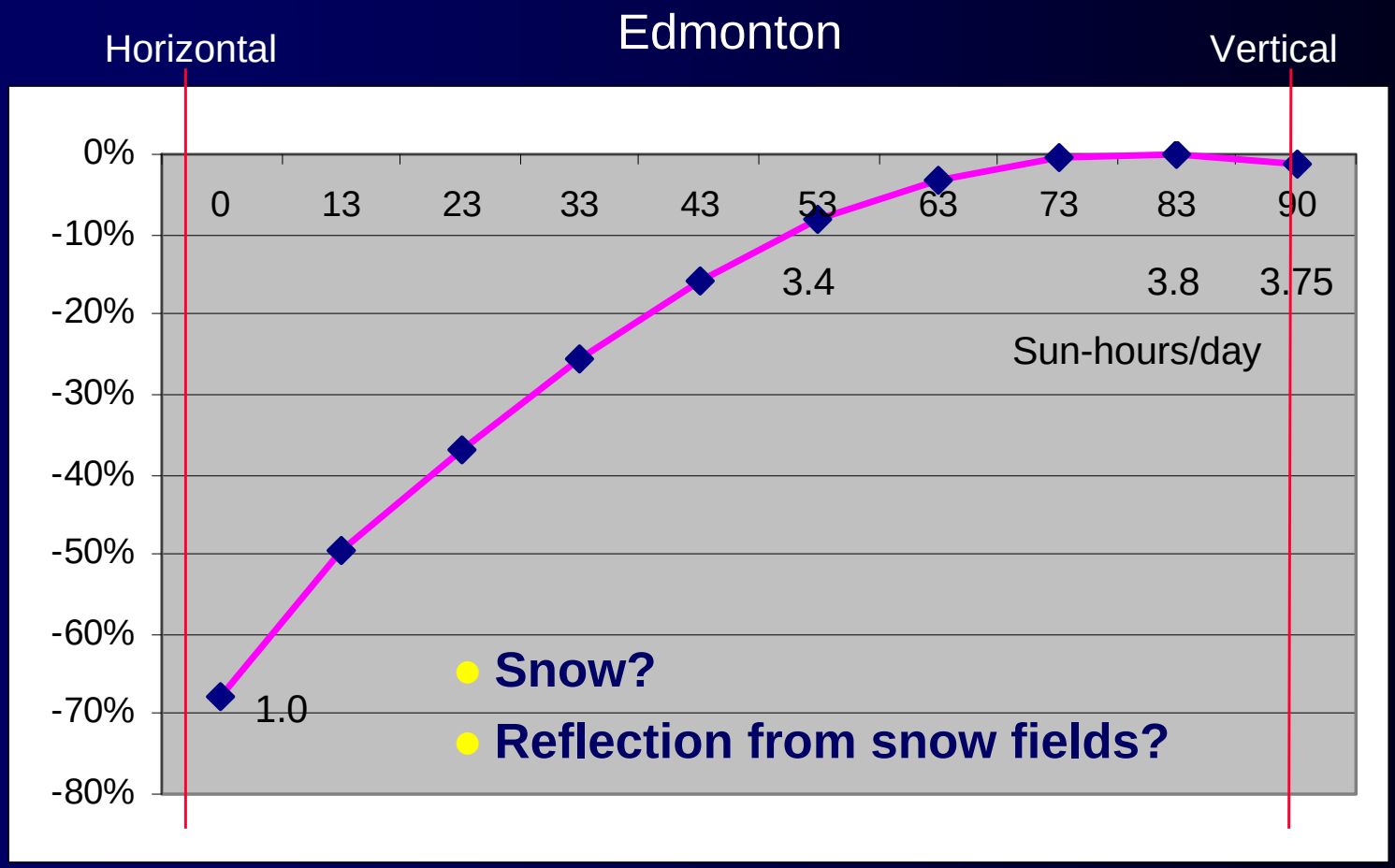
- wide range of angles
  to orient and tilt solar equipment and
  still not be too far off maximum

Optimum Annual Solar Tilt Angle



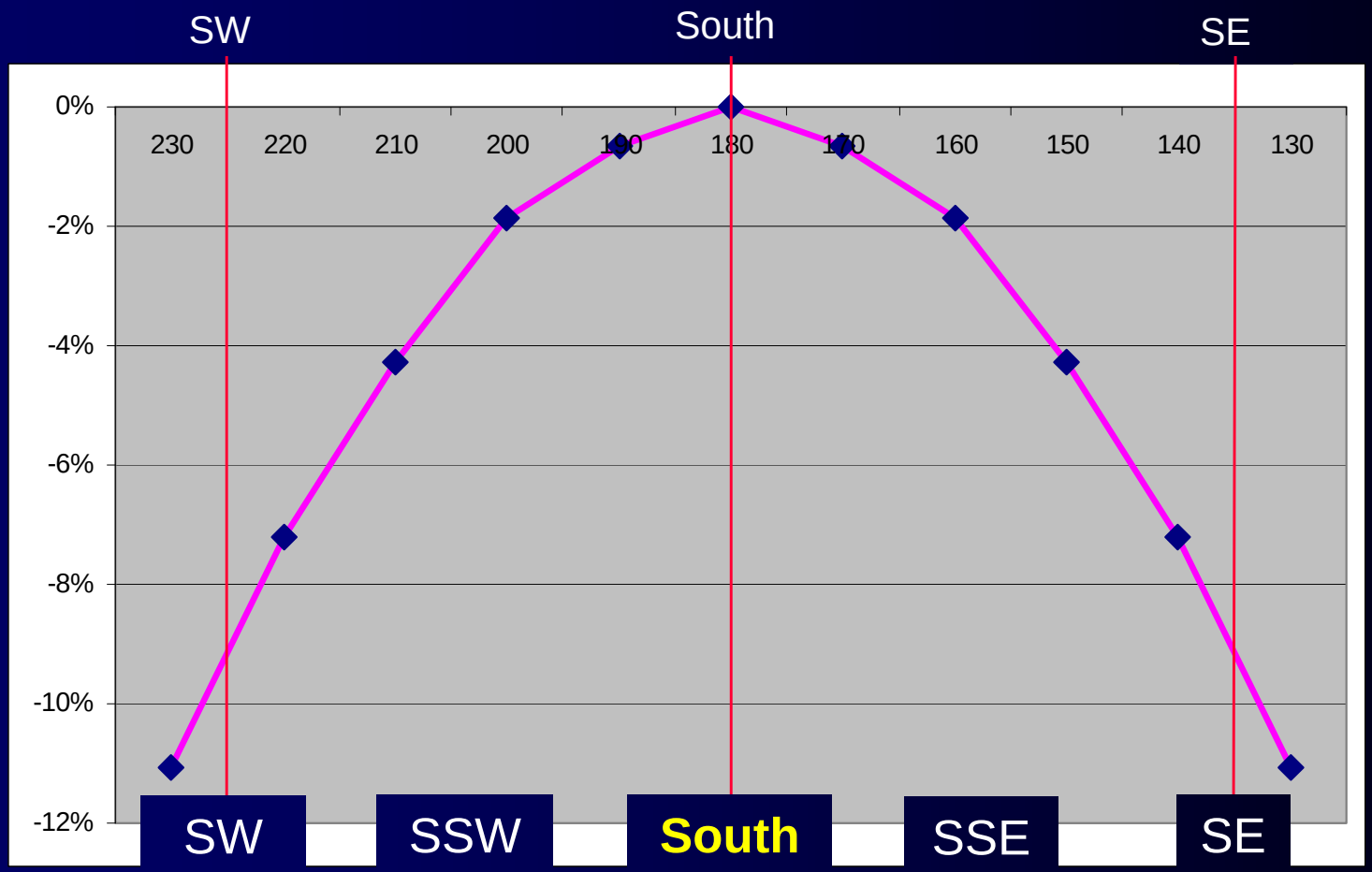
- The maximum annual solar energy production occurs at around a 53° tilt.
- If your goal is to maximise this, your tilt angle can be from 18° to 80° and still be within 10% of the maximum.

Optimum Winter Solar Tilt Angle



- The maximum winter solar energy production occurs at around a 83° tilt.
- If your goal is to maximise this, your tilt angle can be from 50° to 90° and still be within 10% of the maximum.

Optimum Annual Solar Orientation Angle

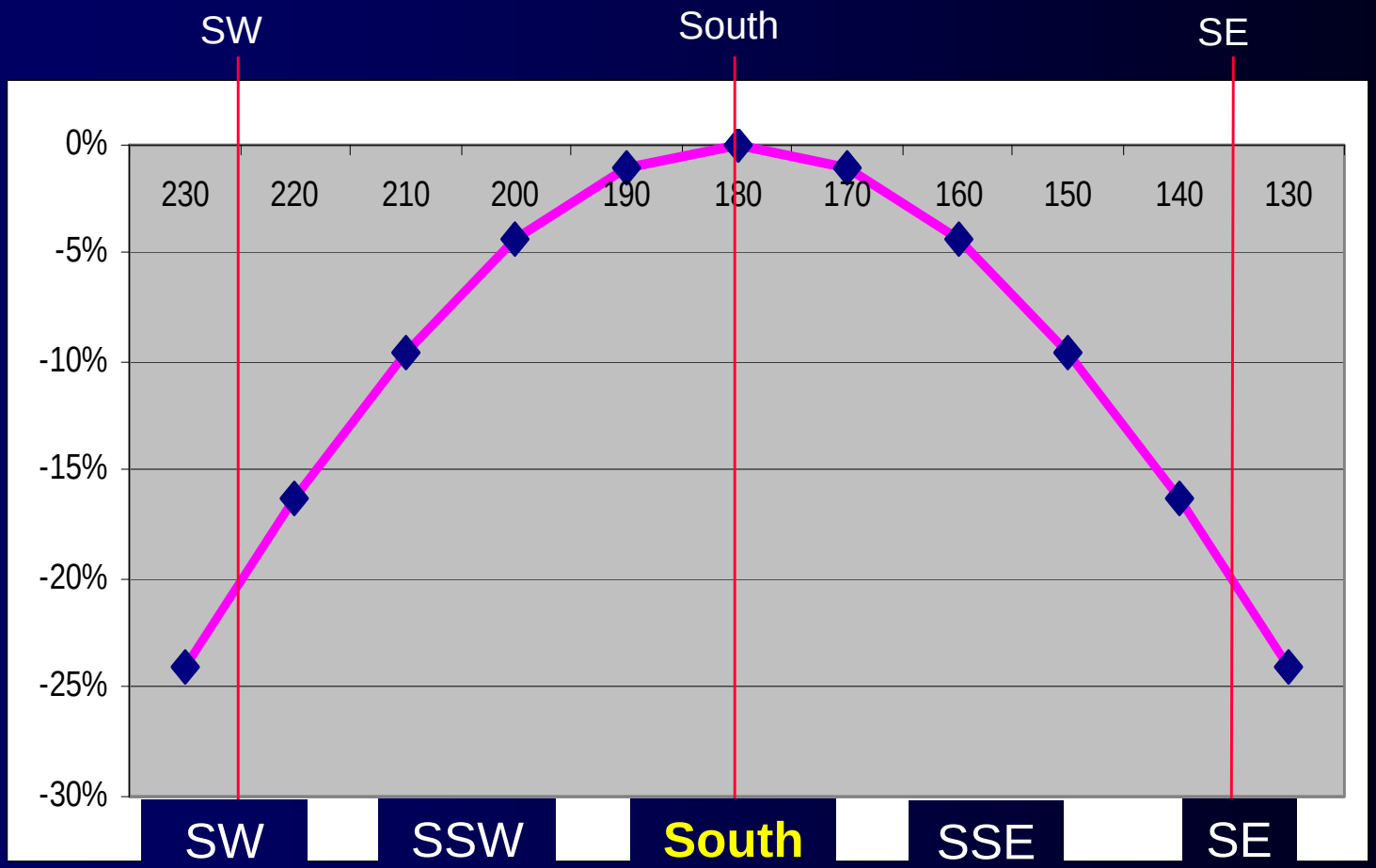


% of energy from optimum annual orientation angle

Edmonton

If the goal is to maximise the annual energy production, which occurs at a due-south orientation angle, you can locate the orientation 45° either side of south and still be within 10% of the maximum.

Optimum Winter Solar Orientation Angle



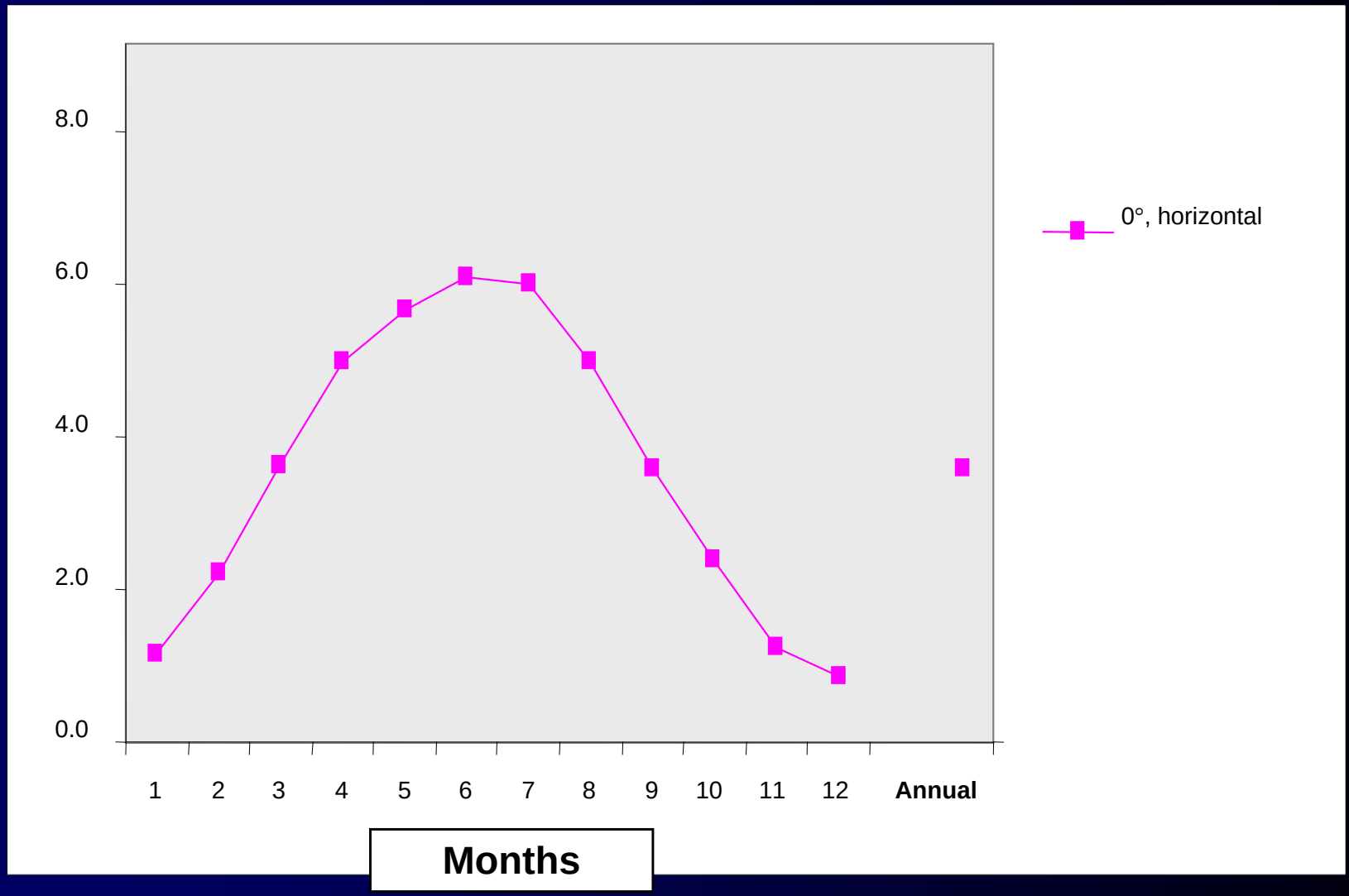
% of energy from optimum winter orientation angle

Edmonton

If the goal is to maximise the winter energy production, which occurs at a due-south orientation angle, you can locate the orientation 30° either side of south and still be within 10% of the maximum.

Solar Radiation – Horizontal

Peak daily sun-hours

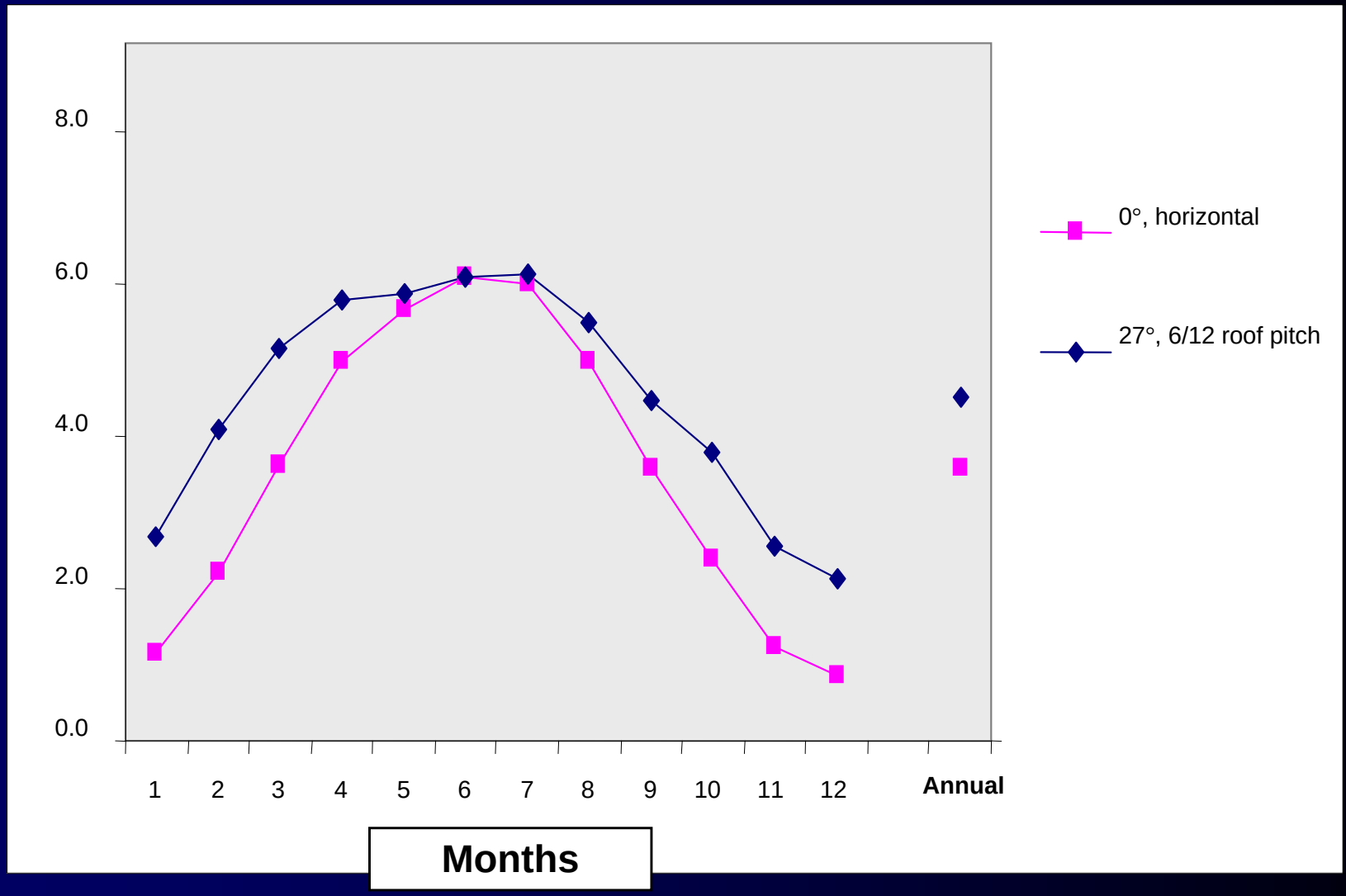


If the world is saved, it will be saved by people with changed minds, … people with a new vision.

Daniel Quinn
author

Solar Radiation – Horizontal and 27°

Peak daily sun-hours

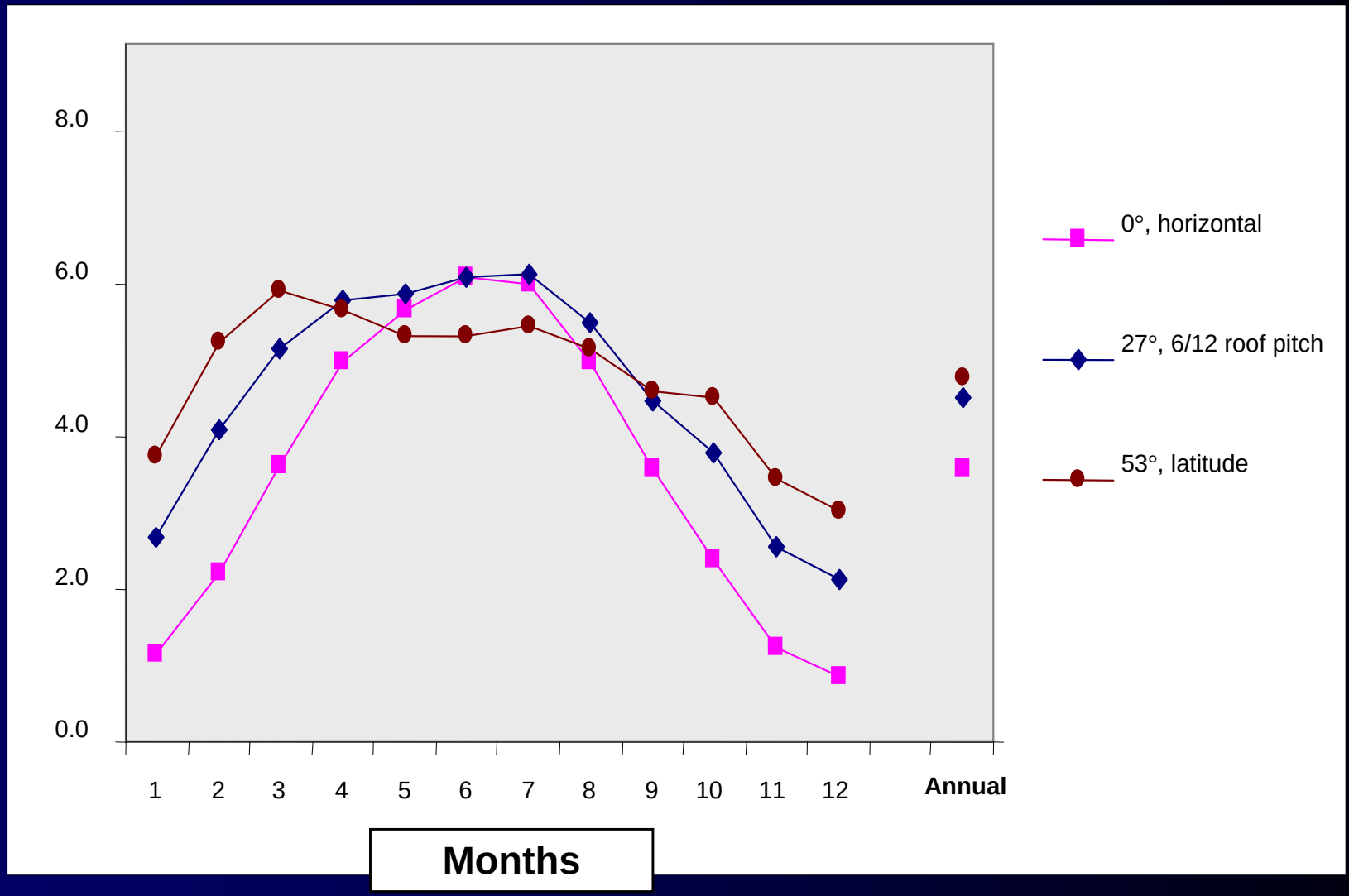


What is the use of a house
... if you haven't got a tolerable planet to put it on?

Henry David Thoreau, America

Solar Radiation – Horizontal, 27°, 53°

Peak daily sun-hours

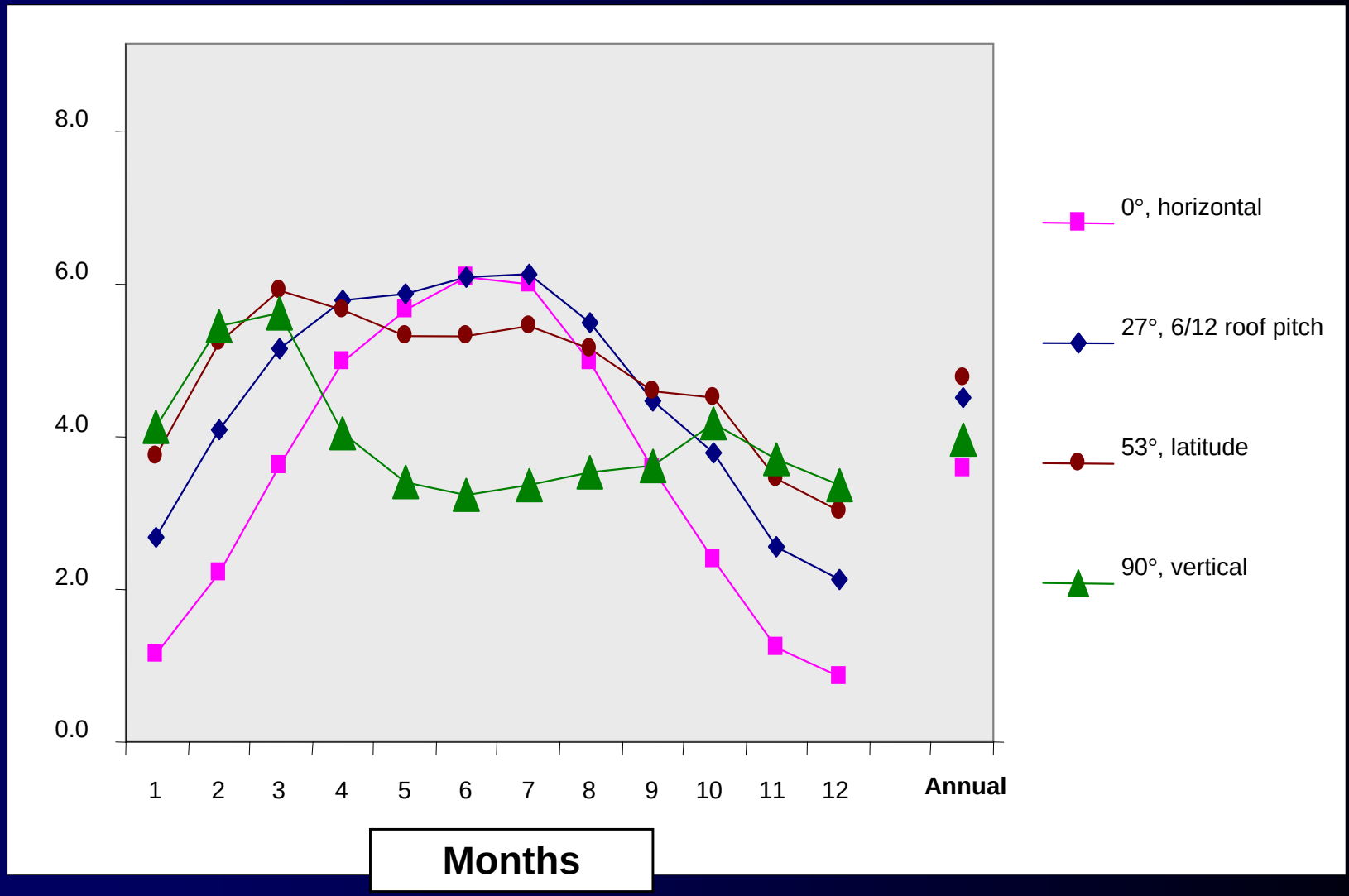


You cannot teach a man anything,
You can only help him discover it within himself.

Galileo

Solar Radiation – Horizontal, 27°, 53°, Vertical

Peak daily sun-hours



In many ways our future is passing us by,
… and our energy riches may one day look like fool's gold.

Gary Lamphier
Edmonton Journal

Questions…?

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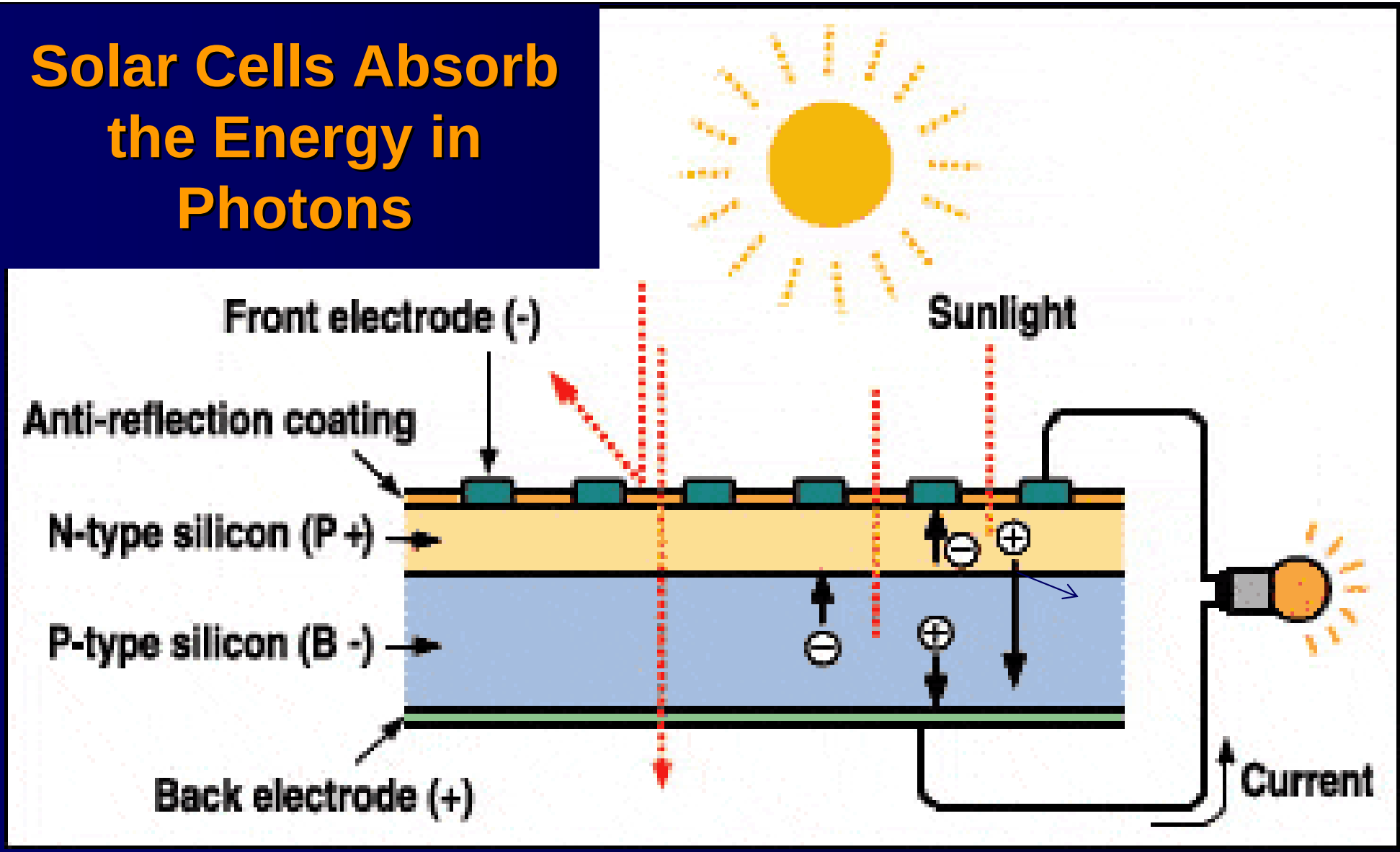
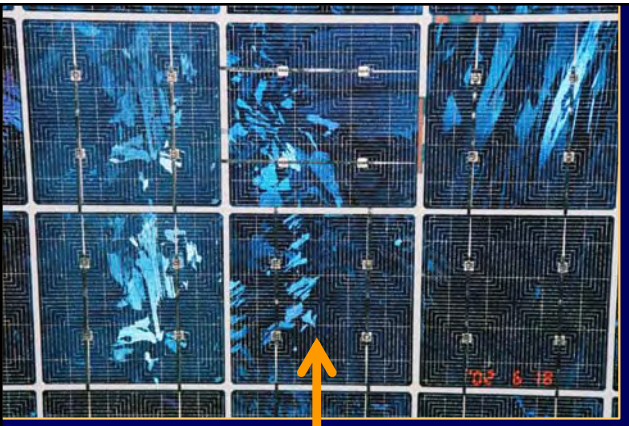
Solar Cells Absorb the Energy in Photons



- The technology is called "photovoltaics", but we only call it "PV".
- The energy in the photons knocks electrons out of their orbital shell
  – 1 electron for 1 photon.
- The electric field generated by this turns the electrons into an electric current.
- Wires carry the current away.



Solar PV Cell

Solar PV Module

PV Panel

Solar can generate any amount of electricity.

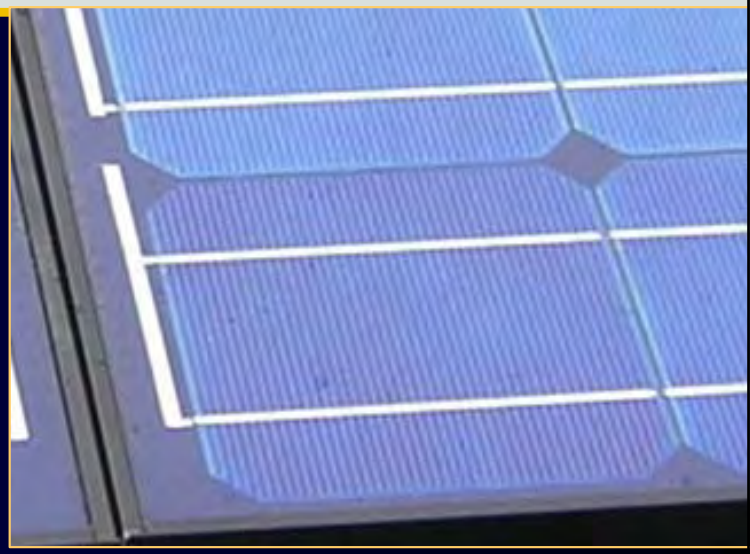
Large systems = more modules.

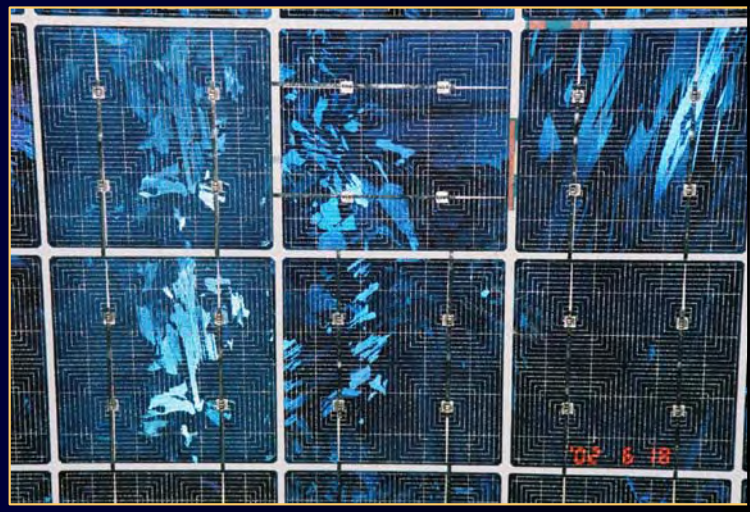
Solar PV Array

PV Modules

- Made in:
  - Japan, Germany, America, Britain, India, Australia, Spain, Canada, France
- Module brands:
  - BP Solar (Britain), Isofoton (Spain), Evergreen (America), Sharp (Japan), Uni-Solar (America), Sanyo (Japan), Sharp, Shell (Netherlands), Kyocera (Japan), Photowatt (France), RWE (Germany), Day4Energy (Canada), SunPower (America) and more…
- Technologies:
  - single-crystal, multi-crystalline
  - thin-film, amorphous

Single crystal





Multi-crystalline

Nature does provide us with a free lunch,
…but only if we control our appetites.

William Ruckelshaus

PV Module Standards

- Design, certified and tested to international standard IEC 61215
- 18 tests including:
  - Hail test – 25 mm at 83 km/h
  - Temperature cycling test, from -40°C to +85°C
  - Damp-heat test – 85°C, 85%RH for 1000 hours
  - UV test
  - Mechanical load test – to withstand wind, snow, ice loads
  - Rated performance
  - Performance at low irradiance
  - Outdoor exposure
  - Hot-spot endurance test
  - Humidity-freeze test
  - Wet insulation resistance test

It may seem impossible to imagine that a technologically advanced society could choose, in essence, to destroy itself, but that is what we are now in the process of doing.

Elizabeth Kolbert
New Yorker

PV Module Power Rating

- What do these names mean?
  - AP 120, MSX 60, GEPV-110, BP 4160
- "110 W" PV module is the rated power of the module… which is the power output of the module at rated conditions
- Rating conditions: Standard Test Conditions (called STC)
  - solar radiation at 1000 W/m^2,
  - air temperature at 25°C, and
  - air mass 1.5 times longer than straight overhead
- Max power = rated power x 125%

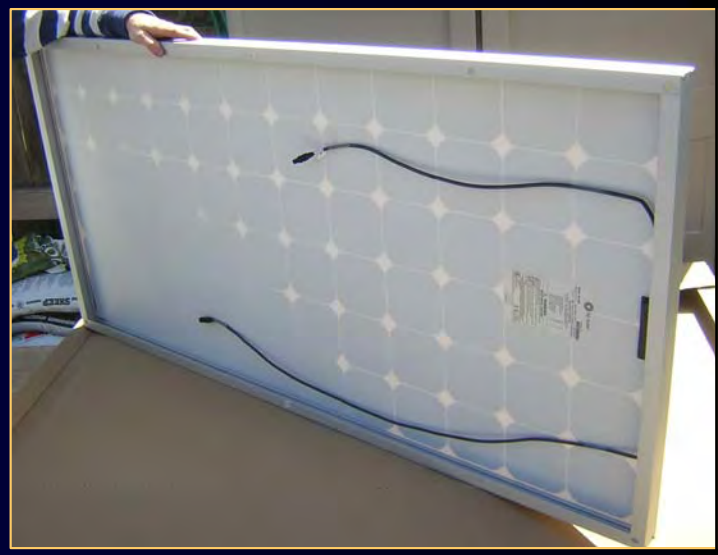
PV System Energy Production

- Performance ratio
  - Equivalent # of hours that the system would have operated at its rated capacity in order to generate the energy that it did
  - Energy / rated capacity kWh/year / kW == hours/year
  - Edmonton: ~1000 hours / year, south facing at optimum tilt angles
  - Calgary: ~1100 hours / year
  - Medicine Hat: ~1250 hours / year
- Total system energy production
  - kWh over the year = rated power x rated operating hours

Socialism collapsed because it did not allow the market to tell the economic truth.
Capitalism may collapse because it does not allow the market to tell the ecological truth.
Øystein Dahle
Exxon Norway

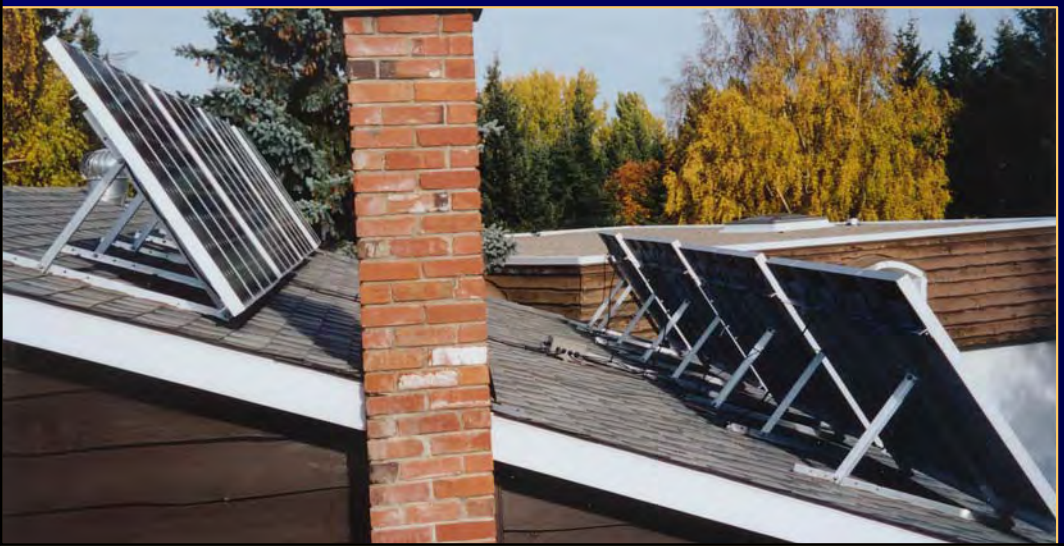
Wiring Connections

- Terminal boxes
  - Fine for small systems
  - Important for low voltage systems where many modules will be connected in parallel
  - Need access to the back of the module
  - Need to be wired together
- Quick connect pigtails (MC, Tyco connectors)
  - Great for larger systems where most of the modules are in series
  - Easy to install



PV Mounting
– on a Roof

- Aluminum rails
- Manufactured product
  - Unirac SunFrame
- Attaching to roof
  - Roof penetrations
  - Ballast weights
- Can have seasonal tracking



PV Array Mounting – on the Ground or other Structures

- Ground
- Trellis, canopy, or other structures
- Wooden, metal, manufactured

5 kW
AAMDC building
Leduc

PV Array Mounting – on a Pole

- Need space for this
- Likely will never be used in a city
- Would work well on a farm

Where there is a will, there is a way…
It's not about economics. It is about a will.

PV Array Tracking…

- Seasonal single axis
  - E-W axis, facing due south, tracking up-down
  - 12% more
- Daily single axis – N-S
  - N-S axis, optimum array tilt, tracking E-W
  - 31% more
- Daily single axis – angled
  - angled axis, optimum axis tilt, tracking E-W
  - 25% more
- Daily + seasonal 2-axis
  - tracking E-W and up-down
  - 39% more

Usually the cost of the PV array tracker and a system's increase in energy production is comparable to a fixed tilt system with a bigger PV array!

PV Tilt Angle – seasonal adjustments

- Pros
  - It can be done
  - It increases the amount of energy collected… by 10%??
- Cons
  - People usually don't want to get up onto their roof
  - Needs to be done twice a year
  - People usually do it for a few years and then quit!

Historians talk about the Stone Age, the Bronze Age, and the Iron Age.
Before too long the Petroleum Age will also be over.

Electricity Storage

- Electricity storage
  - VERY expensive
  - A battery of electrochemical cells
  - Flywheels, ultra-capacitors
- Electrochemical cells
  - Lead acid (flooded) – very common
  - Lead acid (sealed) – Absorbed Glass Mat (AGM) – needed in cold weather

  …
  - Shallow discharge (car battery, UPS systems)
  - Deep discharge (fork lift, golf cart)

Battery Sizing

- Sized according to how many days of autonomy you want to have from a generator, the grid, or the sun
  - typically 5 to 7 days or so
- Storage capacity is measured in
  - Ah of electrical charge, or
  - kWh of electrical energy
- Need to have the largest voltage possible
- Need to minimize the number of cells in parallel

Battery Maintenance

- ALWAYS wear your battery clothes…
  - they will be full of holes because of the battery acid!
- Check liquid levels
- Monthly "equalization" charge
- Clean
- Replace damaged and leaking ones
- Lifetime:
  - 5 years if you do not know what you're doing
  - 20 years if you know what you're doing

- …get info from battery supplier

When one tugs at a single thing in nature,
you find it attached to the rest of the world.

John Muir
Conservationist

Solar Electricity – Operating Costs…

- Grid-dependent:
  - no operating costs;
  - basically no maintenance costs.

- Grid-connected with battery bank:
  - no operating costs;
  - maintenance time for the battery bank;
  - short battery lifetime if you are not careful with their maintenance.

Going to a junkyard is a sobering experience…
There you can see the ultimate destination of almost everything we desire. Roger von Oech

DC to AC Inverters

Fronius IG
Austria
grid-dependent
2 kW to 5.1 kW

Xantrex ProSine
Canada
stand-alone inverter/charger
2 kW, 2.5 kW, 3 kW

SMA Sunny Boy
Germany
grid-dependent
0.7 – 6 kW

Xantrex SW
Canada
grid-connected
inverter/charger
2.5 kW & 4 kW

Inverters convert
dc electricity (produced by the solar array)
to ac electricity (used by any AC loads).

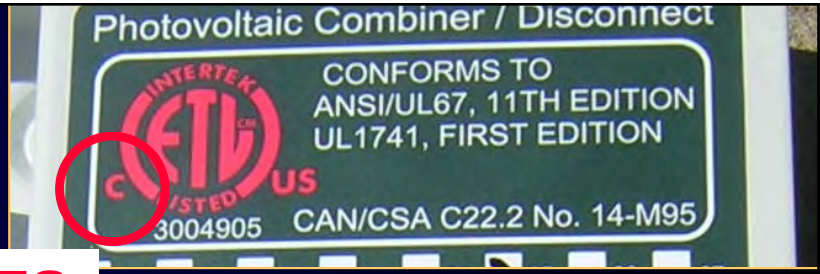
Outback FX
America
stand-alone inverter/charger
2 – 2.5 kW

Xantrex GT
Canada
grid-dependent
3.8 kW

Safety Standards

TRIMLINE training center

CSA International	
Entela	
Intertek Testing Services	
Met Laboratories	
Quality Auditing Institute	
TÜV Rheinland of North America	
TÜV Product Service	
Underwriters' Laboratories	



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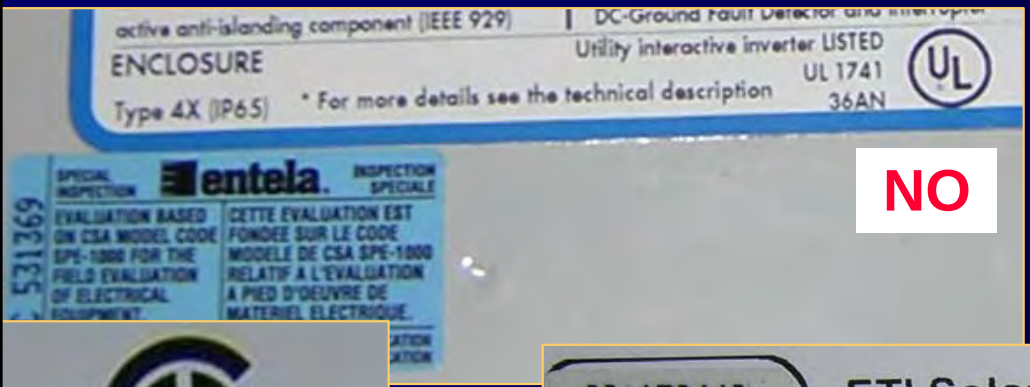
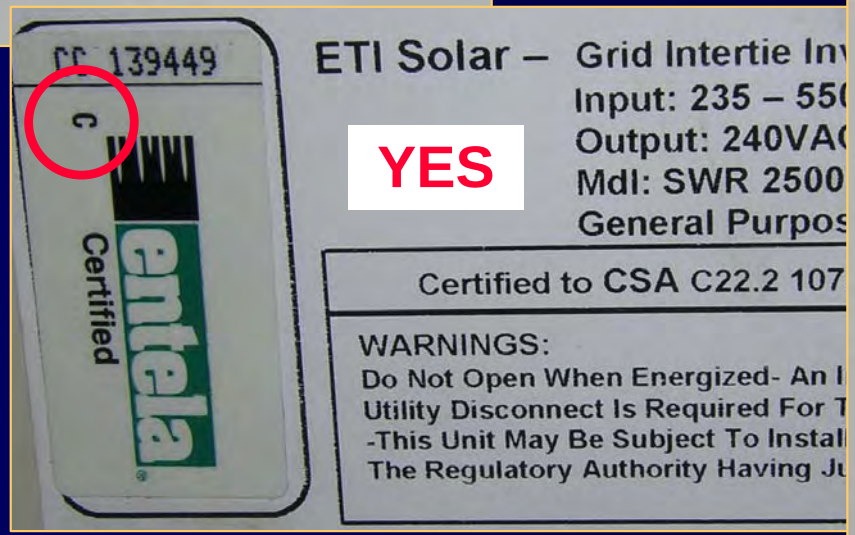


NO

NO



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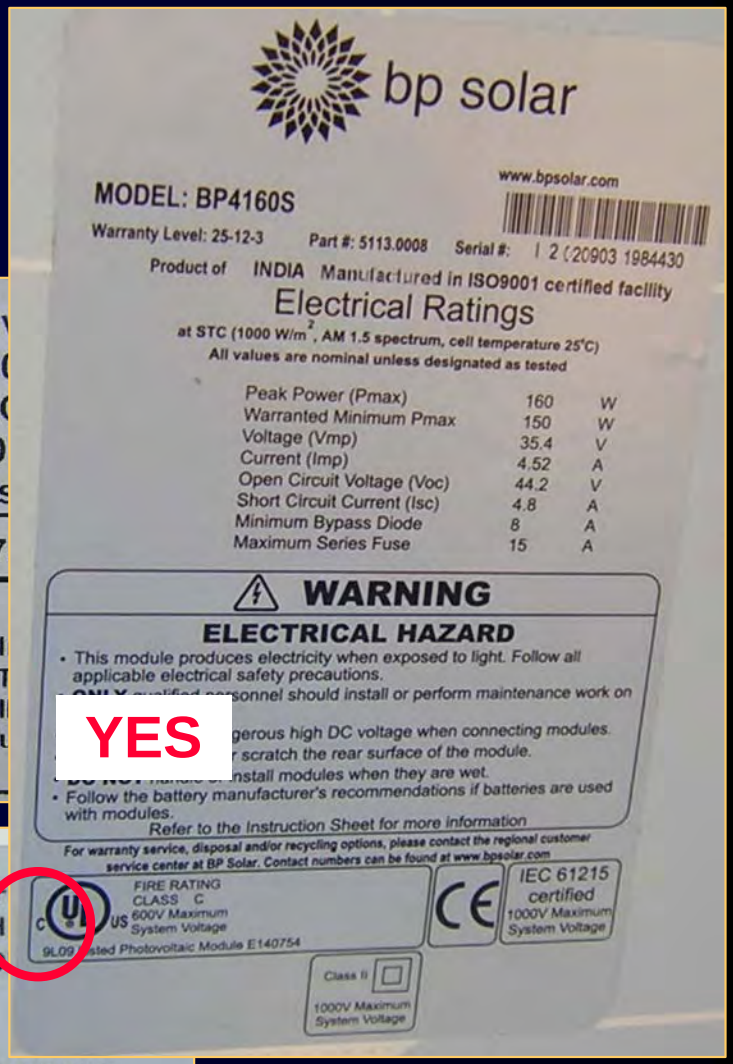

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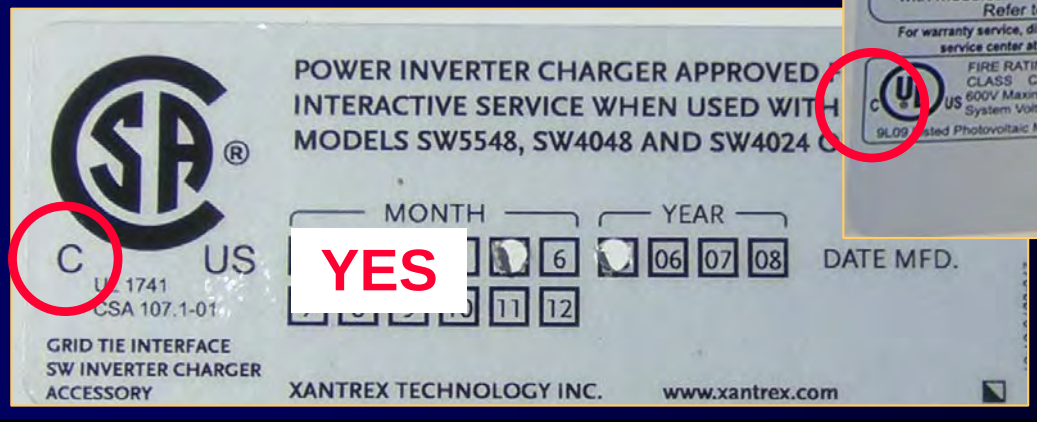

YES

Labels – which are OK?

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Next

Solar Myth:

The energy and emissions invested in solar …never pay back…! ???

- PV is zero-emission electricity.
- Payback for emissions and energy used in its manufacture:
  - 1 to 4 years depending on its application.
- In contrast, what is the energy payback for a coal- or gas-fired electric generating station?

System Operating Costs

- Grid-dependent:
  - no operating costs;
  - basically no maintenance costs.

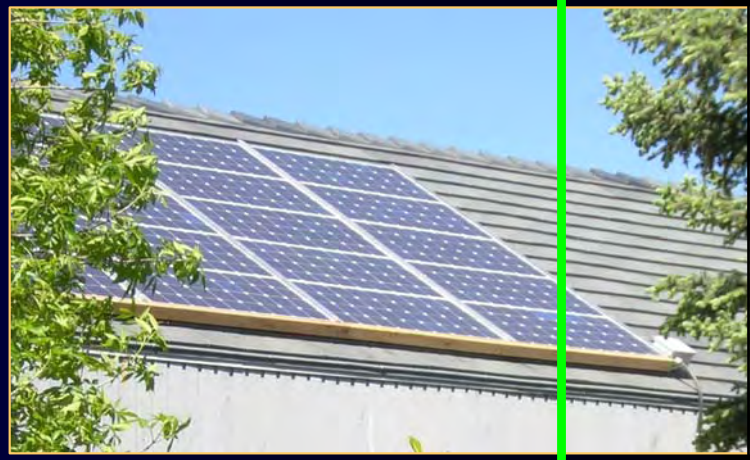
- Grid-connected with battery bank:
  - no operating costs;
  - maintenance time for the battery bank;
  - short battery lifetime if you are not careful with their maintenance.

What to look for with PV prices…

- Modules
  - Price divided by rated power: $/W
  - Example: 60 W PV module for $600 is $10 /W
  - Typically: $5 to 6 /W wholesale, $7+ /W retail
- Inverter
  - Price divided by rated power: $/W
  - Example: 2100 W inverter for $1200 is $0.57 /W
  - Typically: $0.50 to $0.80 /W
- System
  - Small off-grid system: $30 /W
  - House-sized off-grid system: $20-$30 /W
  - On-grid system: $10-$13 /W
  - Your system: _____ kW x $_____/W = $_____k

Costs Breakdown – Grid-Connected

- 2.5 kW grid-connected system in Red Deer: ~$23,000 total price
  - 56% for solar modules
  - 14% engineering design, regulatory approvals, commissioning and project management fees
  - 13% installation and electrical work
  - 10% inverter
  - 5% miscellaneous electrical parts
  - 2% module mounting rack



- Cost to generate this electricity over 25 years:
  - 0 ¢/kWh

The future does not belong to those who are content with today, fearful in the face of new ideas and bold projects. It will belong to those with a personal commitment.

Robert Kennedy
1966

Solar PV System Costs

– grid-connected PV –

- Purchase price:
  - $5k-$100k depending on the size you want!
  - For houses: typically between $15 000 to $40 000
- Price of delivered electricity:
  - 37 ¢/kWh (unsubsidized, fixed price for 25-year life of system)

  to 68 ¢/kWh when you include the cost of money
- Benefits:
  - $100 to $400/year savings in 2007, increasing at 4% per year
  - Save 30% to 100% of your electricity bill
  - ~1 to 3% return on purchase costs, if environmental, social and infrastructure benefits are ignored
  - 37 years to 150 years depending on government policies

Solar Economics

- Off-grid solar often wins economically without question
  - because the cost of bringing in utility power lines at $15,000 /km.

- On-grid solar is competitive
  - with fossil fuels that are not subsidised by society,
  - when all of solar's benefits are valued and
  - when solar is bundled with energy efficiency
  - when we are sold energy that includes all its costs bundled into energy and not unavoidable service charges.

Love does not dominate, it cultivates.
Johann Goethe

How much solar equipment is needed?

- Depends on your electricity consumption, goals for energy saving, budget, location, sightlines and array angles.

- Typically for 100% grid-connected solar electricity:

Household Consumption Value		PV system size	PV system cost
	kWh/year	$/year	# modules**	$
– large user	14,000	$1220	111	~$100 000
– average	6600	$580	52	~$55 000
– electrical wise	4000	$350	32	~$35 000
– very efficient	2000	$180	16	~$22 000

- Average household, 100% off-grid solar with no backup – $150 000+???

** 120 W module, 1050 h/y run-time…

PV System Performance

- PV performance ratio
  - # of hours that the PV system effectively operates at its rated capacity in order to generate its energy
  - $$\frac{\text{Energy per year}}{\text{rated generating capacity}} = \frac{\text{kWh/year}}{\text{kW}} = \frac{\text{hours}}{\text{year}}$$
  - For Edmonton: This is 1000 hours/year for a PV system that is at its optimum tilt and orientation angle (and a fixed angle array)
    (less at other angles) (different at other locations)
- Example calculation
  - 1 kW solar PV system x 1000 hours/year = 1000 kWh/year of energy

For more detailed calculations use the RETScreen spreadsheet analysis software available free from Natural Resources Canada www.retscreen.net

Rough array size...

- Fill out the form with your electricity consumption.
- Use the performance numbers to determine the system size to give you all your electricity consumption.

a) Your annual electricity consumption = _____ kWh/year

b) PV performance is ~1000 hours/year in Edmonton for optimal tilt and orientation angles

c) Find # of kW of capacity for 100% solar electricity = _____ kW [= a) divided by b)]

d) Portion of your electricity that you want from the sun = _____%

e) Your PV array size = _____ kW [= c) multiplied by d)]

Performance Rules of Thumb

– grid-connected PV –

- Approximate performance and cost data for Edmonton:
  - Rated operating hours: 1000 hours/year
  - PV module efficiency: 13% to 17%
  - Array area: 130 to 170 W/m^2 (13% x 1000 W/m^2)
  - Installed system cost: $8-10/W

- So if you use 6000 kWh of electricity per year, then:
  - You need a 6 kW PV array (6000 kWh/year / 1000 h/year)
  - Area of 6 kW PV array 35 to 45 m^2 (6000 / 130 W/m^2)
  - It will cost you $60,000 (6000 W x $10/W)

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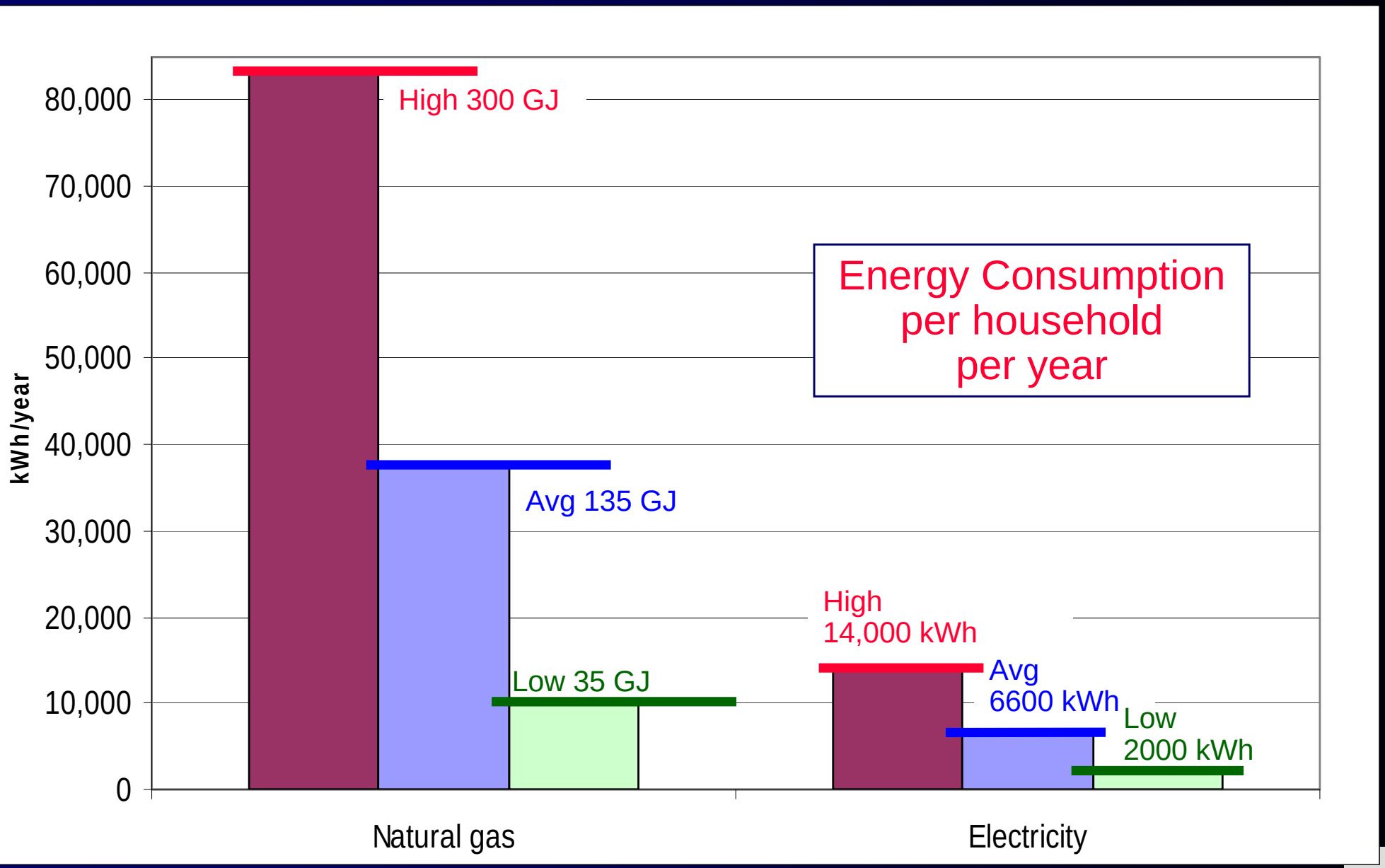
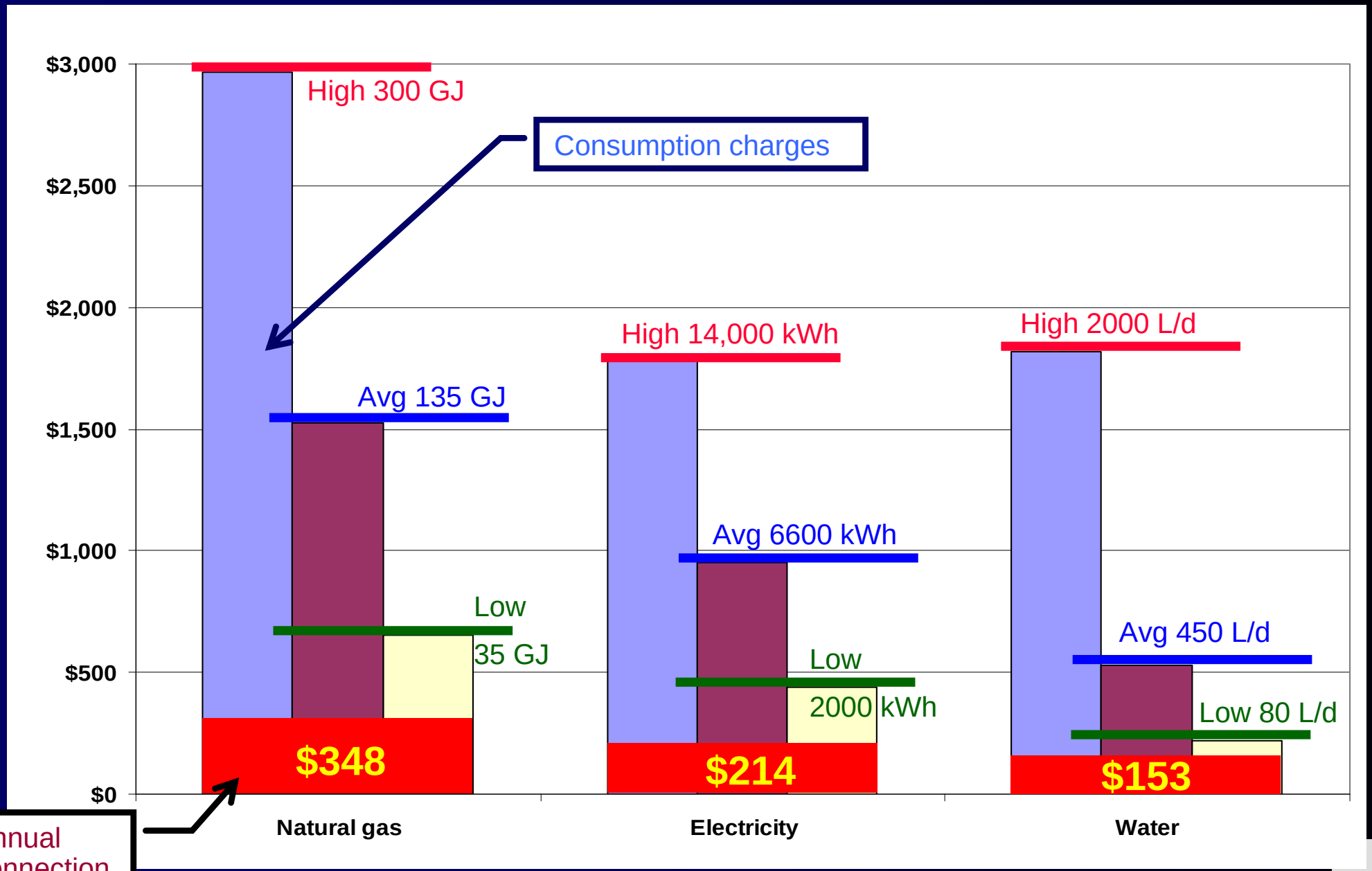
Next

Background: Our Energy Consumption

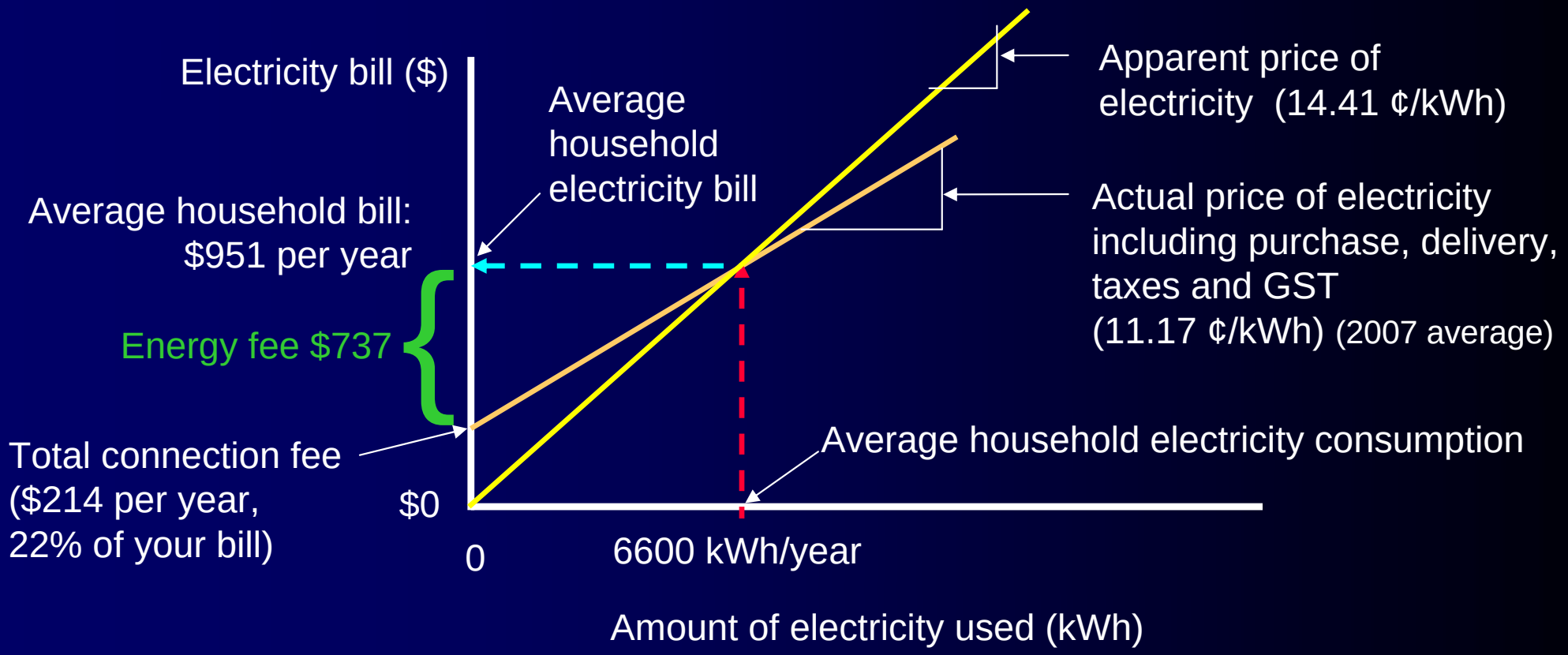


Background: Our Utility Bills



Electricity Bill (Edmonton)

- Connect fee + energy fee
- Selling electricity, delivering electricity, city access fees, GST
- Energy fee = quantity of electricity purchased and delivered + municipal access fee + GST
- For a typical house, the potential savings are $737 (78% of your bill) unless you go completely off-grid.



Natural gas price of $8.73/GJ expressed in ¢/kWh to compare with electricity: 3.14 ¢/kWh

Energy Efficiency *vs* Energy Conservation

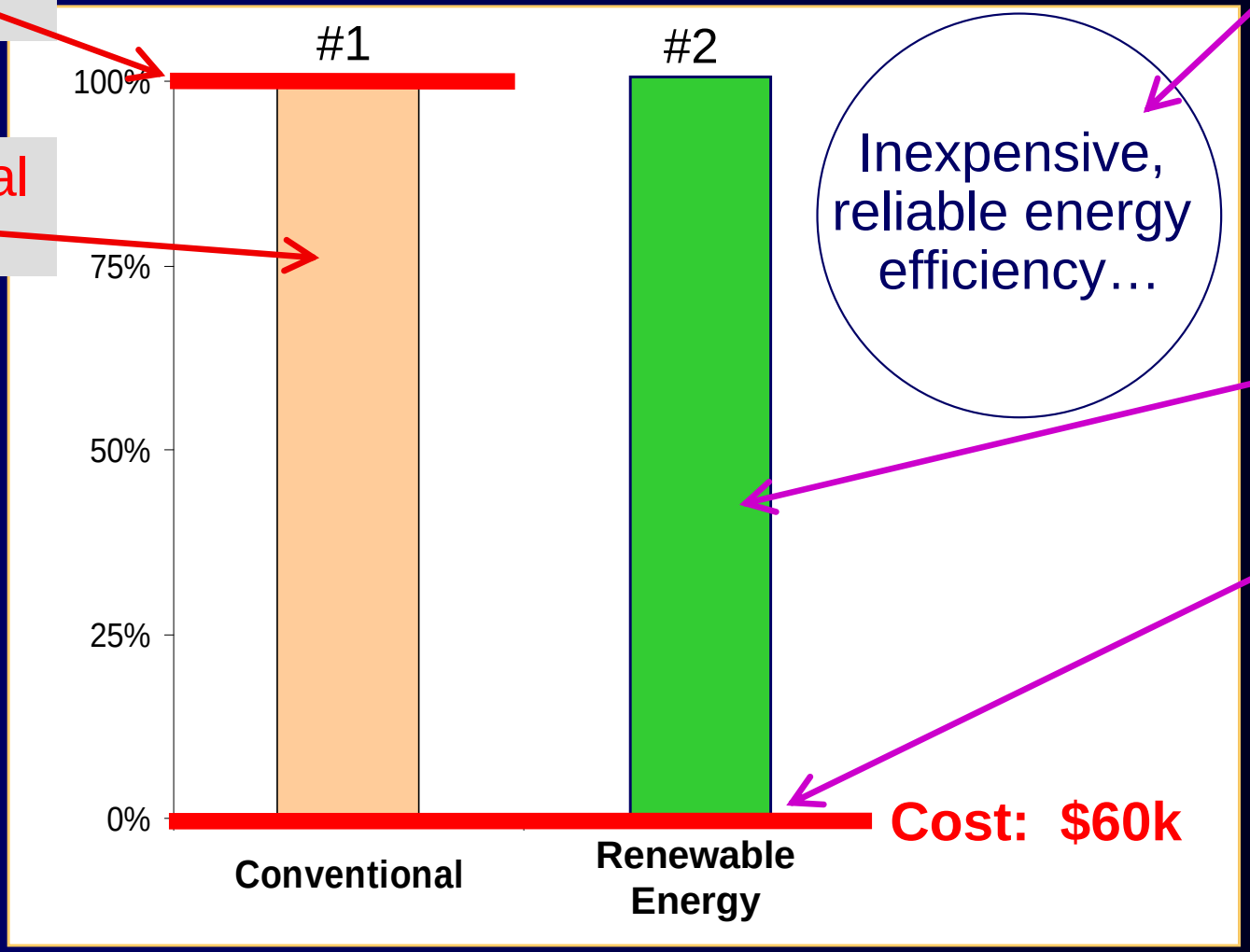
- Energy conservation means
  – doing without something (comfort, convenience, entertainment, etc)
- Energy efficiency means
  – having the same service (of comfort, convenience, entertainment, etc) but using less energy doing it.
- I prefer to focus on energy efficiency…
  – because I want the energy service –
  – I just don't want the consequences of it (costs and environmental degradation)

Reducing your electricity bills with solar PV…

– the most expensive way…

Purchased Electricity

Conventional Electricity



Where is it?

Add expensive solar electricity

Net zero electricity home

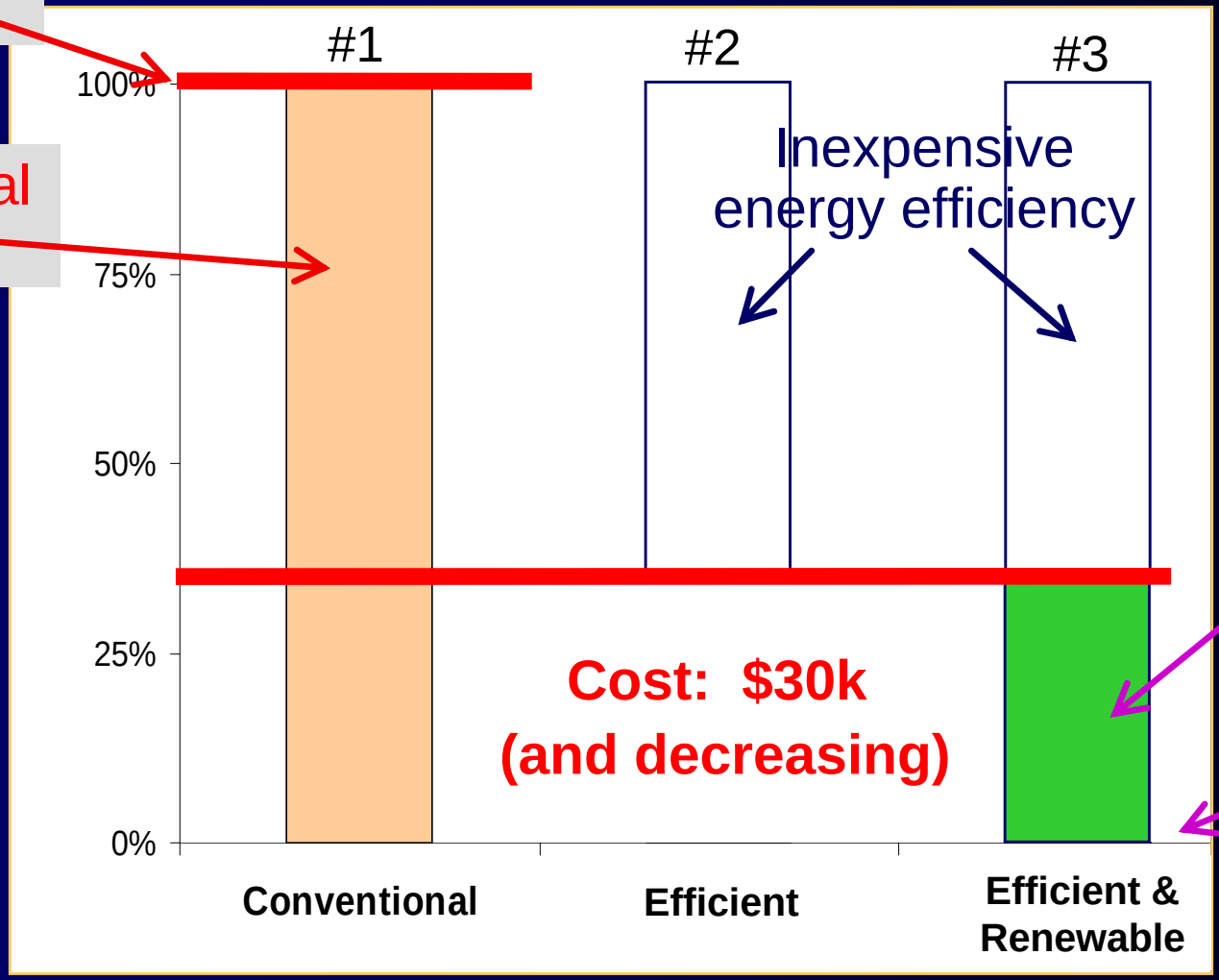
I am what I am – not because of what I should be or have to be…
…but because what I am made to be.

Reducing your electricity bills with solar PV…

– the least expensive way…

Purchased Electricity

Conventional Electricity



(but… energy efficiency is emotionally boring)

More expensive solar electricity

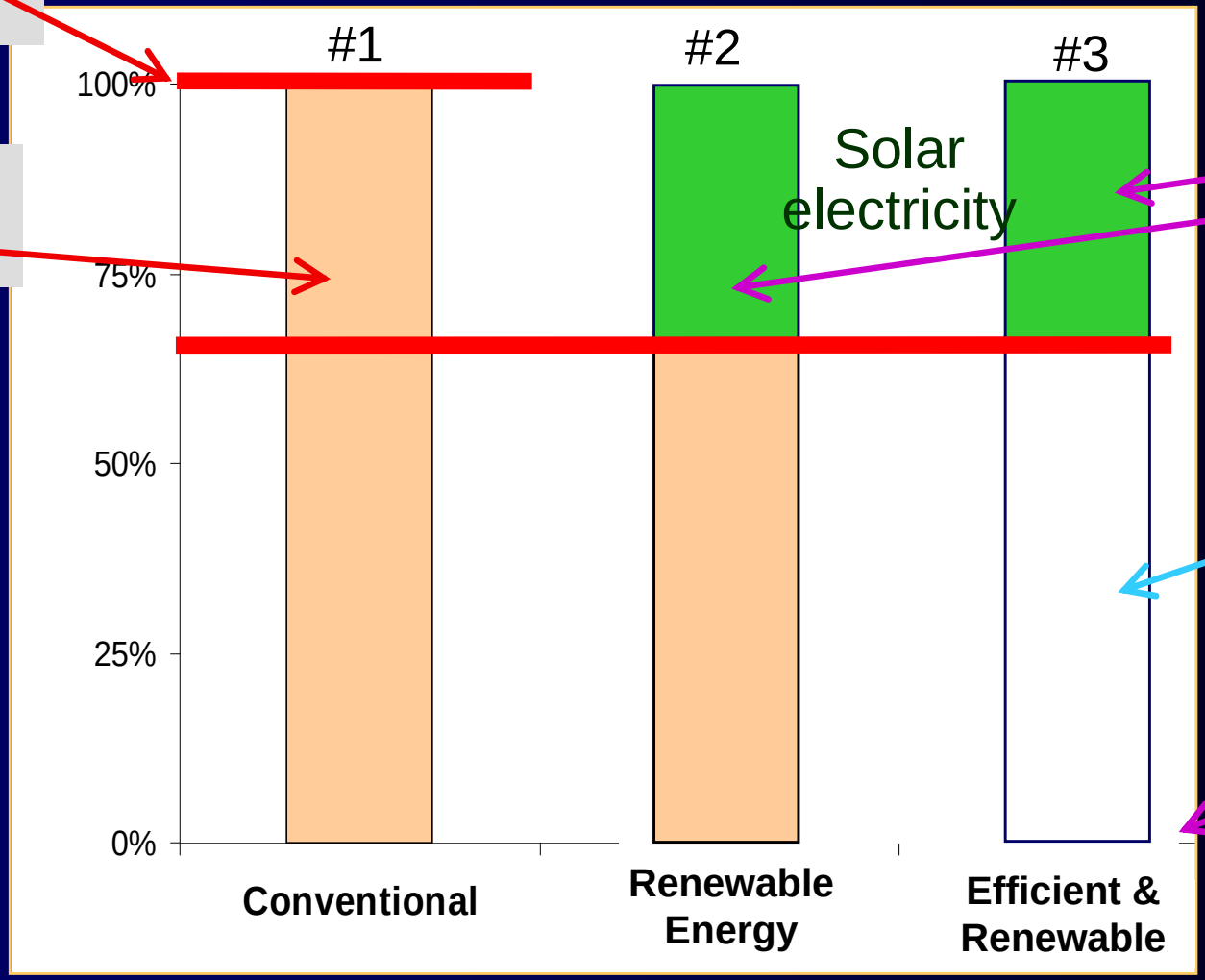
Net zero electricity home

Reducing your electricity bills with solar PV…

– the most exciting way…

Purchased Electricity

Conventional Electricity



More expensive… yeah, but really exciting

Energy efficiency: most important, least expensive

Net zero electricity home

Energy efficiency is expensive... NOT!

- Whether it is heating or electricity, energy efficiency is the **1st** and most important solution to any energy issue:
  - It is the **cheapest form** of energy – cheaper than utility energy!
  - It is the **most secure** form of energy – you don't need to care about supply and price!
  - It **reduces** our **health costs** caused by energy projects!
  - It **reduces** our environmental **footprint**!
  - It helps to **share** our resource **wealth** around our communities and with the next generation.

Where is your electricity going?

- Easy to use
- Kill A Watt meter available from
  - Edmonton Public Library (borrow like a book)
  - Canadian Tire ($25)
- Other meters

People who are doing it…

Tim Belec, Pigeon Lake

High efficiency dishwasher

Low energy Sunfrost freezer

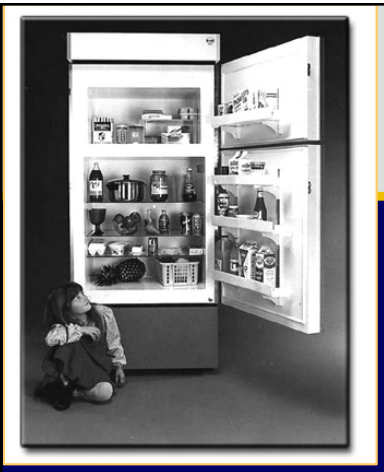
Low energy Sunfrost fridge

The Cost of Energy Efficiency

- Compact Fluorescent Light Bulbs -

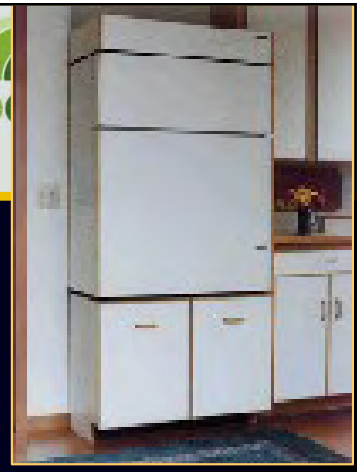
Cost of electricity in Edmonton (including delivery and taxes)	11.17 ¢/kWh
Cost of energy efficiency: • 20 W compact fluorescent light bulb (cost $4) • Replacing a 100 W incandescent light bulb • Same amount of light, but 1/5 the electricity and emissions Using 2007 average price data: 100 W cost $12.23/year to run; 20 W cost $2.45/year to run; savings are $9.78 in electricity. Extra gas costs for heating are $2.96/year (for standard efficiency furnace). Emission reductions are 56 kg CO2/year (including increase in furnace GHG) Note: All these economic #s change significantly when the price of electricity and gas changes.	2.4 ¢/kWh energy cost! $6.45/year savings 237% return on purchase costs 5 month payback in costs!
Savings in average electricity bill for each 100 W light bulb changed!	1.3%
# of 100W to 20W bulb changes to give 1 Tonne of GHGs saved:	18

Concern for man and his fate must always form the chief interest of all technical endeavours....
Never forget this in the midst of your diagrams and equations. Albert Einstein, 1931



The Cost of Energy Efficiency

- Fridges -



Cost of energy efficiency: • New fridge that replaced my 20-year old fridge • Reduced its energy use and emissions to ¼ • Purchase price $1035 Using 2007 average price data: Old fridge cost $189/year to run; new one cost $40/year to run; savings is $149 in electricity. Extra gas costs for heating are $45/year. Emission reductions are 857 kg/year. Note: All these economic #s change significantly when the price of electricity and gas changes.	9.3 ¢/kWh energy cost $62/year savings 6.0% return on purchase costs Simple cost payback: 16.6 years without including increase in electricity prices
Savings in an average household electricity bill!	20%
Portion of 1-Tonne of GHGs saved:	86%

Electrical energy efficiency is a secure investment.

Insanity is doing the same thing over and over …and expecting different results.

Benjamin Franklin

Importance of Energy Efficiency

	Reasons for Electricity Savings		Price	Avg House
1.	**Total Electrical Service**		**¢/kWh**	**6600 kWh**
2.	Savings -- lifestyle choices		0 ¢	0%
3.	Savings -- solar PV		37-68 ¢	0%
4.	Savings -- appliance efficiency		1 to 4 ¢	0%
5.	Fossil-fired utility electricity		11.17 ¢	100%
6.	Net electricity required by house		**11.17 ¢**	**6600 kWh**
7.	**Net solar electricity production**			**0%**
8.	**Net Fossil Electricity Required**		**11.17 ¢**	**6600 kWh**
9.	Net CO2 emissions			5696 kg
10.	**Electricity cost @ current prices**			**$737**

It is not a sign of weakness to change direction,
but a mark of moral strength and wisdom in the light of further thought.

Peter Watson, Anglican
Archbishop of Melbourne

Importance of Energy Efficiency

	Reasons for Electricity Savings	My House	Price	Avg House
1.	**Total Electrical Service**	**6600 kWh**	**¢/kWh**	**6600 kWh**
2.	Savings -- # people in house, lifestyle choices (~2500 kWh)	38%	0 ¢	0%
3.	Savings -- solar PV (~2100 kWh)	32%	37-68 ¢	0%
4.	Savings -- appliance efficiency (~1900 kWh)	28%	2 to 9 ¢	0%
5.	Fossil-fired utility electricity	2%	11.17 ¢	100%
6.	Net electricity required by house	**2000 kWh**	**11.17 ¢**	**6600 kWh**
7.	**Net solar electricity production**	**1853 kWh**	**30 ¢**	**0%**
8.	**Net Fossil Electricity Required**	**147 kWh**	**11.17 ¢**	**6600 kWh**
9.	Net CO2 emissions	127 kg		5696 kg
10.	**Electricity cost @ current prices**	**$16**		**$737**

The difference between what we do and what we are capable of doing would suffice to solve most of the world's problems. Mahatma Gandhi

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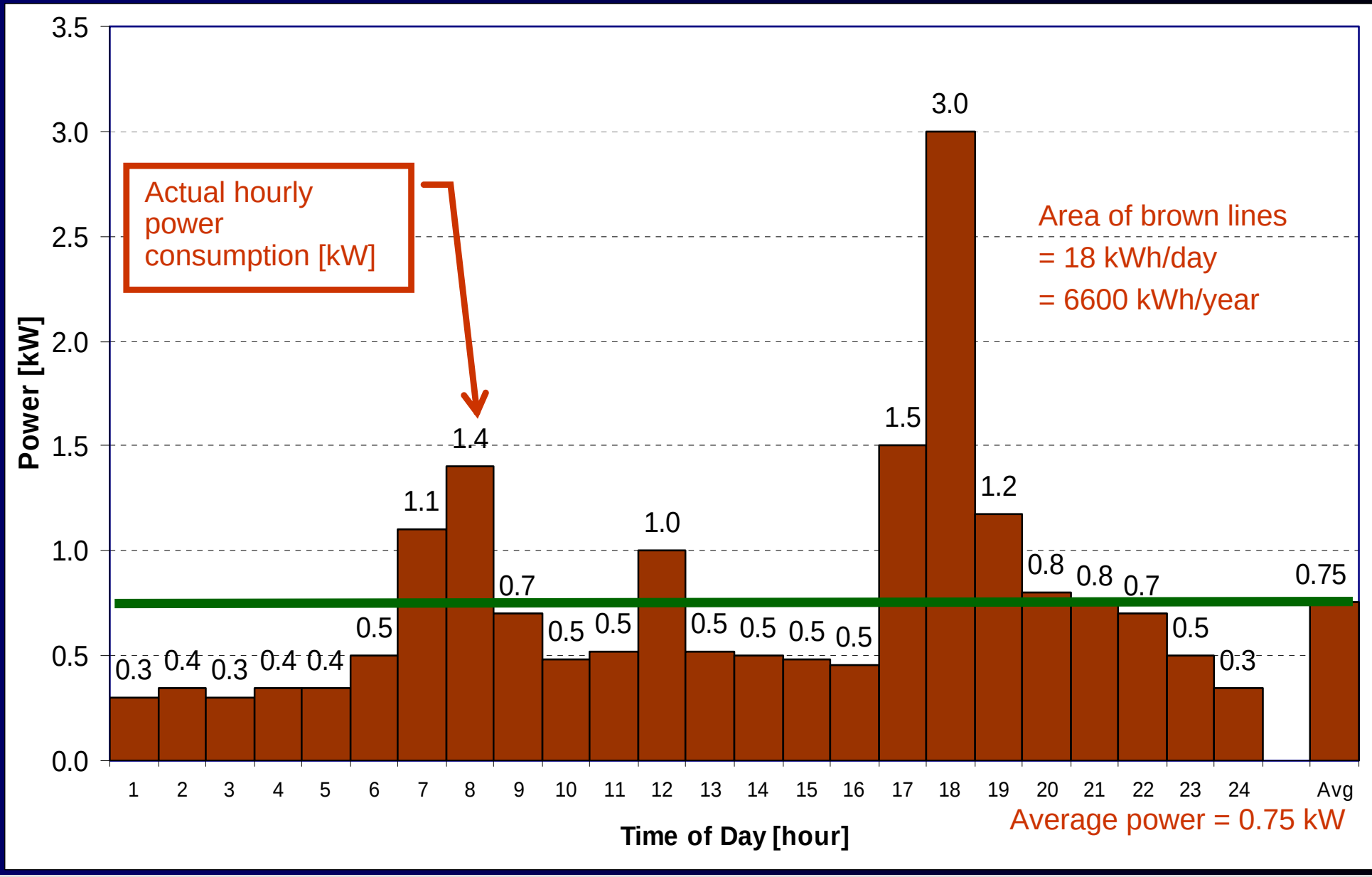
Making the simple complicated is commonplace. Charles Mingus
Making the complicated simple, awesomely simple, that's creativity.

Exporting to the Grid

– What is Really Happening?

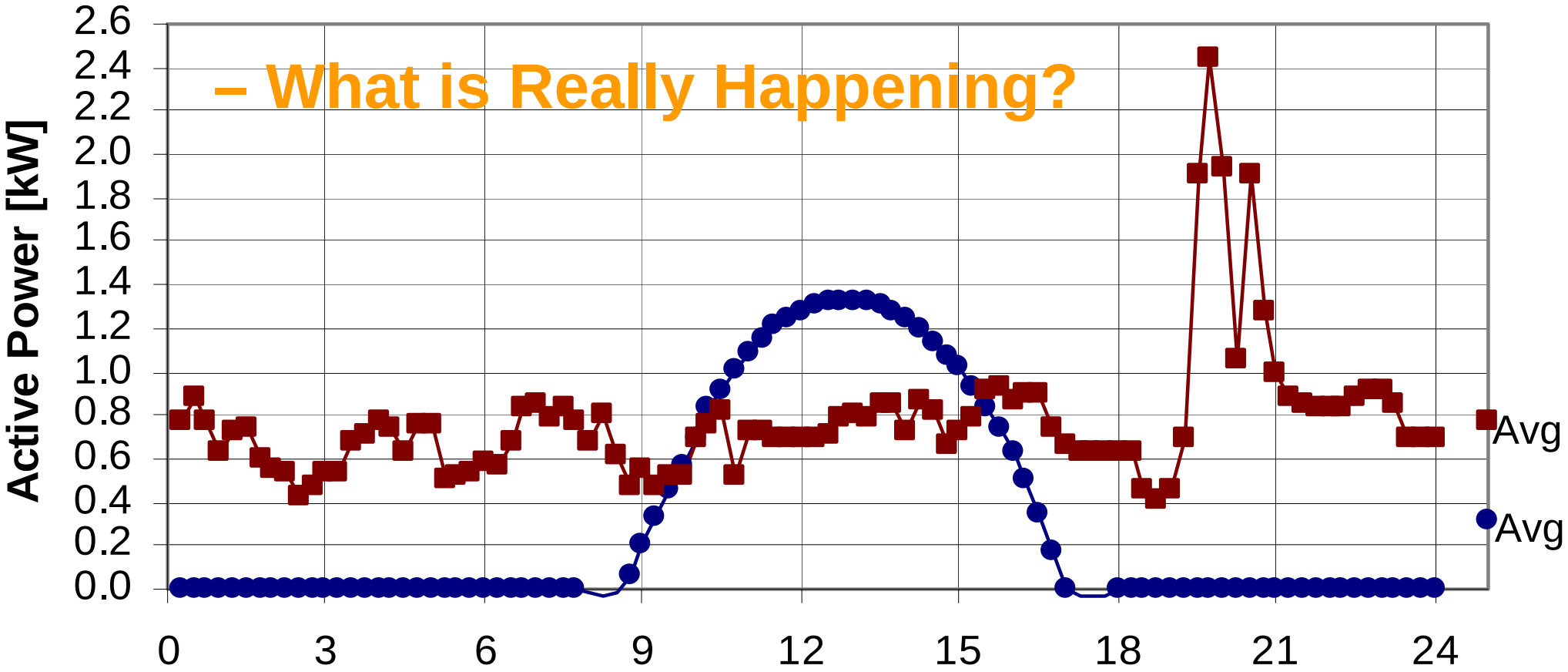
	Scenario:	#1.	#2.	#3.
	Consumption [kWh/year]	2000	2000	2000
A.	Generation [kWh/year]	1500	2000	2500
B.	How much is imported?	?	?	?
C.	How much is exported?	?	?	?

Daily House Electrical Load Profile



Consumption and PV Generation Profiles

– What is Really Happening?



Solar energy:	190 W/m²,	4.6 sun-hours
System efficiency:	7.8% !!	
Operating time:	3.2 hours	

Electrical consumption:	773 W, 18.6 kWh
Solar PV generation:	312 W, 7.5 kWh
Excess electricity exported:	30%, 2.2 kWh
Deficit electricity imported:	72%, 13.3 kWh
Solar fraction:	gross 40%, 28% net

Connecting to the Grid

This is another course in itself…

- Can be done…
- Issues:
  - Alberta's generator regulatory process
    - 60 paperwork steps to connect a system, involving
      - Petroleum Registry of Alberta,
      - Alberta Electric System Operator,
      - Alberta Utilities Commission.
    - Another 16 regulatory steps to sell the electricity…
  - Cost of being paid for exported electricity
    - Meter data handling costs (up to $288 per month (ATCO Electric))
    - Electricity market participation costs ($268 per year)
- Alberta Energy is implementing their plans to simplify this by July…

How does "net metering" work?

("net metering" means "running your meter backward")

- as solar power system owners see it

Energy Retailer & Wires Service Provider

Exported electricity is carried to neighbour without extra carriage fees, and displaces the electricity that would have been otherwise provided by the Energy Retailer.

Electricity distribution lines

1 kWh

Electricity paid in full

1

Import

kWh

Ordinary kWh meter (goes both ways)

2

1 kWh

PV system owner runs the meter backwards, sending the previously imported electricity back for full credit. In effect, the PV system owner stores the Energy Retailer's electricity but without charging any storage fee.

Export

3

1 kWh

4

Neighbour pays the ER and the WSP full fees for the electricity and its delivery.

kWh

Ordinary kWh meter

PV system owner

Neighbour

1 kWh supplied, 1 kWh paid for

How does net metering work?

- how the Wires Service Providers see it

Energy Retailer & Wires Service Provider

1 kWh

The Wires Service Providers "store" in its wires the PV electricity produced in the daytime.

3

Electricity distribution lines

4

1 kWh

1 kWh

Electricity paid in full

1

2

PV system owner runs the meter backwards, reversing the full charges for the same amount of previously imported electricity.

The Wires Service Provider "re-delivers" the exported electricity back to the PV system owner at night, offsetting the amount exported in the daytime.

Import

Export

kWh

Ordinary kWh meter (goes both ways)

PV system owner

Some Wires Service Providers have said that by reversing the meter, the PV system owner steals electricity from the Energy Retailer, the electricity that was previously sold and delivered in step 1.

1 kWh supplied, 1 kWh paid for

How does 1-way metering work?

- how the micropower system owner's sees it

Energy Retailer & Wires Service Provider

The Energy Retailer contracts the Wires Service Provider to deliver the energy to neighbours for full fees but without taking custody of it!

Electricity distribution lines

1 kWh

1 kWh

3

1 kWh

The AESO gives the energy to the Energy Retailer to sell to neighbours, but without having to pay for it!

Electricity paid in full

1

2

Energy is supplied to the AESO for free. The public considers this to be stolen electricity.

4

Import

Export

kWh

Latched (one-way) kWh meter

kWh

Ordinary kWh meter

When electricity is being reverse fed, these meters have an inaccuracy of 100%!

PV system owner

Neighbour

1 kWh supplied, 2 kWh paid for!

How does net billing work?

Energy Retailer

Some Wire Service Providers have meter reading fees that are quite high relative to the value of the electricity delivered.

($2 to $10 fees per day to deliver 40¢ to $1.50 worth of electricity). Its time we correct this.

Electricity distribution lines

1 kWh

Electricity paid in full

1

Import

2

1 kWh

Export

3

1 kWh

Energy Retailer sells it to the neighbour for full retail price.

4

kWh

Bidirectional kWh meter

kWh

Ordinary kWh meter

PV system owner

Net billing permits exported electricity to be valued at any price, such as:
- a discounted wholesale price,
- a price equal to the import price, or
- a premium feed-in (green) price.

Neighbour

1 kWh supplied, 1 kWh paid for

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Cold Climate Solar House, Edmonton

2 kW ARISE GX 5000 inverter.

205 VDC, 240 VAC, 2.3 kW PV

Installed in 1995

Cost now $21,000

Electricity generation: ~$200 per year

Supplies ~100% of annual electricity needs

Sponsored by EPCOR, NRCan, City of Edmonton, HME in 1995.

2.3 kW solar PV

Sells excess to the Alberta Electric System Operator's Energy Trading System

Buys from EPCOR

We are all faced with a series of great opportunities brilliantly disguised as impossible situations.

Tim Belec's Home, Westerose

2.5 kW SunTie inverter

- Exports on any sunny day of the year.
- Needs to have net metering but is being refused.
- Utility company wanted him to purchase a bi-directional meter for $1215.
- Currently the system is running as a guerrilla!

Installed in 2002

Cost now ~$7,000

Electricity generation: ~$50 per year

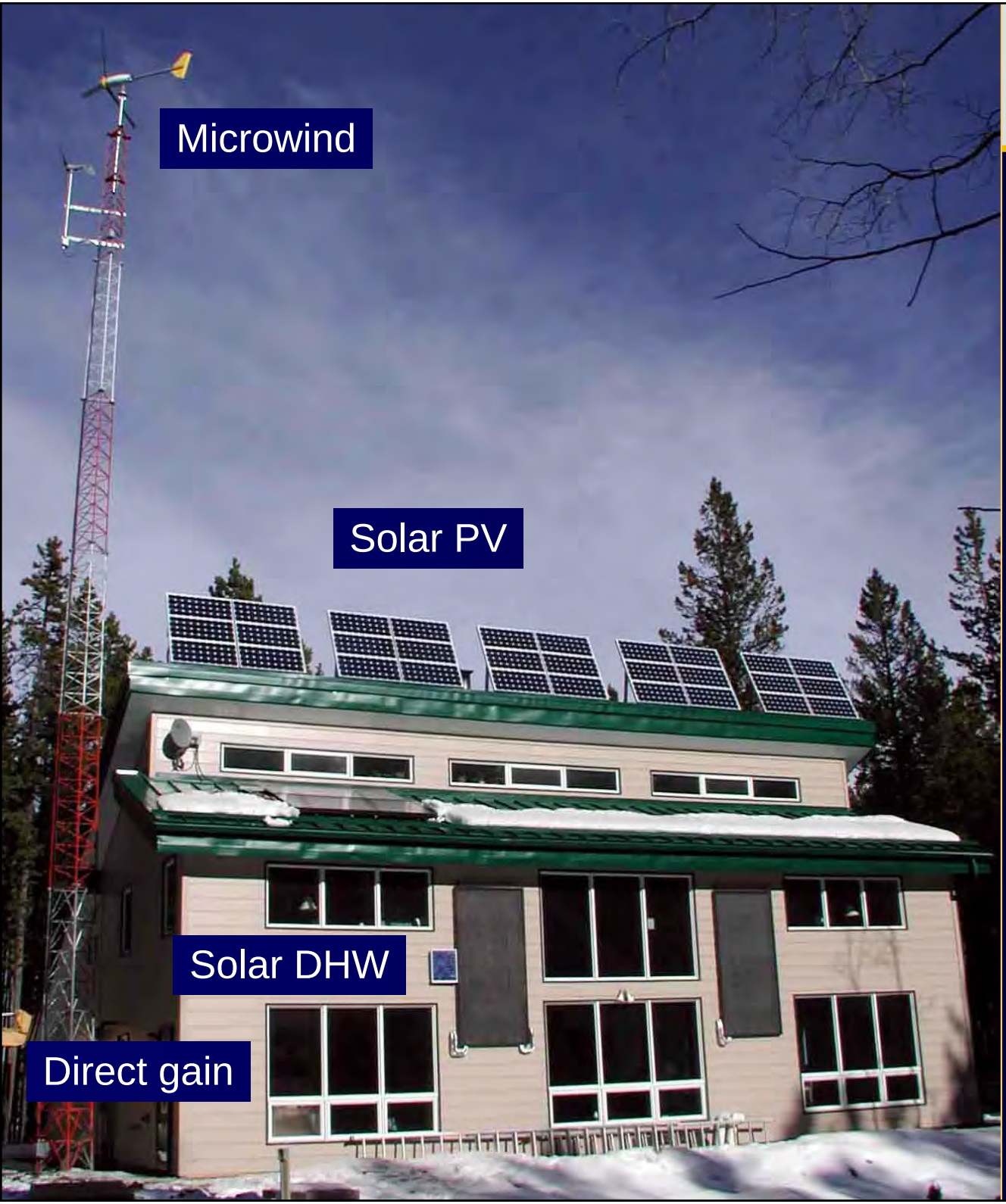
Annual electricity export value: $6

500 W solar PV

Needs net metering

We make a living by what we get...
but we make a life by what we give.

Winston Churchill, England



People who are doing it… Ralph Carter, Bragg Creek

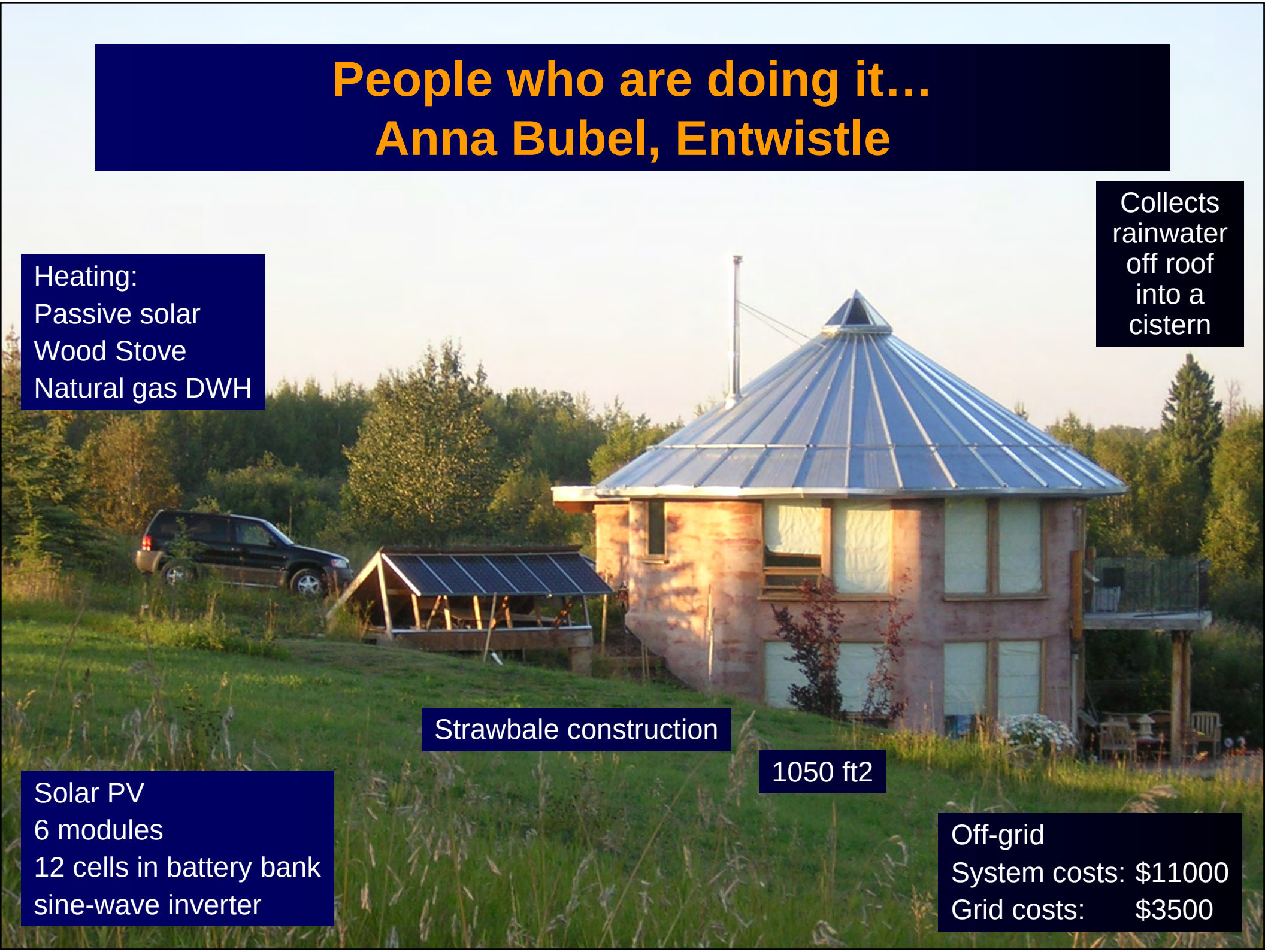
Home energy efficiency

Home energy strategy

Off-grid electric,
uses natural gas for heating

NO electrical backup!

People who are doing it…
Anna Bubel, Entwistle



Heating:
Passive solar
Wood Stove
Natural gas DWH

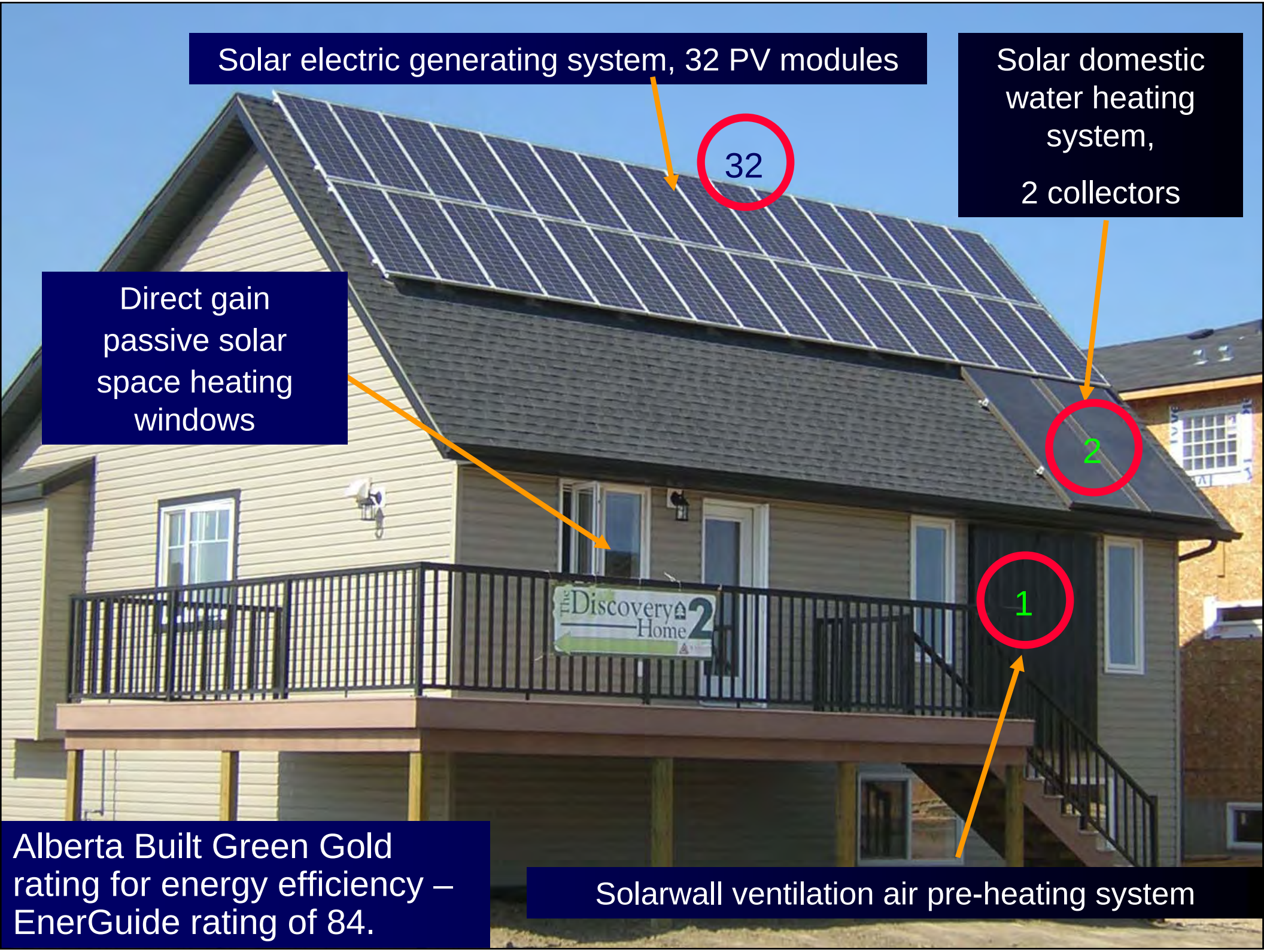
Collects rainwater off roof into a cistern

Strawbale construction

1050 ft2

Solar PV
6 modules
12 cells in battery bank
sine-wave inverter

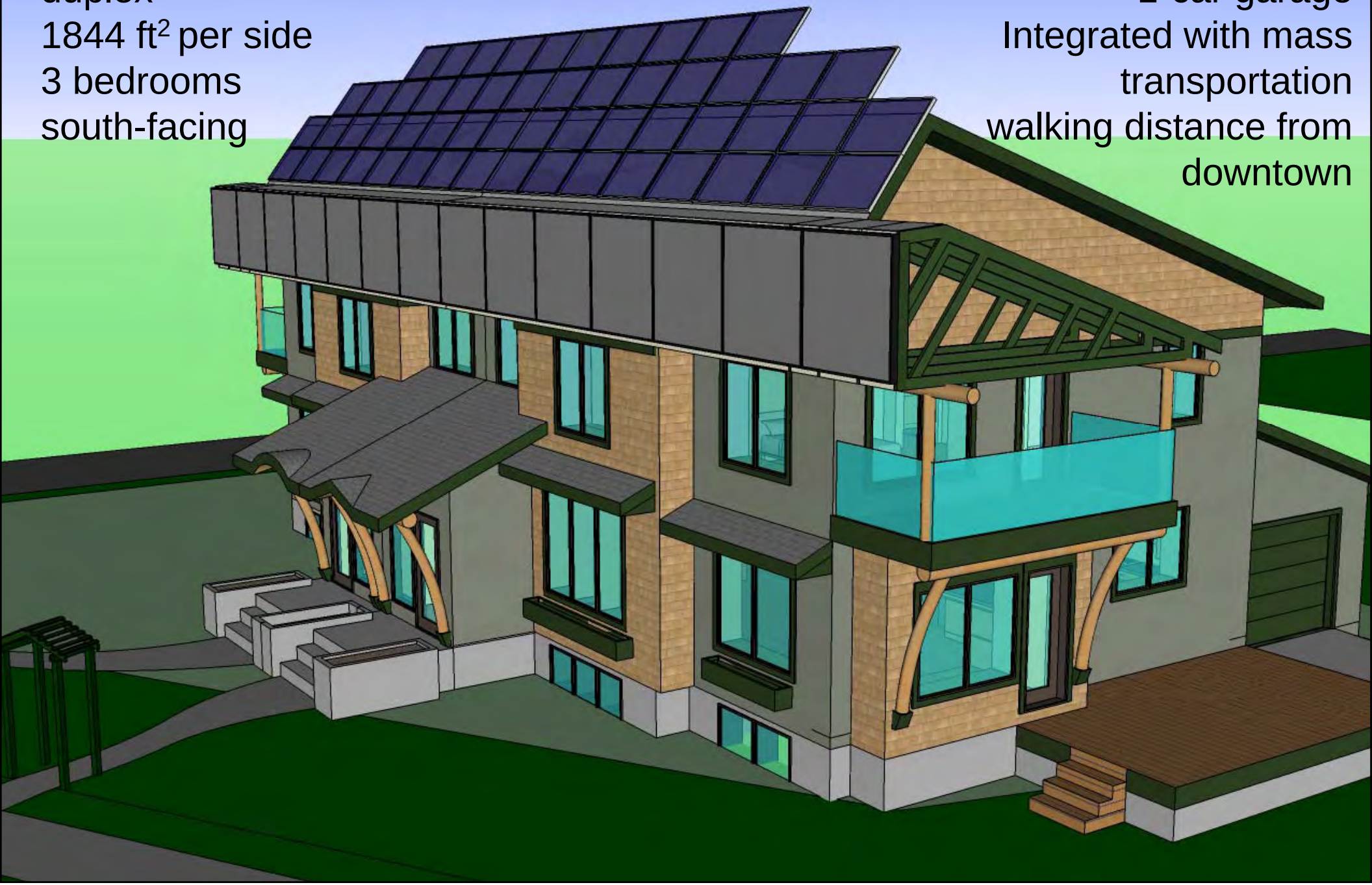
Off-grid
System costs: $11000
Grid costs: $3500


Solar electric generating system, 32 PV modules
32
Solar domestic water heating system,
2 collectors
2
Direct gain passive solar space heating windows
The Discovery Home 2
1
Alberta Built Green Gold rating for energy efficiency – EnerGuide rating of 84.
Solarwall ventilation air pre-heating system

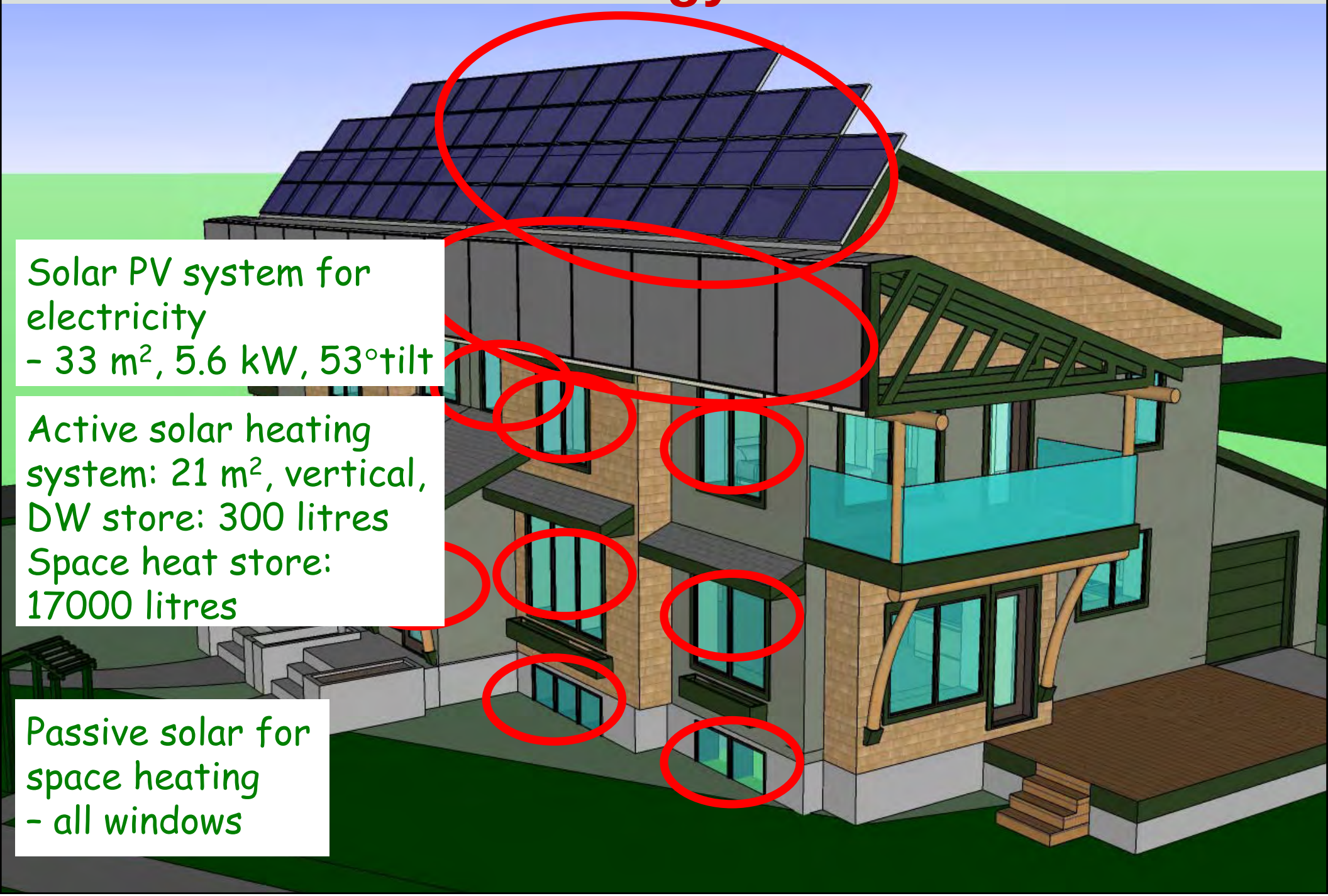
Riverdale NetZero Energy Home

duplex
1844 ft^2 per side
3 bedrooms
south-facing

1-car garage
Integrated with mass transportation
walking distance from downtown



Riverdale NetZero Energy Home



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Your own solar system…

Getting ready

- Decide why you want solar in your house
  - $ savings, emission savings, peer leadership…
- The solar industry is contacted by many many tyre kickers…
  - This is not helpful to anyone
  - If you come prepared then you will show that you are serious and so get noticed and respected

In the past 30 years, 1/3 of Earth resources have been consumed. In the next 50 years, the population will double, & natural resources will fall by 50 - 75%/person. Worldwide Fund for Nature, 1998

Your own solar system…

1. How much solar electricity do you need?

- Size of your solar PV system depends on:

  How much electricity do you use in a year?

  - average residential electricity use is 6600 kWh (24 GJ)
    (range from 2400 to 14000)

  If you use less electricity to begin with,
  then the size of your solar PV system is smaller!
  …and way less expensive

- Get your electricity bills together for at least 1 year
  (2 years is even better).
- Add up all the kWh that you use.
  - This gives equipment suppliers a good idea of how much energy you use and so what % that their system can supply you

Some men have thousands of reasons why they cannot do what they want to…
when all they need is one reason why they can.

Your own solar system…

2. How much do you want?

- Size of your solar PV system depends on:

  How much of your electricity you want to get from the sun?

  How many $ per year?

  or

  What % of your energy? 10%, 50%, 100%, ???

  or

  How many kWh are you wanting?

- This number is a target.

  You don't have to have all your electricity provided by solar.

  This is decided by knowing how much electricity you are using and what is your budget – and it is a guess until you know the other figures.

Your own solar system…

3. What is your budget?

- Size of your solar PV system depends on:

  How much do you want to spend?
  - a solar PV system is generally modular and so can be sized to fit your budget
  - you can often oversize components for some parts of it (like the inverter) and then add more PV modules on the roof later…

38

36

4 solar PV modules

6

12

16

18

Your own solar system…

4. Where do you live?

- Size of your solar PV system depends on:

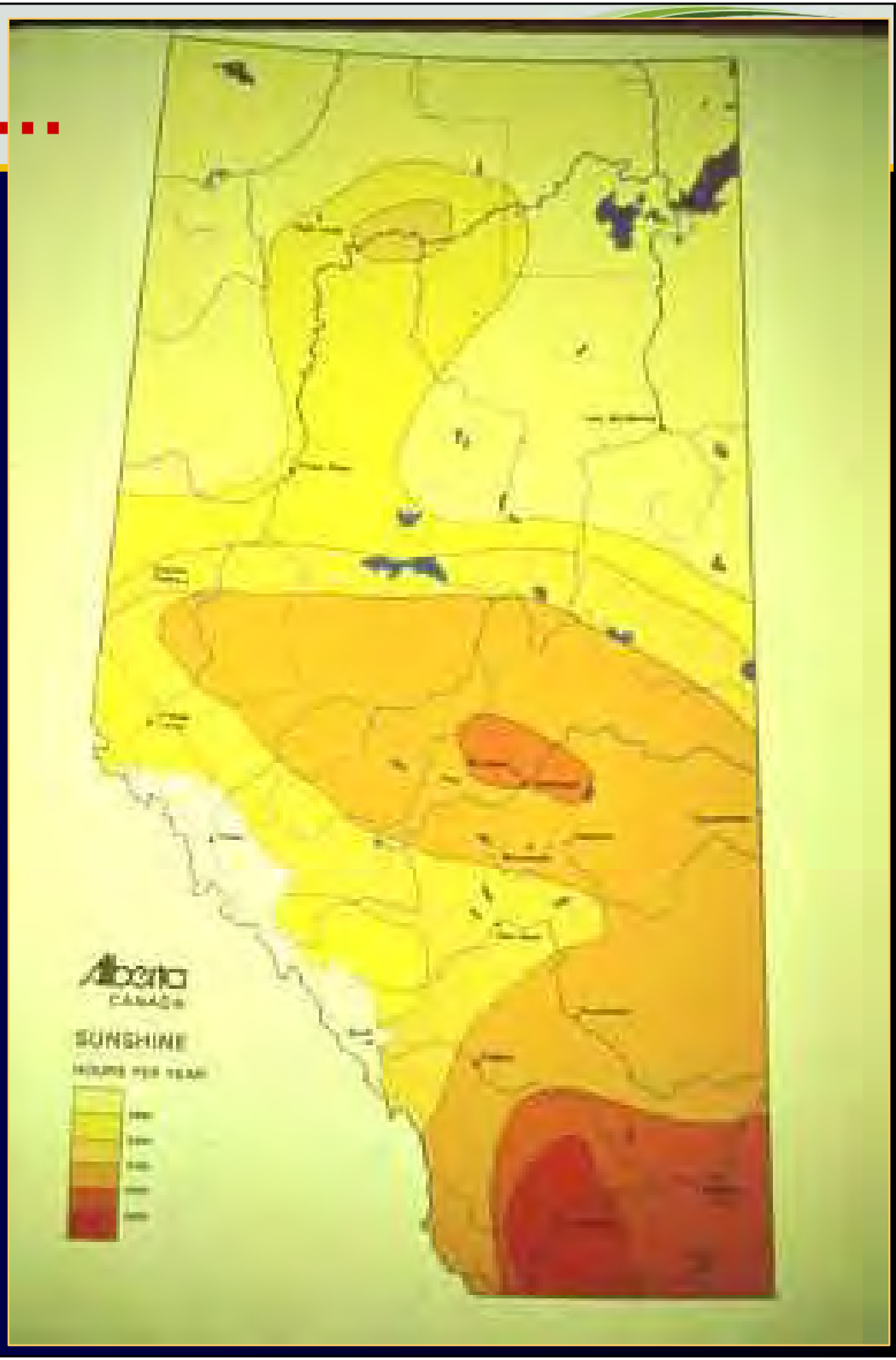
  How much energy is in the sunlight where you are located?

  - 20% difference annually on a 6/12 roof between Fort McMurray and Lethbridge

  - 20% difference in the winter on a vertical surface between Fort McM & Lethbridge

RETScreen spreadsheet analysis software available free from Natural Resources Canada

www.retscreen.net



Your own solar system…

5. What are your solar sightlines?

- Size of your solar PV system depends on:

  How clear are your solar sightlines from obstructions?

  - from trees (now and in the future)
  - from other houses or high buildings?

- Shading can effectively turn off your solar PV system
  - where are your coniferous and deciduous trees?

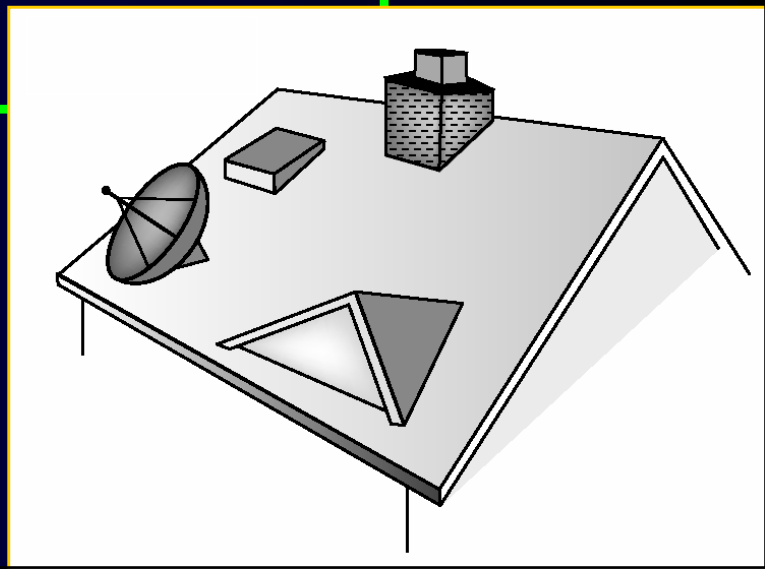
Your own solar system…

6. What are your roof and wall orientations?

- Size of your solar PV system is affected by:
  - does your roof slope north and south?
  - are your walls facing south
  - is your back yard or your front yard facing south?
  - are they free from obstructions? (vents, dormers)
  - how much area is there?

What do you do if they are not the right orientation?

Too many obstructions fill up the roof



How to get a good PV array location?

- Consider something other than the house roof!
- Consider the
  - House wall
  - Window shading
  - Garage roof
  - Yard feature – garden trellis
  - Pole mount
  - Pad mount

Preparing a new home

- Space from attic/roof/wall to mechanical room
  - 2" conduit for electrical cables
  - "Chase" for 2 insulated solar hot water pipes
  - Make sure these are sealed to prevent air and moisture from entering/leaving the house
- Space in electrical room
  - Inverter and 2 switches need approx 1 m^2 of wall area, add another 2 m^2 or more if there is a battery bank
  - Battery bank needs 2 to 10 m^2 of floor area depending on size

Your own solar system

Approaching designers and suppliers…

- Supplier
  - …designs and specifies the system based on your needs and desires
  - Does the supplier know how to design well?
  - How do you evaluate their design and prices?
- Installer
  - …installs the system according to the design of the supplier
  - Does the installer know how to install well?
  - How do you evaluate their prices?
  - Electrician can install a solar power system
  - You can install it yourself

Your own solar system

…Approaching designers and suppliers

- Look at the Eco-Solar Products and Services list for suppliers
- Contact 3 suppliers
  - Look at web sites to see what they supply.
  - Ask for 3 references to make sure they know what they are speaking about.

- Make sure they are members of their industry association:
  - Canadian Solar Industries Association (www.cansia.ca)

Your own solar system

…Approaching designers and suppliers

- Give the supplier some photos of your house, showing:
  - the view of the front yard from the south,
    - showing the general house and trees,
  - the roof and walls,
    - showing obstructions, slopes, and shapes
  - the view to the south from the house,
    - showing trees and other buildings
  - the furnace/electrical room
    - to show them an idea of how much space there is on the floor and walls available for equipment

Your own solar system

…Approaching designers and suppliers

- Good suppliers know how to <u>design</u> and <u>size</u> your *<u>system</u>*, not just supply you with some parts!
  - Ask lots of questions to make sure they know what they are talking about.
  - Do they have a system package for you (rather than bits and pieces)?
  - Do they have professional brochures of their equipment?

Your own solar system

…Approaching designers and suppliers

- Good suppliers:
  - Do they have a list of all the parts that are needed
    - so you get an idea of how organised they are,
    - so you see what may be missing and that you still need to organise on your own?
  - Do they have a relationship with qualified installers with whom they have worked before?
    - You don't want to go out and try and find one on your own!
    - Suppliers don't necessarily make good installers!

Your own solar system

How to buy…

- Be aware when getting price quotes for systems:
  - Is it a firm quote or an estimate?
  - Are they interested in talking with you about your energy needs or just selling you a system?
  - Calculate their system price in $ per array W (for PV)
  - Ask them what makes them better compared to others. Don't let them put down their competitors, just ask them to make themselves look good.
- Go with confidence… contact me if you have any Q.

Questions…?

- What haven't I covered for you?

It's our **turn** now…

It's our **choice**…

our wallet

our community and children

and the planet

await us…

If not here… then where?

If not you… then who?

If not now… then when?


The Tides are Changing, Everywhere…
…now, what is our task ?
…where can our life make a difference ?
One person can make a difference
… and every person should try.
John Fitzgerald
Kennedy

Gordon Howell, P.Eng.
Howell-Mayhew Engineering
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Photo credits: Gordon Howell and several others

Alberta Emerald Foundation

Context: over the ages…

- Stone age
  - a short period… come and gone
- Bronze age
  - a short period… come and gone
- Iron age
  - a short period… come and gone
- Oil age
  - a short period…
  - our great grandfathers did not have fossil fuels to use, and
  - our grandkids will likely not have fossil fuels to use…!!!
  - at least they won't be cheap…

- Whatever are we doing?

I do not believe in a fate that falls on men however they act;
but I do believe in a fate that falls on men unless they act. +G.K. Chesterson

Our energy today and tomorrow…

- Now our energy is:
  - Dirty
  - Insecure
  - Very unreliable in developing countries
  - Becoming increasingly unreliable here
  - Cheap to build, expensive to operate
  - Increasingly volatile prices that cannot be planned on…

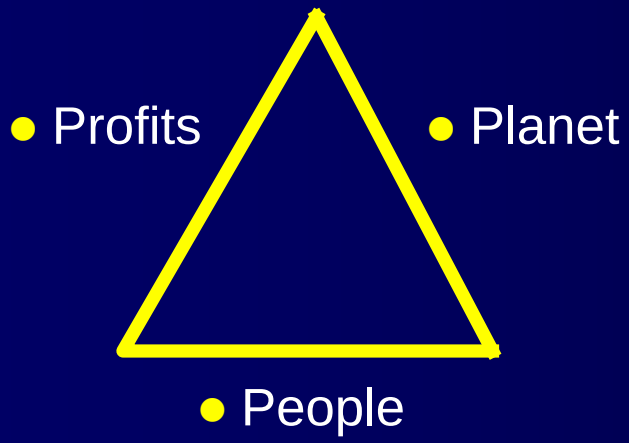
- The energy we want and need:
  - Clean
  - Secure
  - Reliable
  - Cheap

- Where solar energy is:
  - Clean
  - Secure
  - Variable due to weather
  - Cheap to operate, expensive to buy

Context – The Founding Principles for Sustainable Development

- Economically advantageous
- Socially responsible to the community
- Environmentally sensitive

Also known as the 3 Ps:



Mountain Equipment Co-op:

Everything we do has an impact – on the planet, on communities, on individuals, and on the local and global economy.

We believe a sustainable world reflects these three interdependent principles:

- The planet has a limited carrying capacity and we are all dependent on a healthy, functioning biosphere.
- Individuals can best meet their needs in caring and vibrant communities.
- A just economy is dependant on an equitable society and a healthy planet.

Context – Costs? Benefits? Values? Legacy…

Not everything that counts can be counted,
and not everything that can be counted... counts.

sign over Albert Einstein's desk

Solar energy – technology – choices – legacy for the future

- It is not just about technology and costs…
  - It is also about how we go about making choices when we build our infrastructure in the 1st place.
  - A poorly chosen infrastructure burdens us for generations to come!
  - For example: What happens if we spend all our money on cars and roads, but then the price of gasoline goes to $7 per litre… we won't have any money or time left for developing rapid transit systems…

Context – Solutions to Technical Problems

– and sources of barriers

- **Only 5% of a solution is from technology.**

Credit: Joel Nodelman at EPCOR

- ***Ecological*** *(relating to the environment),*
- ***Social*** (relating to others),
- ***Moral*** (relating to right or wrong),
- ***Ethical*** (relating to community standards),
- ***Educational*** (relating to those who are not aware),
- ***Legal*** (relating to risk, power, control),
- ***Financial*** (relating to sharing, pulling together, personal insecurity),
- ***Psychological*** (relating to ego, prestige, status, job security, self-esteem),
- ***Territorial*** (relating to who has the space to influence others),
- ***Political*** (relating to power, control)!

- **The other 95% focuses on relationships and being in community…!**

Those who make peaceful change impossible,
make violent change inevitable. John F. Kennedy, America

Context – Is ignoring the environment the right way to get our energy ?

Is this what we want to do?

Do we really want to keep going in this direction?

Context – From where does our electricity come?

- 64% of Alberta's electricity is generated from coal.
- 31% from natural gas.
- Is our coal clean ? ***NO!***

Keephills Power Plant

Wabamun Alberta

Do we really want to keep going in this direction?

Context – What are the real costs of electricity ?

The Ontario Ministry of Energy and the Ontario Medical Association says:

- the air pollution in Ontario caused by coal-fired electricity generation
- kills 688 people,
- causes 1100 emergency room visits, and
- more than 300,000 minor illnesses per year.

- The pollution includes mercury, NOx, SOx, acid rain, particulates…

They are saying that this is an epidemic!

But do we care…???

Our lives begin to end the day we become silent about things that matter. Martin Luther King, Jr., America

Do we really want to keep going in this direction?

Context – What are the real costs of electricity ?

- Average electricity price in Edmonton in 2007: 11.17 ¢/kWh.

- The Ontario Ministry of Energy says that the environmental damage caused by coal electricity is between 13 ¢/kWh

  – we need to double+ our electricity prices to pay for this!

- Thus the cost of the environmental damage caused by an average home's electricity consumption is

  $860 per year!

So who pays for this???

Political will arises from personal momentum…

We need to be the leaders to our governments and corporations.

Context – What really is going on with oil ?

For the first time we have information that:

(1) worldwide oil discoveries have been rapidly declining since 1960s

(2) discoveries today are at level of discoveries in 1930s

(3) actual data – Arabian oil fields and all other major global production are declining in oil output: peaked & growth is over

(4) all other prior & recent assumptions/projections are based on very limited or no data

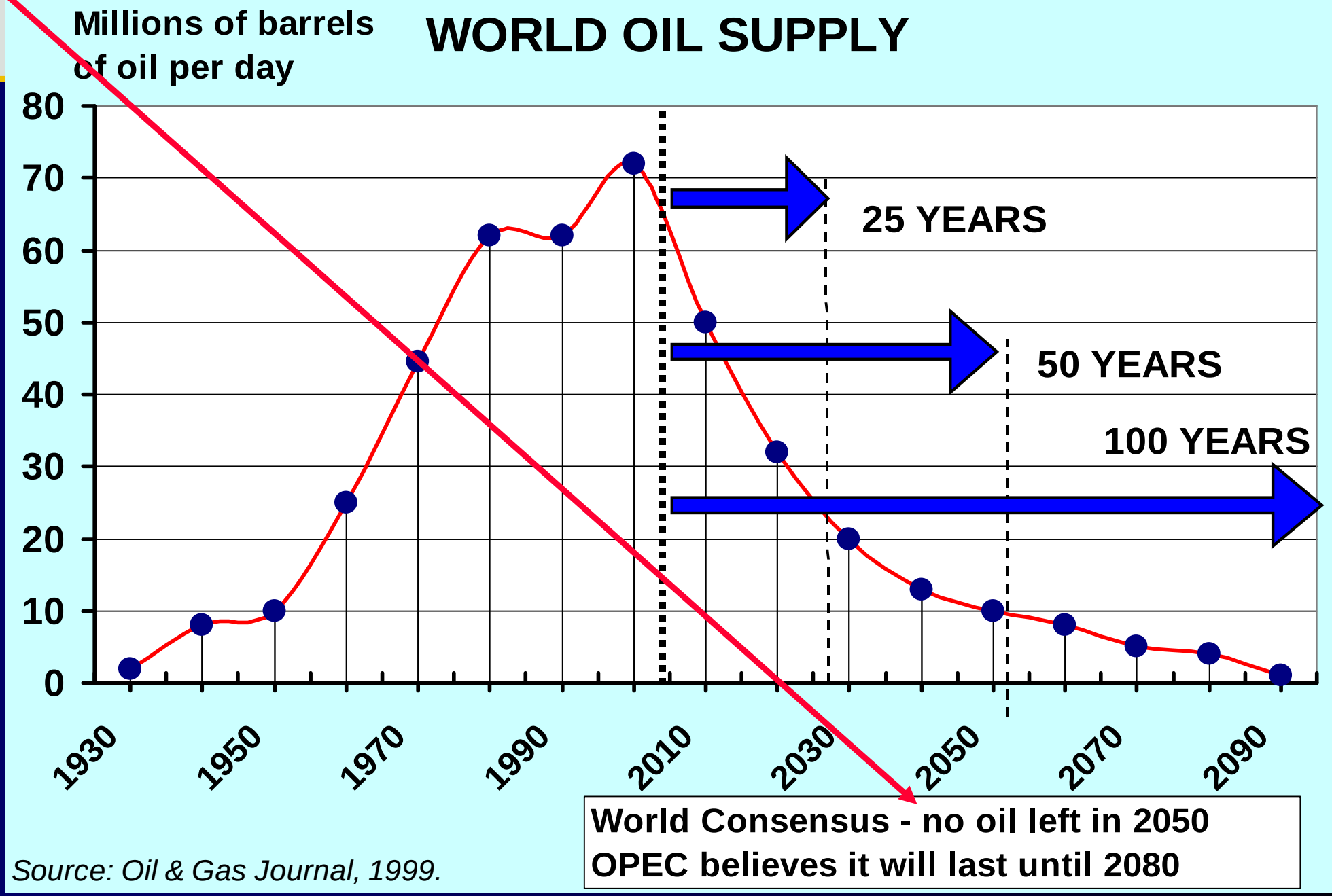
(5) almost all people claim this wouldn't occur for 20-60 more years!

"Twilight in the Desert: The coming Saudi Oil Shock & the World Economy"

2005 May

Simmons & Company
Houston energy investment banker since 1970s
www.simmonsco-intl.com

WORLD OIL SUPPLY



Source: Oil & Gas Journal, 1999.

Context – What really is going on with the politics of energy ?

- The major oil companies talk about plenty of oil
  and that they can produce more,
  but if you look at ExxonMobil, ChevronTexaco, BP,
  all their production is going down every year.
- They don't replace and they don't add to production, but they say there's plenty of oil around.
- "Now why would they say that? …"
- A chief economist with one of the major oil companies said,

  "can you imagine what would happen if one of these major oil company's CEO's got up, made a speech and said, 'We're running out of oil'? There'd be panic. They're not going to make the statement. They're going to say there's plenty of oil around".

Boone Pickens
Founder, Mesa Petroleum
11th National Clean Cities Conference

Where there is a will, there is a way…
It's not about economics. It is about a will.

Context – What is really going on with gas supplies in Alberta ?

- How much natural gas supply do we have in Alberta…?
  - 8 years…. 20 years… coal-bed methane… Arctic gas…
- Why is the government subsidizing natural gas in the winter?
- Alberta is debt free??? The government has a $9B charge for cleaning up gas wells that they have allowed the gas industry to abandon!
- Legacy: The natural gas that was flared between 1924 and 1938 would have been worth $10B today… but our grandparents didn't give a thought to us!

  Do we care about our grandkids…???

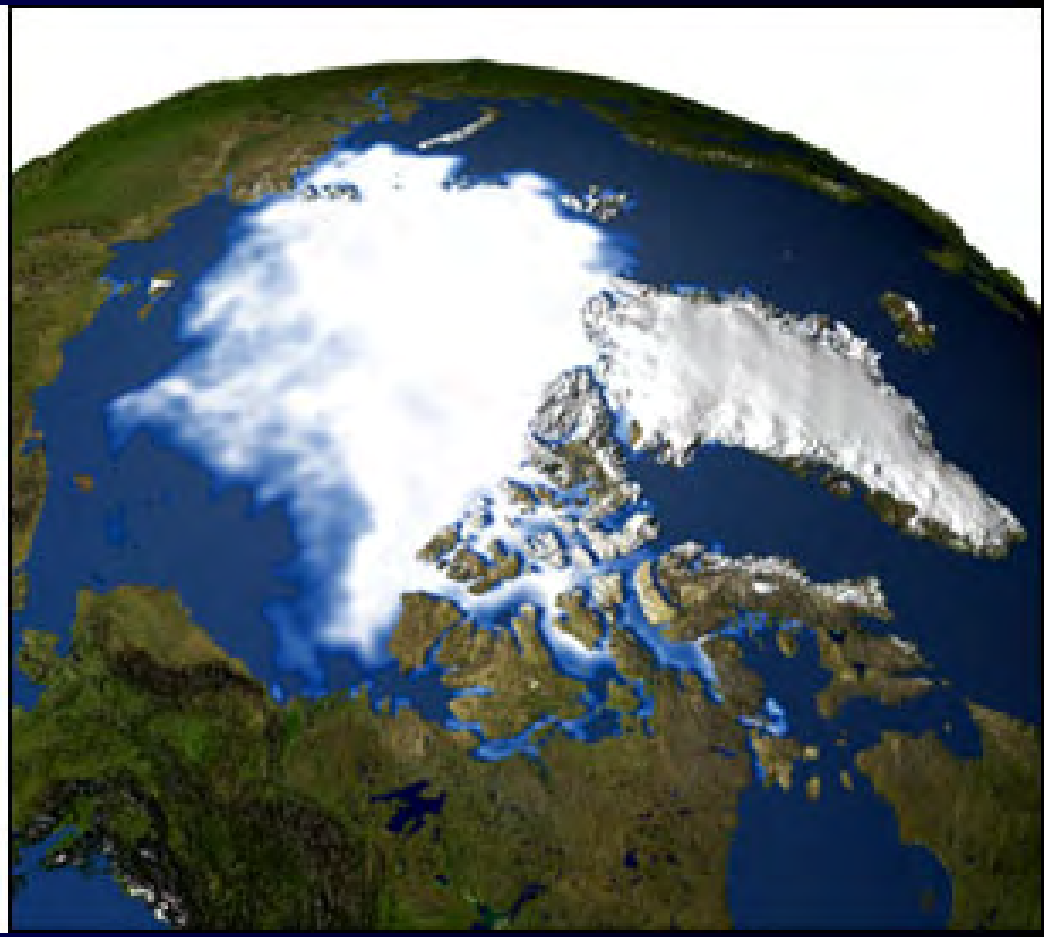
Let him that would move the world first move himself.

Socrates
Greece

Context – What's happening with the Arctic ice cap?

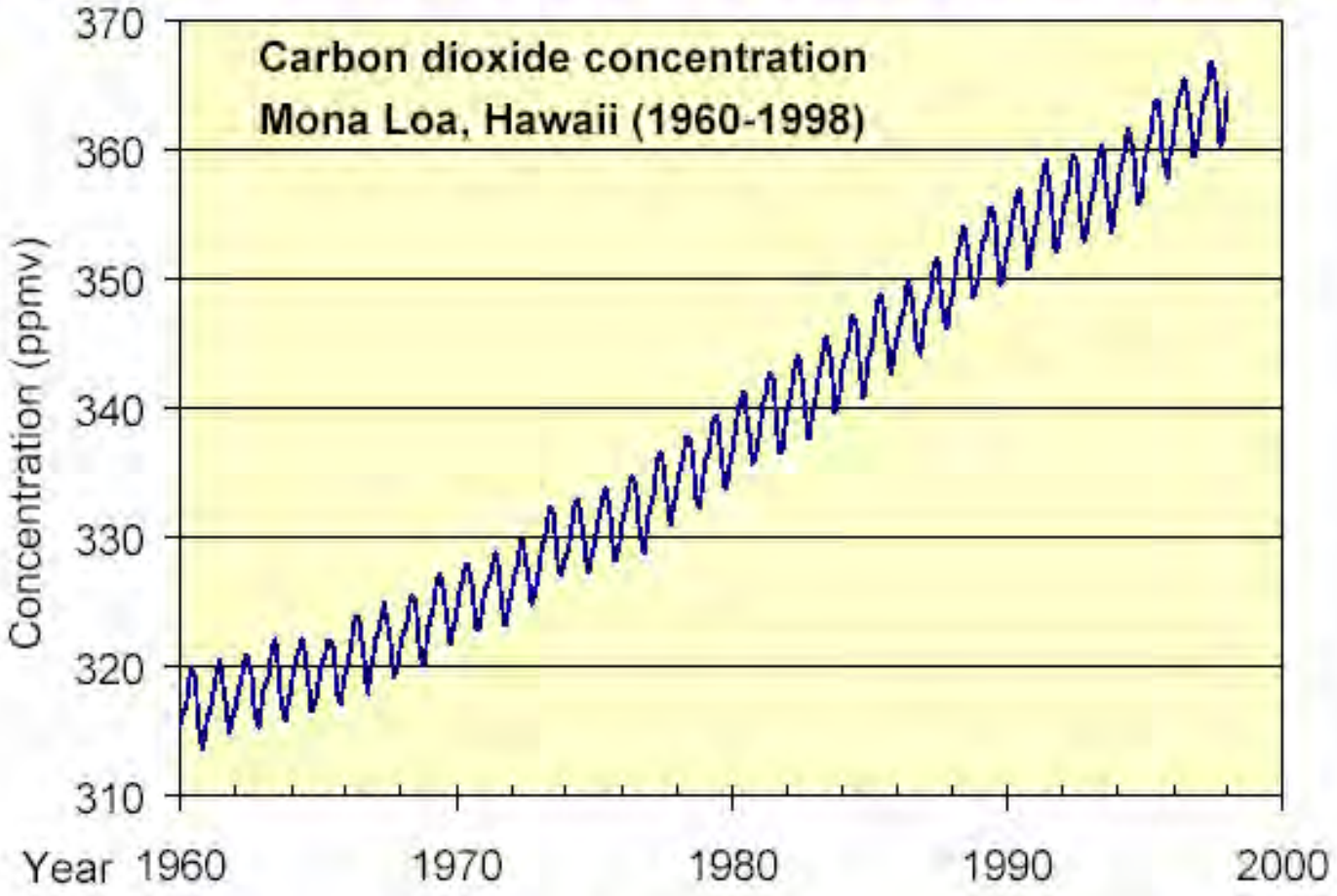
1979

2003



Context – Environmental Issues

Carbon dioxide concentration



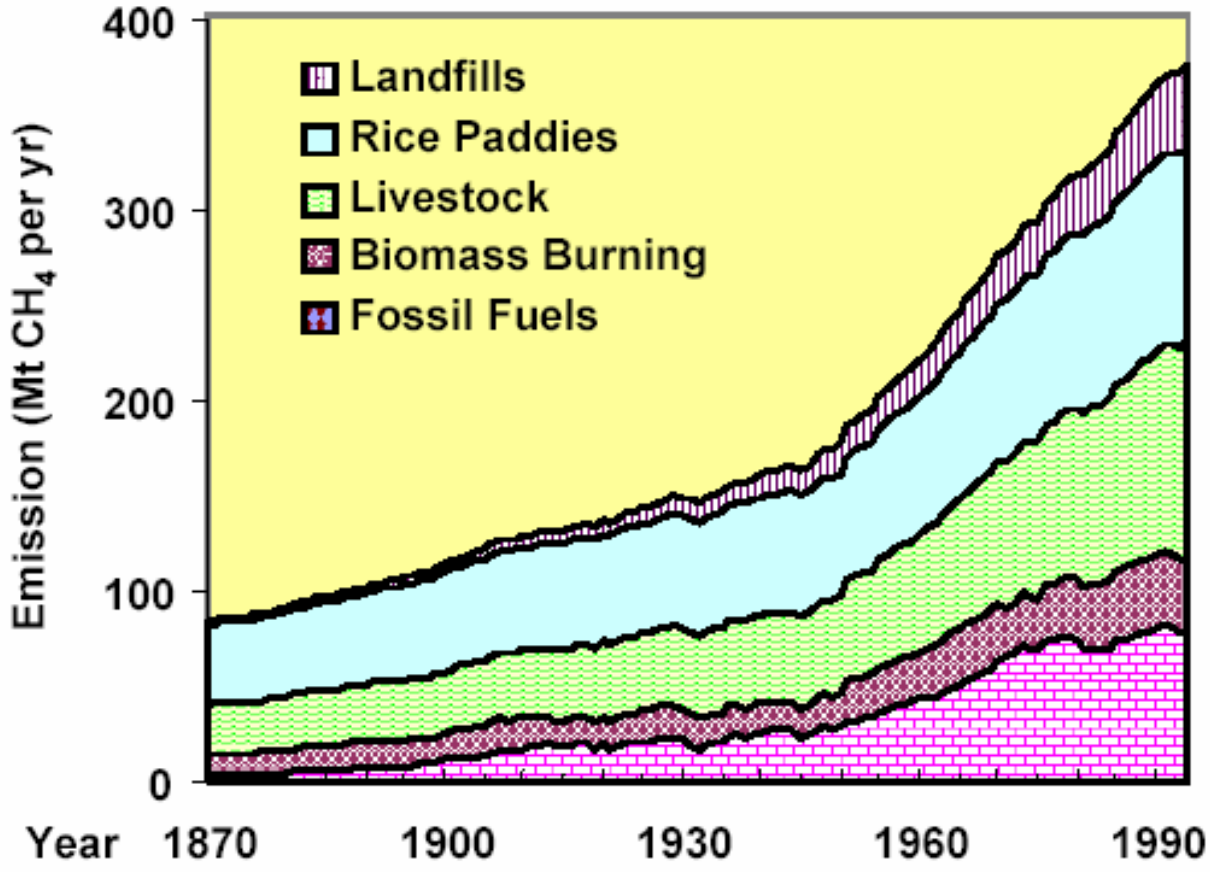
Carbon dioxide has risen by 31% from a pre-industrial concentration of 285 ppmv in 1750 to 370 ppmv in 2001. Over 60% of this increase has occurred in the last forty years.

Seeds

2-13

Context – Environmental Issues

Methane emissions (megatonnes/year)



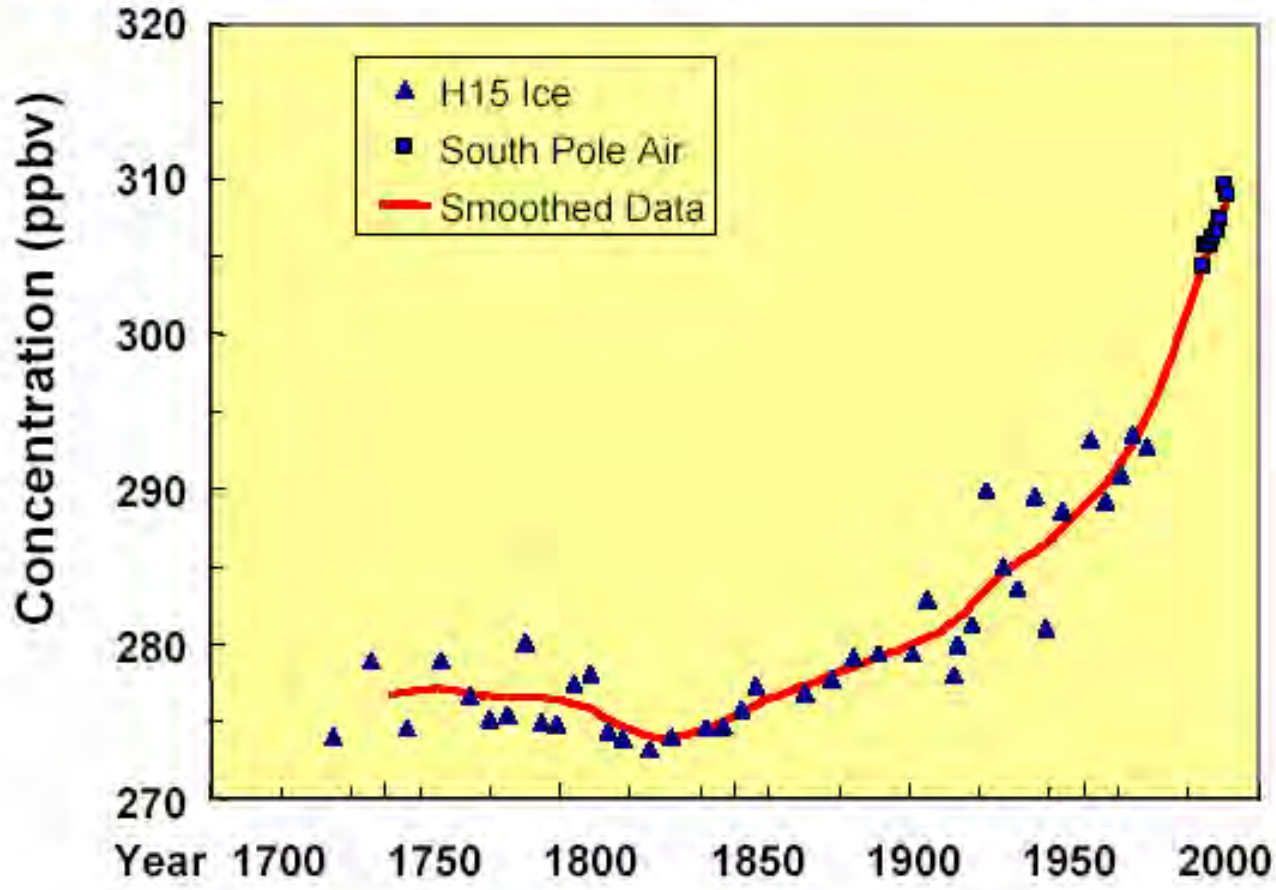
Methane emissions have increased almost four times the pre-industrial levels and over the past decade are increasing at about 0.7% per year. Data from L. D. Harvey, 2000.

Seeds

2-15

Context – Environmental Issues

Nitrous oxide concentration (1730-1995)

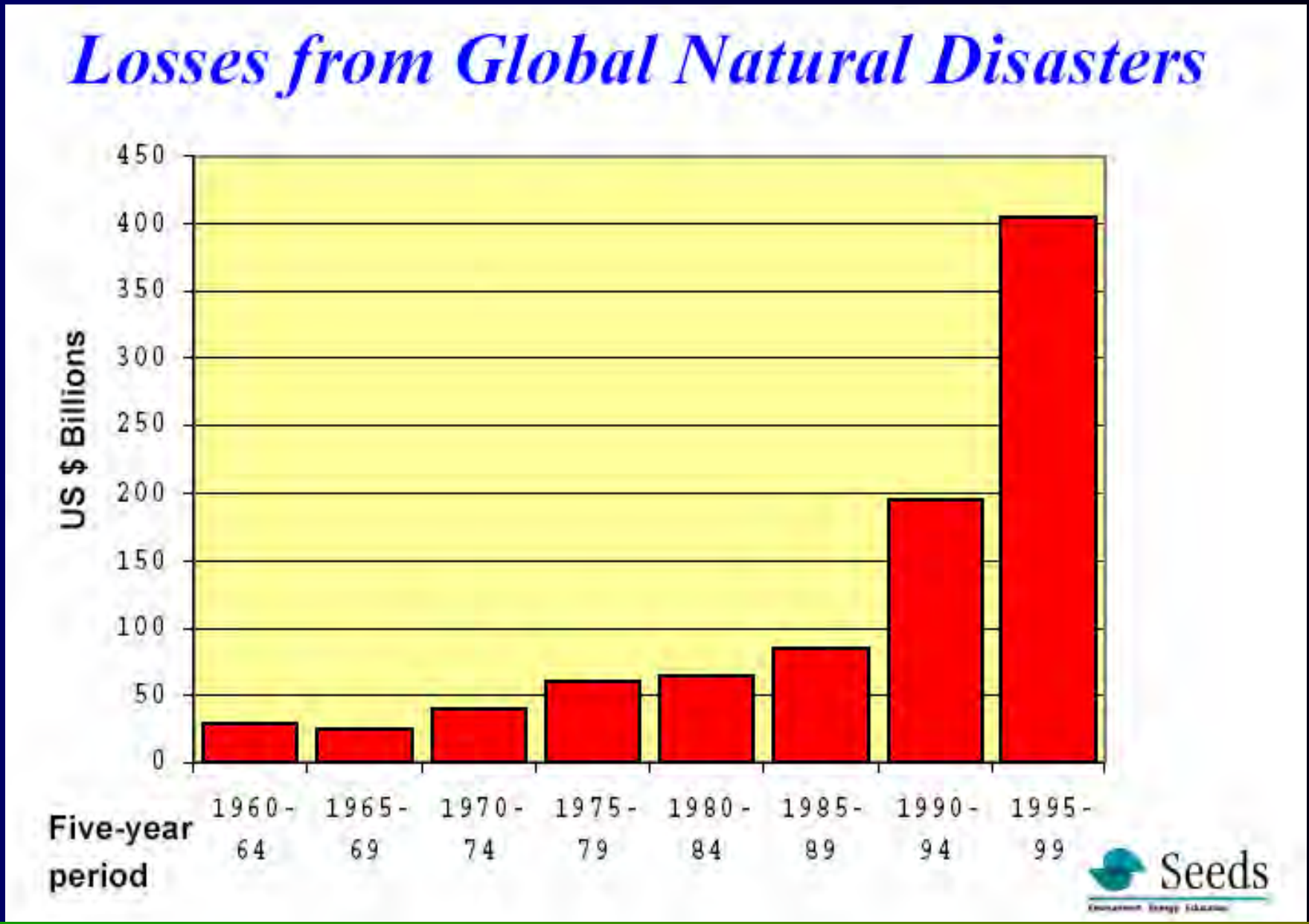


Nitrous oxide concentrations in parts per billion by volume (ppbv) from 1730 to 1995 measured at Antarctica.
Data from L. D. Harvey, 2000.

Seeds

2-16

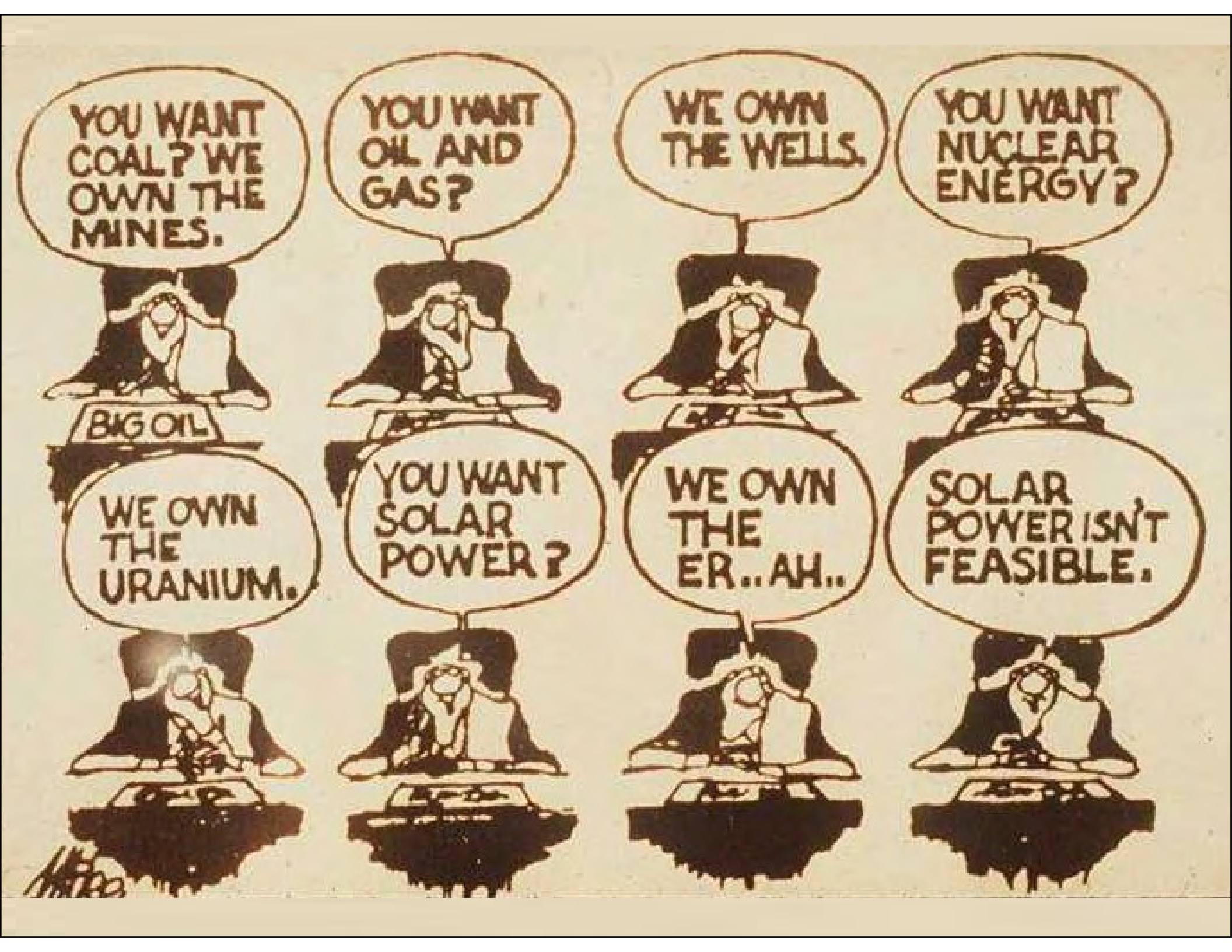
Context – Environmental Issues



Context – What's happening with water ?

- We are on a threshold of catastrophic water scarcity.
- By 2050, 4.2 billion people cannot meet the requirement of 50 litres of water/person.
- Oceans are being over- exhausted and will cease to sustain human life.

United Nation's Annual Population Report (Nov. 2001)


YOU WANT COAL? WE OWN THE MINES.
BIG OIL
WE OWN THE URANIUM.
YOU WANT OIL AND GAS?
YOU WANT SOLAR POWER?
WE OWN THE WELLS.
WE OWN THE ER.. AH..
YOU WANT NUCLEAR ENERGY?
SOLAR POWER ISN'T FEASIBLE.

Gordon Howell, P.Eng.
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Alberta Emerald Foundation

Development of Alberta's Solar Resource

- Alberta's solar energy resource today is similar to the tar sands of several decades ago:
  - rich resource
  - currently expensive
  - not a lot of experience in Alberta
  - many barriers to utilization
  - many opportunities to develop jobs, products and markets for the world

- Key issues: how to store energy? – from day to night, from summer to winter

Government Response to our Solar Resource

	Alberta
Policies that facilitate	None
Policies that subsidize	None
Development programmes – industrial capacity, infrastructure, regulations, research, standards, issues…	None
Taxation policies	Solar power is treated like an industrial power generator – industrial taxes are 4x the value of the electricity generated!
Policies that subsidize competing energy sources	– Natural gas rebates in the winter – Low oil, gas, and coal royalty rates – Tax holidays for the tar sands – No environmental royalties !!

Socialism collapsed because it did not allow the market to tell the economic truth.
Capitalism may collapse because it does not allow the market to tell the ecological truth.

Øystein Dahle
Exxon Norway

Policy Contrasts…

- In contrast to Canada and Alberta…

  billions are being spent in other industrialized countries to develop their solar energy sector:

- Industrial capacity
- Manufacturing processes
- Regulations
- Products
- Infrastructure integration
- World market development…
- Research
- Infrastructure
- Services
- Applications

"We don't know what to do about solar energy because we don't know how to tax it."
Alberta Energy in 2003 June