Grid-Connected Solar Electricity

– Costs and Economics –

Energy Options Behind the Farm Gate

Taber

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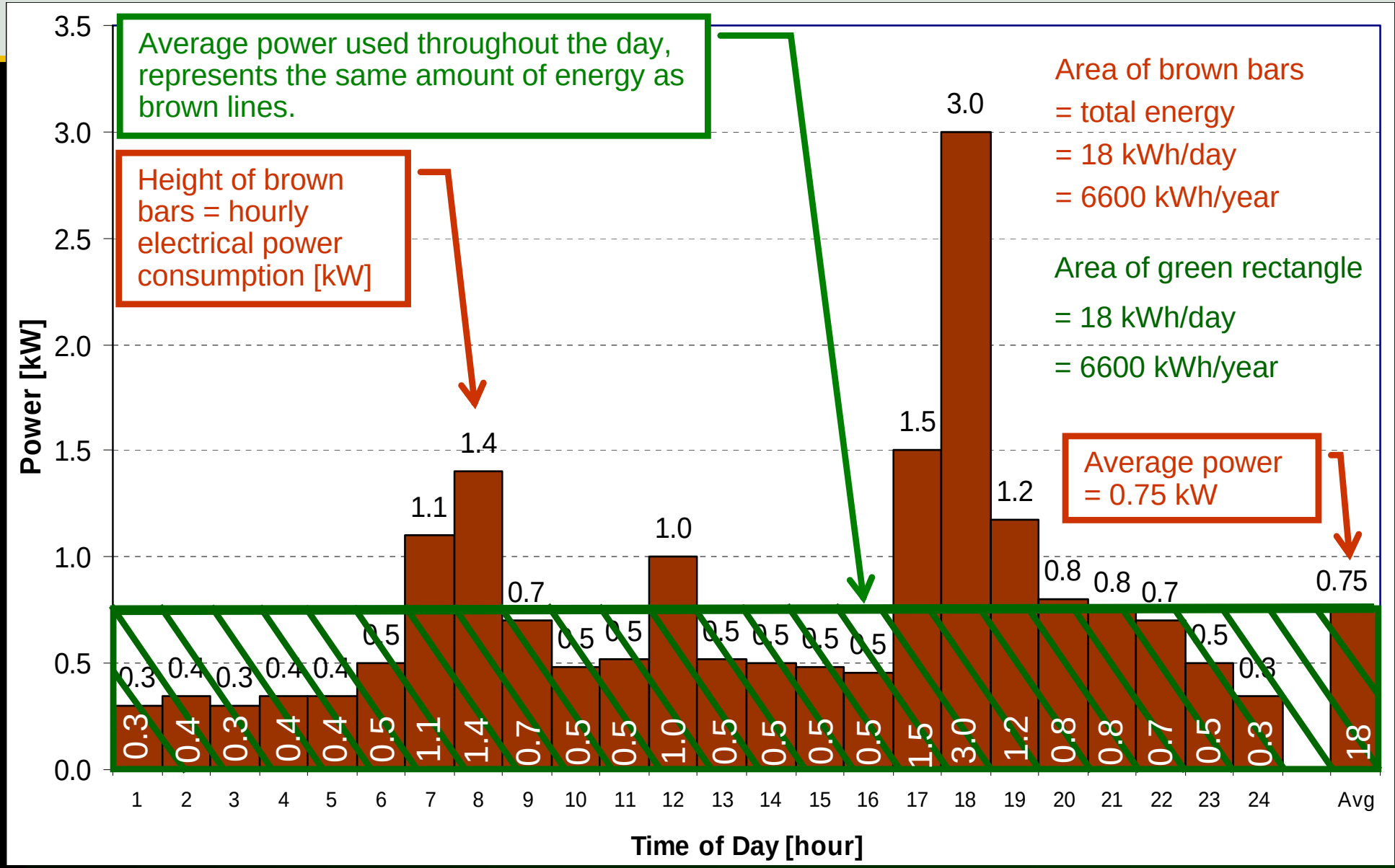
Content of presentations

- Chapter 1
  - Solar Resource
  - Components
  - How does it work
- Chapter 2
  - Performance, size
  - Costs
  - Economics
- Chapter 3
  - Connecting to the grid
  - Steps to get your own solar power system
- Chapter 4 (your homework)
  - Get your electricity bills together
  - Download this presentation from www.hme.ca/presentations
  - Take steps to get your own system

Until there is awareness there will be no consensus to change.

Martin Luther King Jr.
America

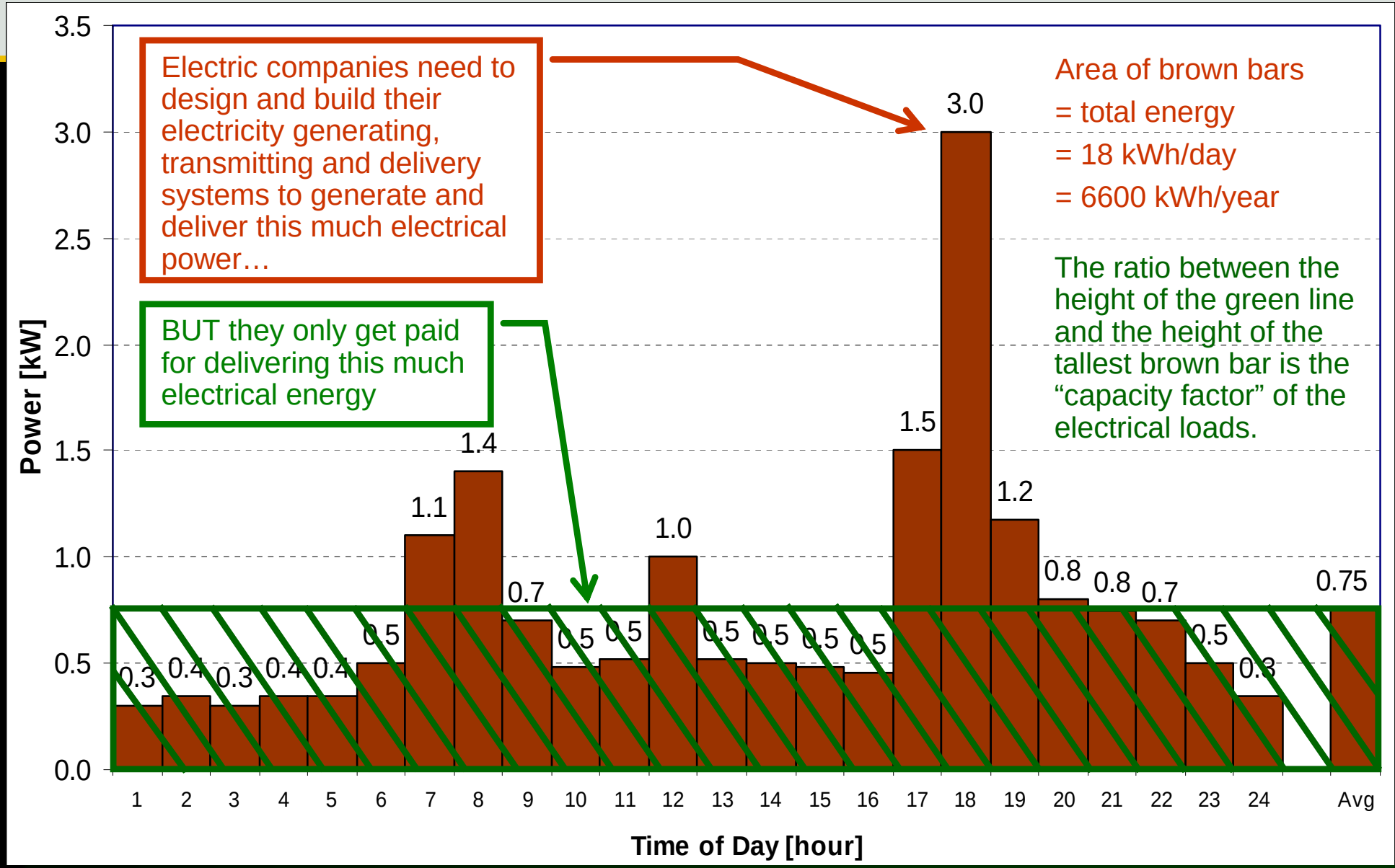
Background: Energy *vs.* Power



Energy = Power x Time
kWh = kW x h

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

Background: Energy *vs.* Power



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PV System Capacity Rating

- PV system sizes are shown as the number of kilowatts [kW] of rated ability to generate electrical power (not energy).
  - 2.4 kW typical size for a house (12 modules of 200 W each)
  - 6.1 kW approximate size to supply all electricity for an average house (36 modules of 170 W each)
  - 0.1 kW smallest grid-connected system (1 module of 100 W)
  - 11,000 kW biggest grid-connected system (150,000 kW ones are under development) (36,650 modules of 300 W each)

Efficiency can save 75 percent of our electricity at a lower cost than making it at existing power plants.

Amory Lovins, 2006
Rocky Mountain Institute

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PV System Yield =

- # of hours that the PV system effectively operates at its rated capacity in order to generate its energy
  - $\frac{\text{Energy per year}}{\text{rated generating capacity}} = \frac{\text{kWh/year}}{\text{kW}} = \frac{\text{hours}}{\text{year}}$
  - Solar power system performance is affected by
    - tilt angle and orientation angle (or whether it is tracking the sun)
    - latitude and location of site
    - shading (trees, obstructing objects, buildings, snow cover)
    - soiling
    - PV module mis-match (keep them all the same)
    - Inverter and wiring efficiency

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

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PV System Energy Production

- System yield
  - Edmonton: ~1000 hours / year, south facing at optimum tilt angles
  - Calgary: ~1100 hours / year
  - Medicine Hat: ~1250 hours / year (similar to Taber and Lethbridge)

  - Could be reduced by 30% to 50% by shading and non-optimal orientation.

- Example calculation
  - 3 kW solar PV system
    x 1250 hours/year
    = 3750 kWh/year of energy

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

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Rough PV array capacity…

- Add up your electricity consumption for 1 year or 2 years.

- Use the performance numbers to determine your system capacity:

  a) Your annual electricity consumption = _____ kWh/year

  b) PV performance is ~1250 hours/year in Taber 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 capacity = _____ kW [= c) multiplied by d)]

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PV Array Area

- Use this to find the area of your PV array:

  a) PV module efficiency: 13% to 17%

  b) Module production-area: 130 to 170 W/m^2 [= a) x 1000 W/m^2]

  c) Your PV array capacity: _____ kW

  d) Your PV array area: _____ m2

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

African Proverb

What to look for with PV prices…

- Modules
  - Price divided by rated power: $/ W
  - Example: 200 W PV module for $1000 is $5 / W
  - Typically: $4 to $6 / W wholesale, $7+ / W retail
- Inverter
  - Price divided by rated power: $/W
  - Example: 6000 W inverter for $3400 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: $8-$12 /W
  - Your system: _____ kW x $_____/ W = $_____k

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PV System Sizing and Costing Summary

1. If you consume 6000 kWh of electricity per year, then, for example:
   - You need a 5 kW PV array (6000 kWh/year / 1200 h/year)
   - Area of 5 kW PV array 31 m^2 (5 kW/ 16% module eff.)
   - It will cost you $42,500 (5 kW x $8.50 / W * 1000)
2. If you spend $3000 on electrically efficient appliances, and thus only consume 4000 kWh of electricity per year, then:
   - You need a 3.3 kW PV array (4000 kWh/year / 1200 h/year)
   - Area of 3.3 kW PV array 21 m^2 (3.3 kW/ 16% module eff.)
   - It will cost you $28,000 (3.3 kW x $8.50 / W * 1000)

- Spend $3000 on electrically efficiency saves you $14,000 on solar PV

PV System Sizing and Costing Summary

- If you consume 120 kWh of electricity per month, this equals 1440 kWh per year, then:
  - You need a 1.2 kW PV array (1440 kWh/year / 1200 h/year)
  - Area of 1.2 kW PV array 7.5 m^2 (1.2 kW/ 16% module eff.)
  - It will cost you $11,000 (1.2 kW x $9 / W * 1000)

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System Cost Proportions

- For large systems
  - 60% to 65% for PV modules
  - 20% installation
  - 10% module mounting
  - 5% to 7% inverter
  - 4% design, regulatory approvals, commissioning and project management fees
  - 1% miscellaneous

- The above % amounts vary with different installation costs

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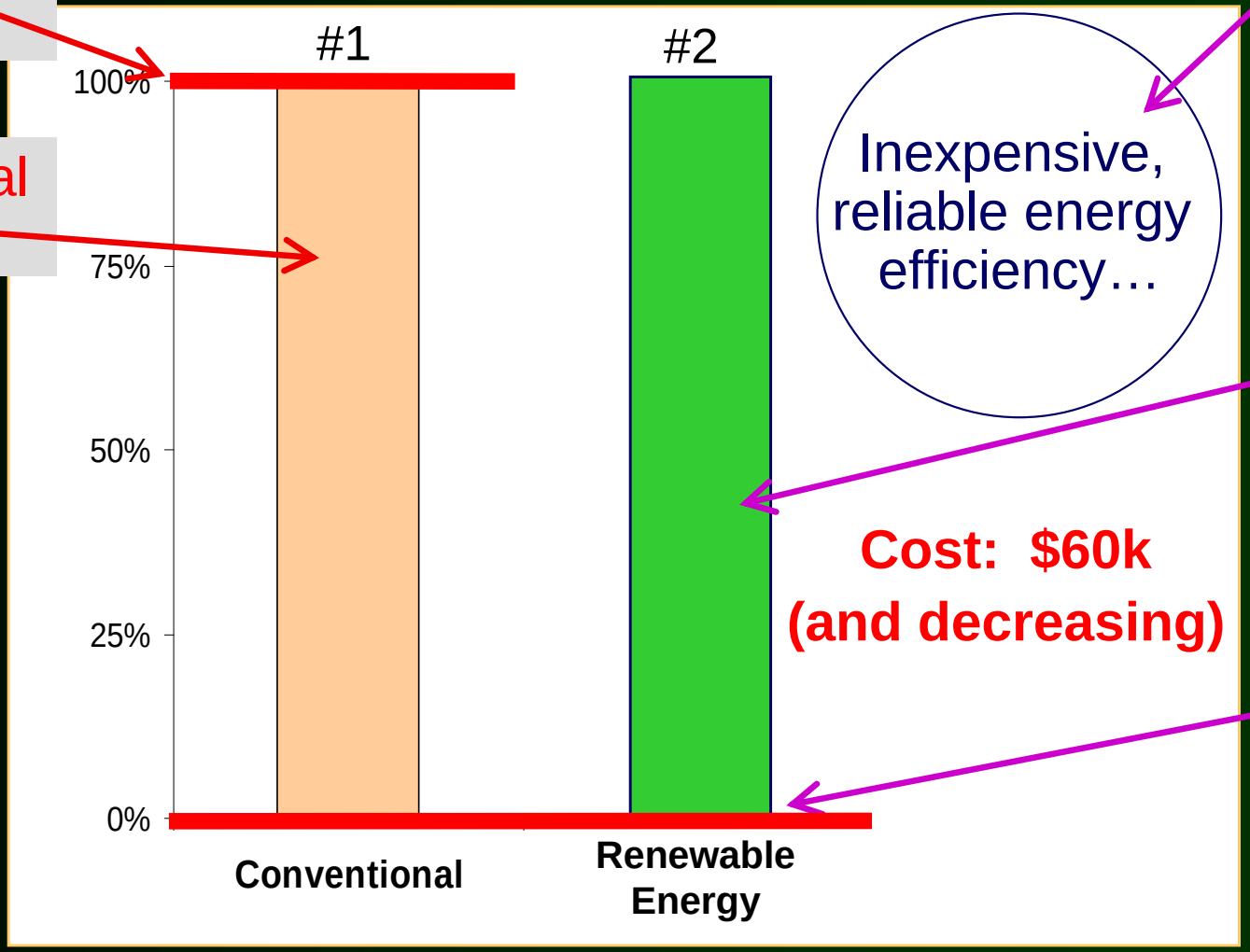
Reducing your electricity bills with solar PV…

Purchased Electricity

Conventional Electricity



Where is it?

Inexpensive, reliable energy efficiency…

Add expensive solar electricity

Cost: $60k (and decreasing)

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.

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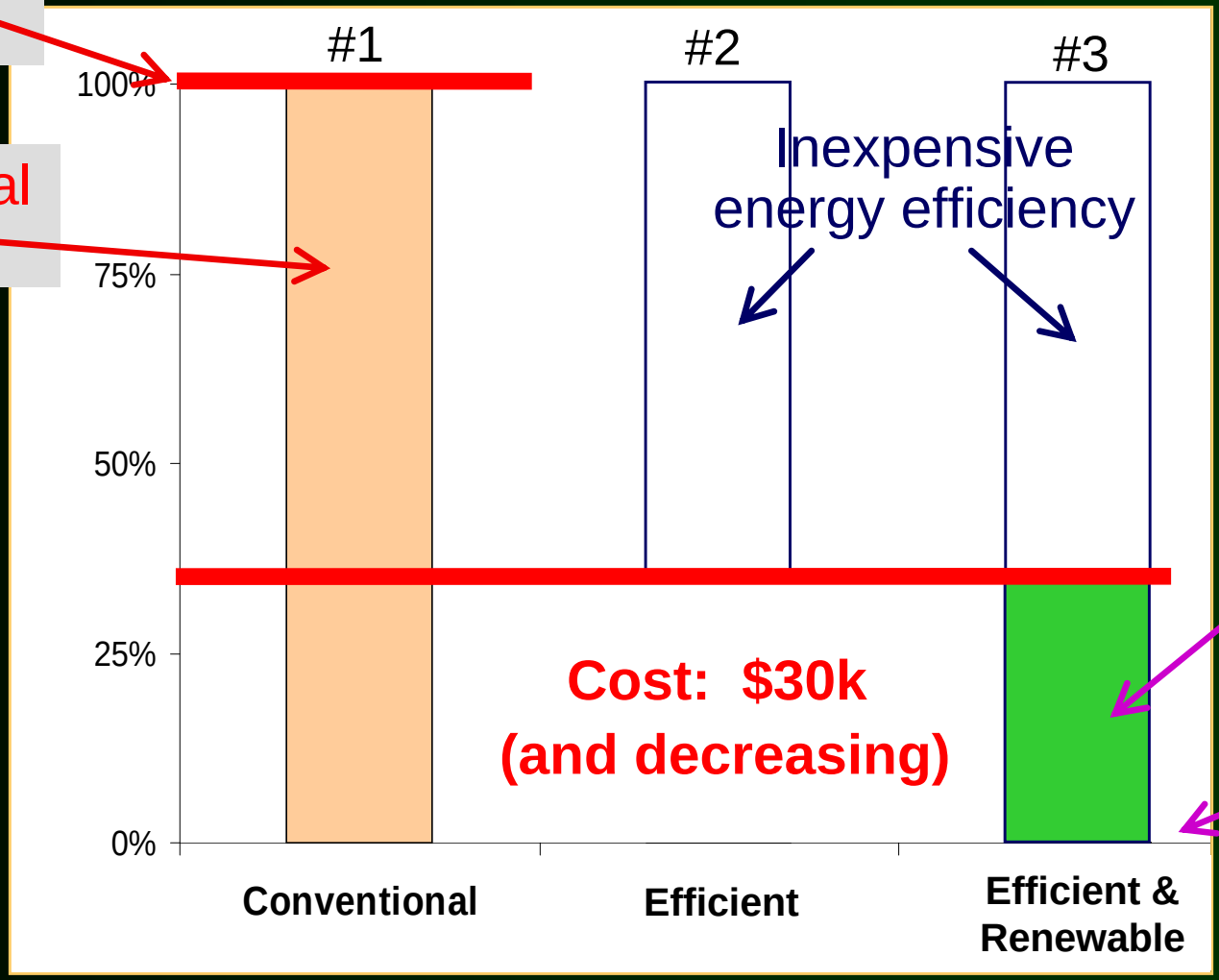
Reducing your electricity bills with solar PV…

Purchased Electricity

Conventional Electricity



(but… energy efficiency is emotionally boring)

More expensive solar electricity

Net zero electricity home

We have greatness within us -- innovative, giving, determined.
It is time for the best in us to come out.

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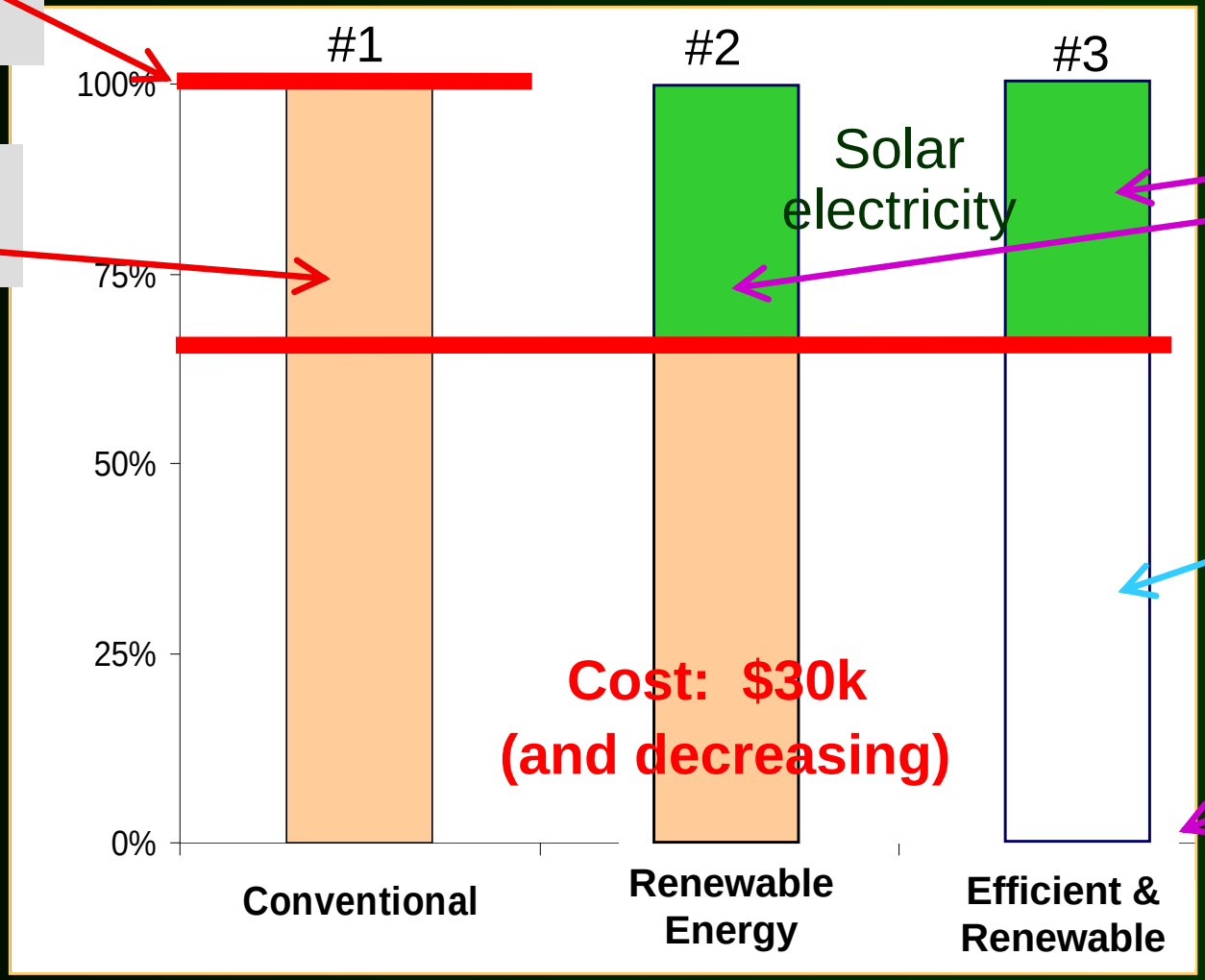
Reducing your electricity bills with solar PV…

Purchased Electricity

Conventional Electricity



More expensive… yeah, but really exciting

Energy efficiency:
most important, least expensive

Net zero electricity home

Energy efficiency is today's biggest global economic challenge.
Office of Energy Efficiency, Natural Resources Canada

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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:

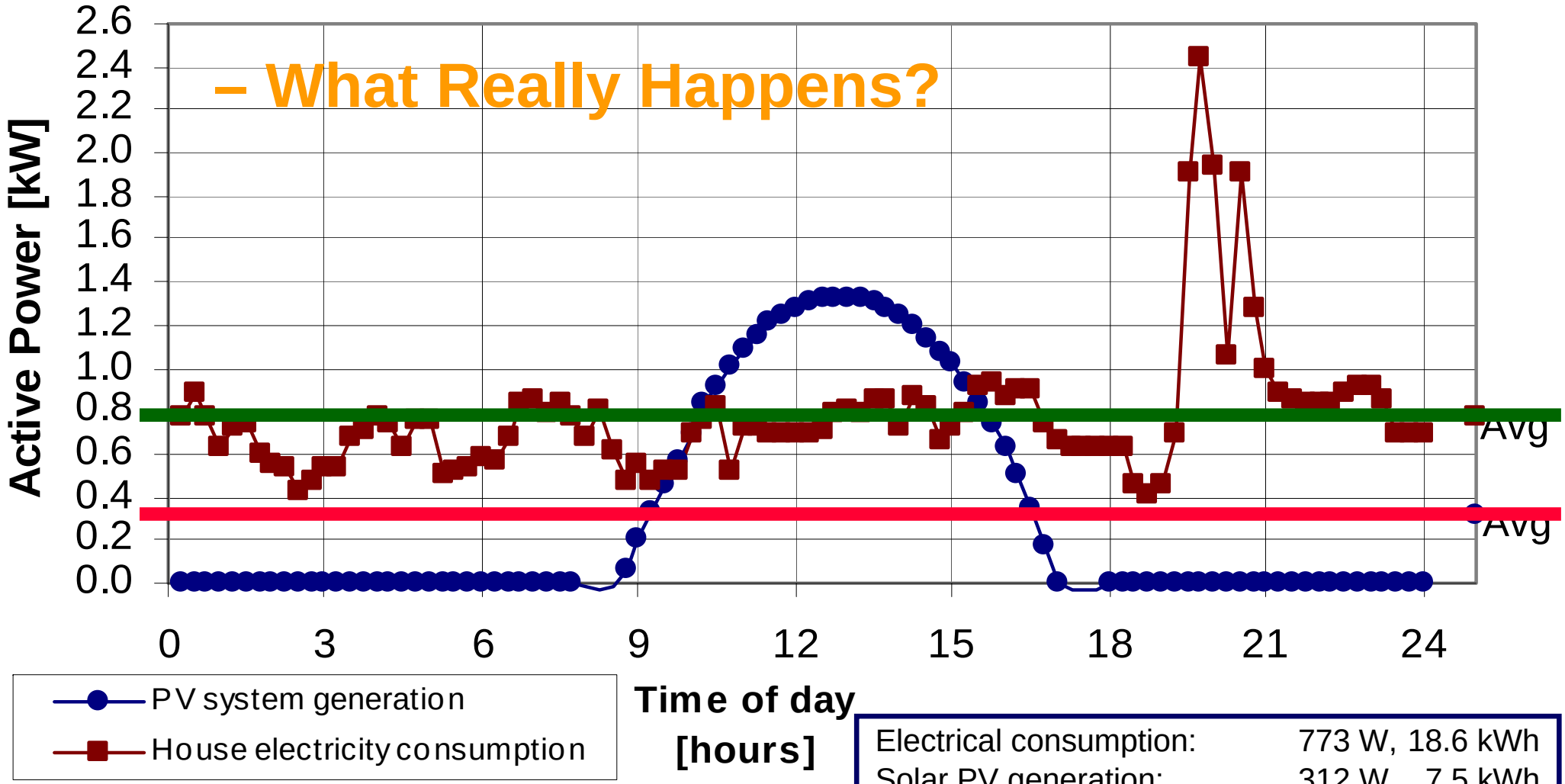
Household	Consumption Value		PV system size	PV system cost
	kWh/year	$/year	# modules**	$
– large user	14,000	$1680	58	~$90 000
– average	6600	$790	28	~$47 000
– electrical wise	4000	$480	17	~$28 000
– very efficient	2000	$240	8	~$17 000

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

** assuming 200 W PV modules, 1200 hours per year rated run-time…

Profiles: Consumption and PV Generation

– when is it importing, when is it exporting?



Solar energy:	190 W/m^2,	4.6 sun-hours
Rated yield:	3.2 hours of operation	

Electrical consumption:	773 W,	18.6 kWh
Solar PV generation:	312 W,	7.5 kWh
Portion of load supplied by PV:	40%	
Excess electricity exported:	30%,	2.2 kWh
Deficit electricity imported:	72%,	13.3 kWh

How does "net metering" work?

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

- as solar power system owners see it

Energy Retailer & Electric Wires Company

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 EWC 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 Energy Retail sees it

Energy Retailer & Electric Wires Company

1 kWh

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

Import

Export

kWh

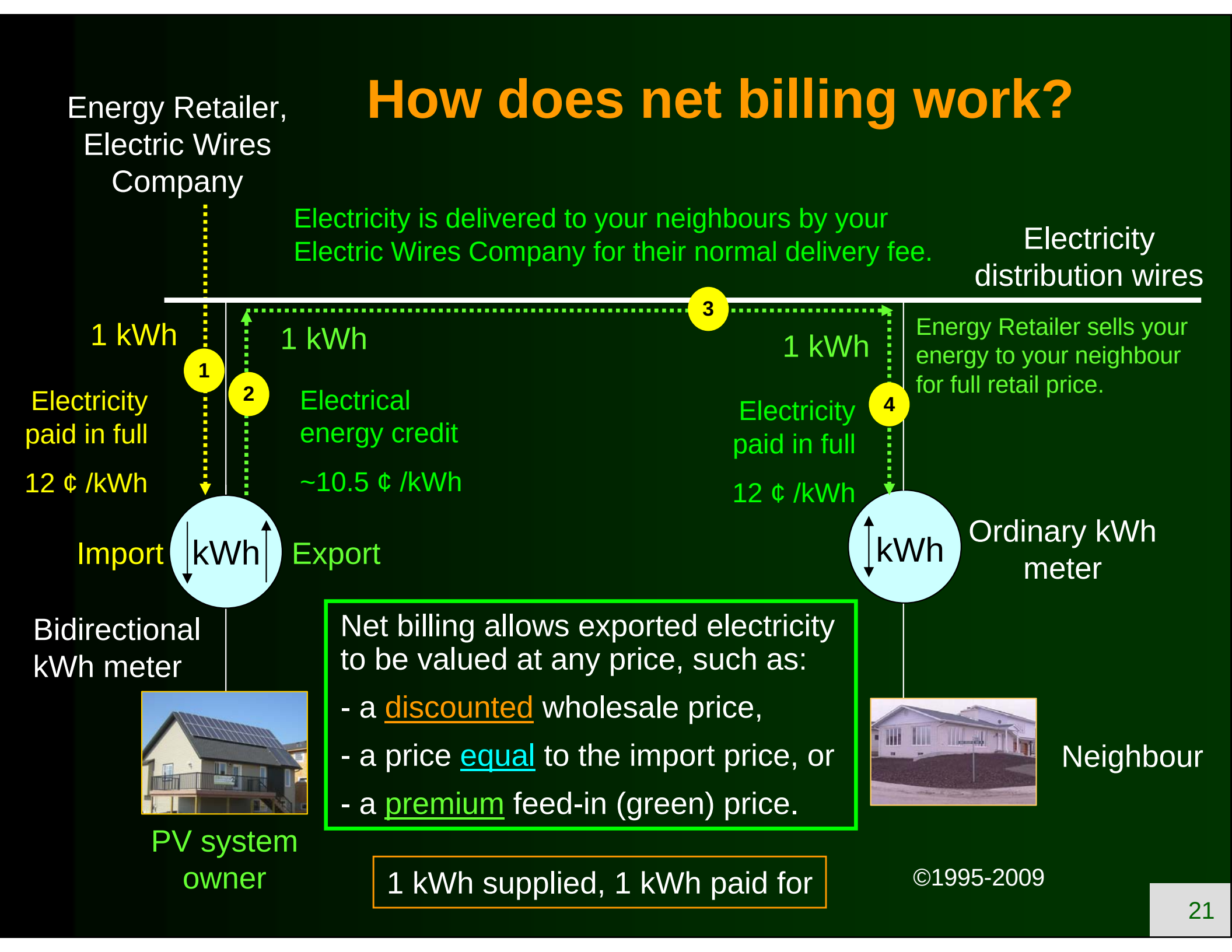
Ordinary kWh meter (goes both ways)

PV system owner

Some Electric Wires Companies 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 net billing work?



PV Economics

- For a 5.6 kW system at $8.50 / W, system installed cost = $47,000
- Simple payback (cost/annual savings)

  = 55 years (Calgary)

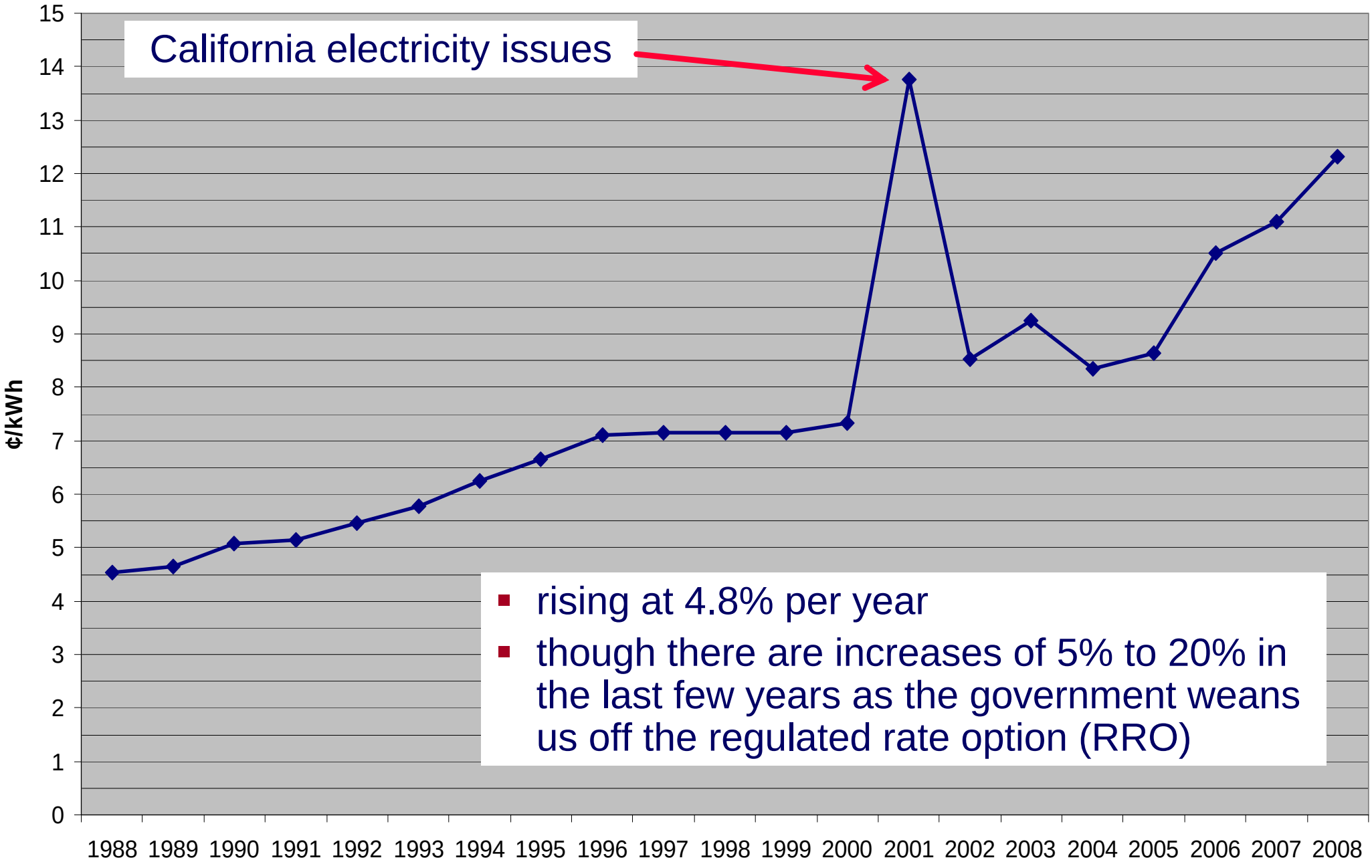
  = 1.8% return on purchase costs

- **But only if…**
  - Financing costs are ignored
  - Increases in grid-electricity prices are ignored
  - Environmental, social and infrastructure benefits are ignored

Economics Indicators

- Payback
  - easy to calculate
  - a bit of a red herring number… though everyone loves to have that number
  - not much with which to compare
- Return on Investment
  - can compare with stock market and bank interest rates
- Energy price (¢/kWh)
  - easy to understand and use
  - easy to compare with other values

Consumer Price of Electricity – Edmonton



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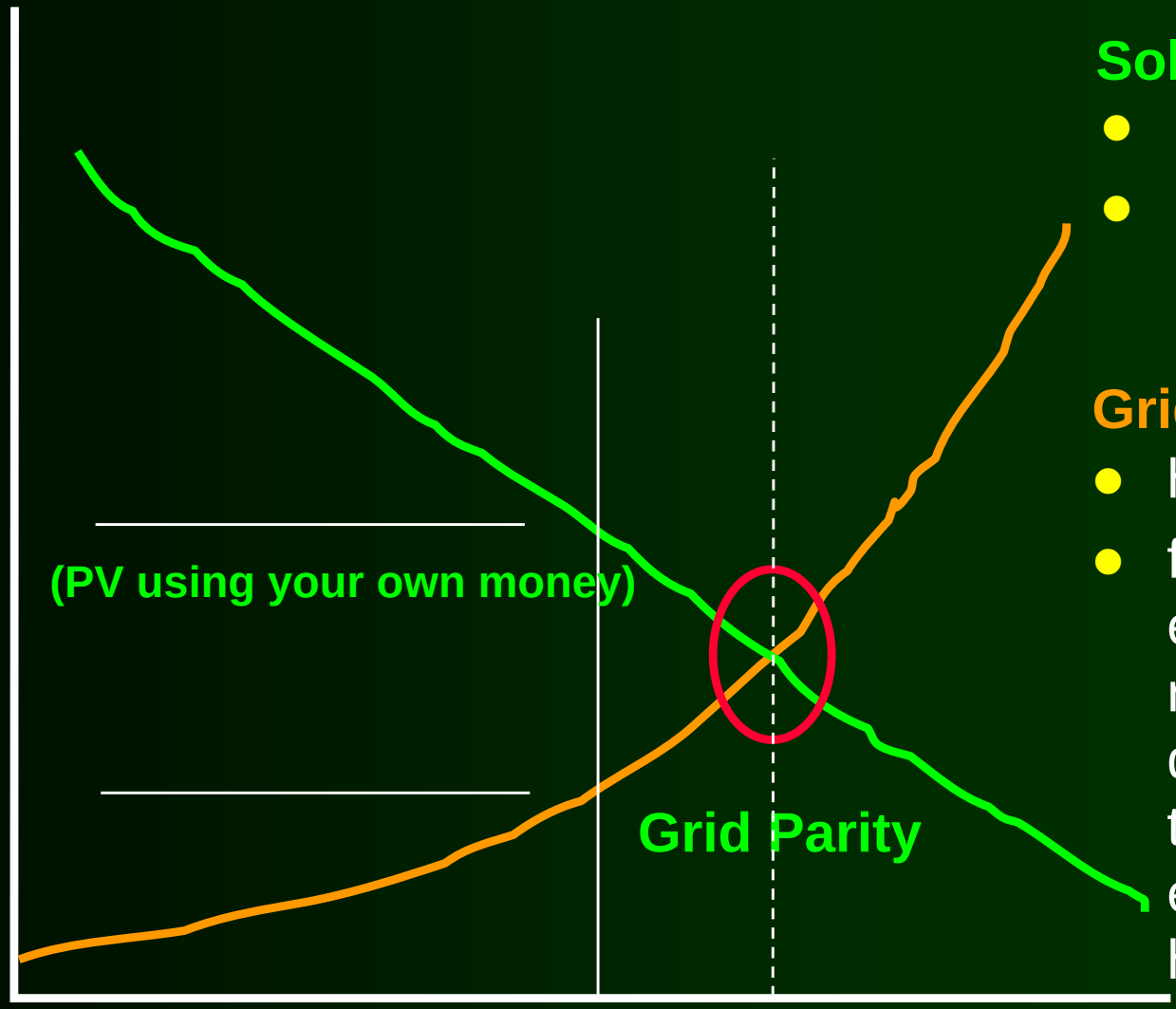
Declining PV Prices, Increasing Grid Prices



Solar PV Price

- unsubsidized
- no environmental side-effects

Grid-Electricity Price

- highly subsidized
- fossil fuel electricity does not pay for the damage it causes to the environment and health care

Grid parity: Utility Solar Assessment Study
www.cleanedge.com, www.solarcatalyst.org

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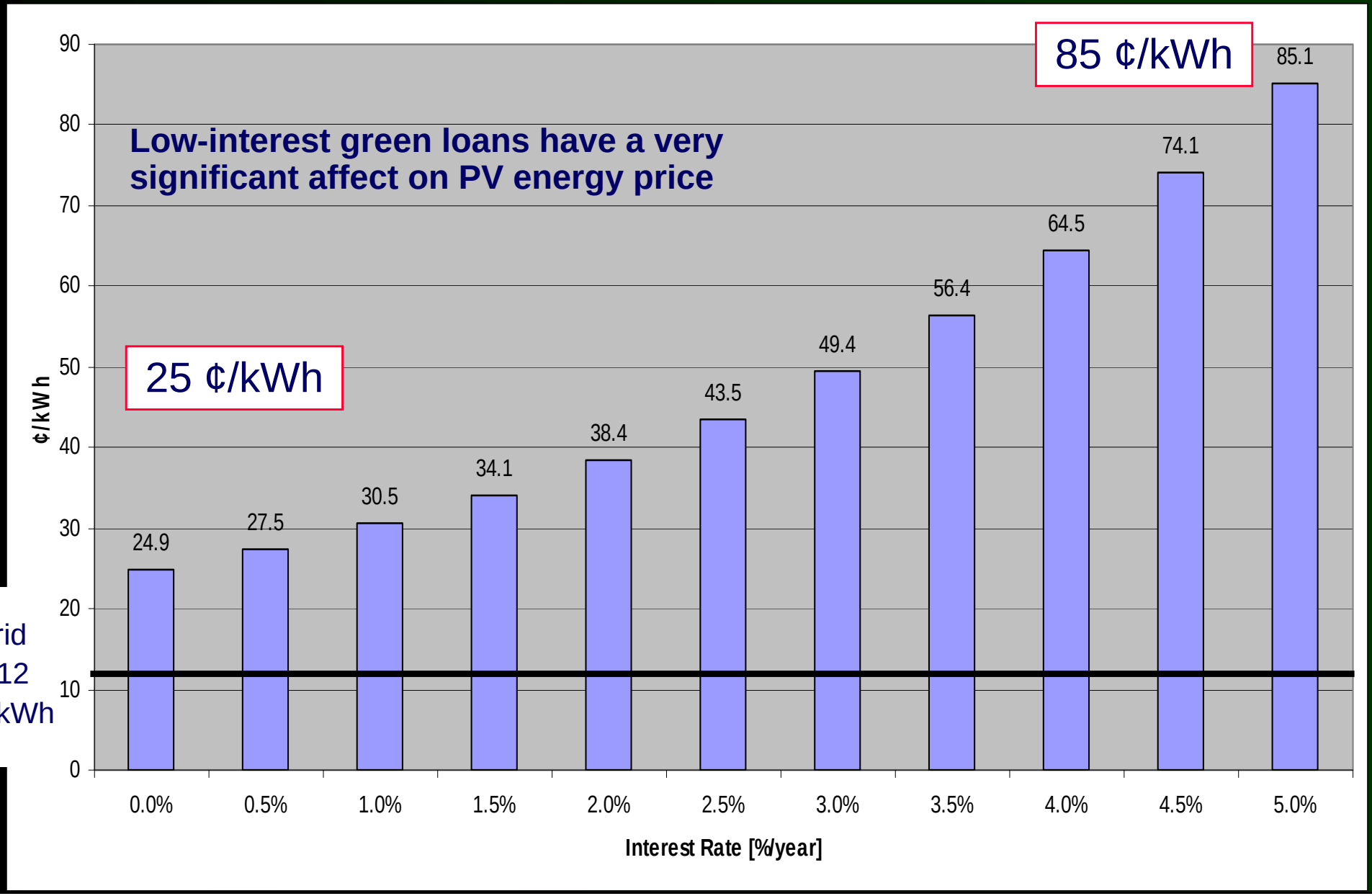
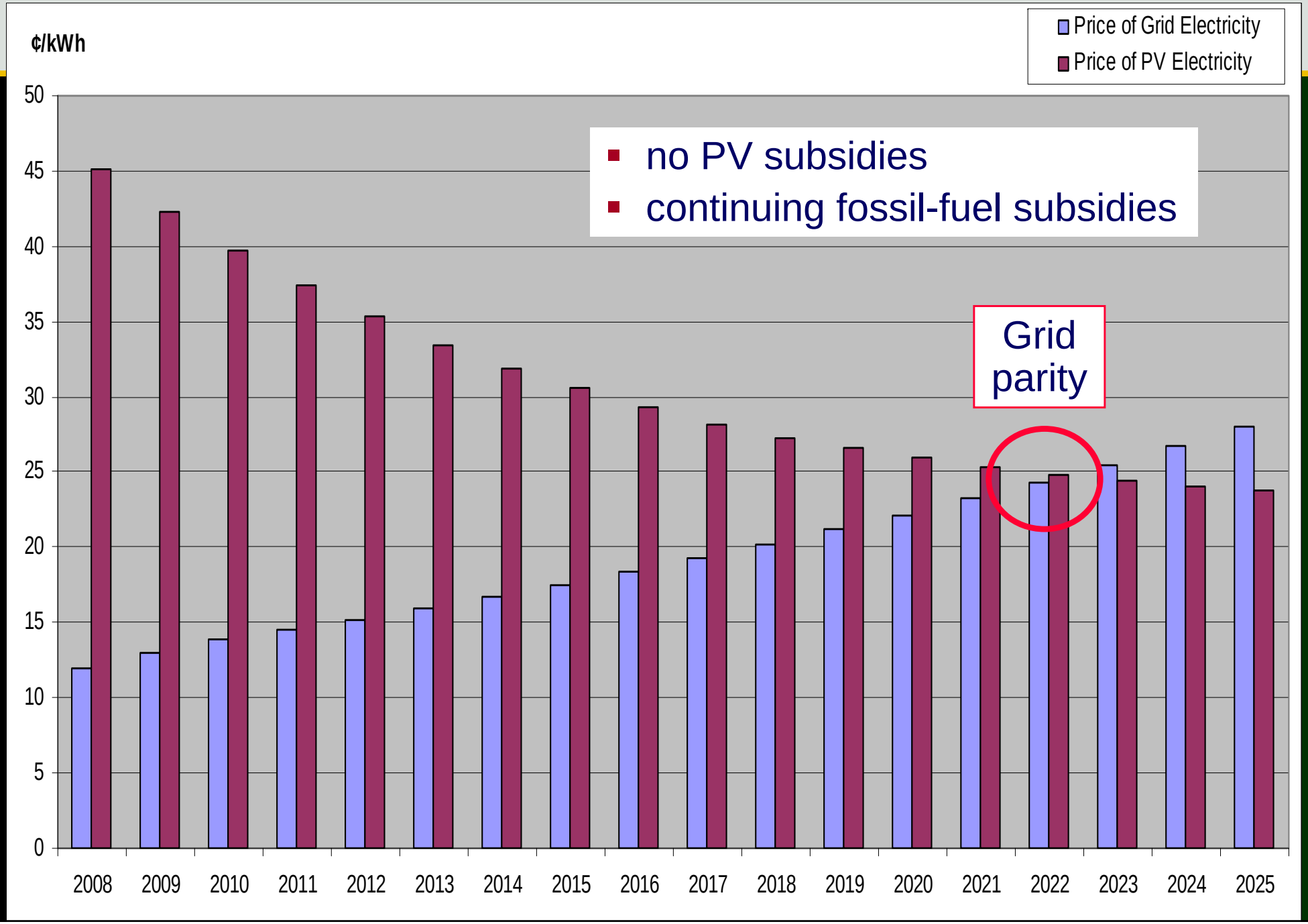
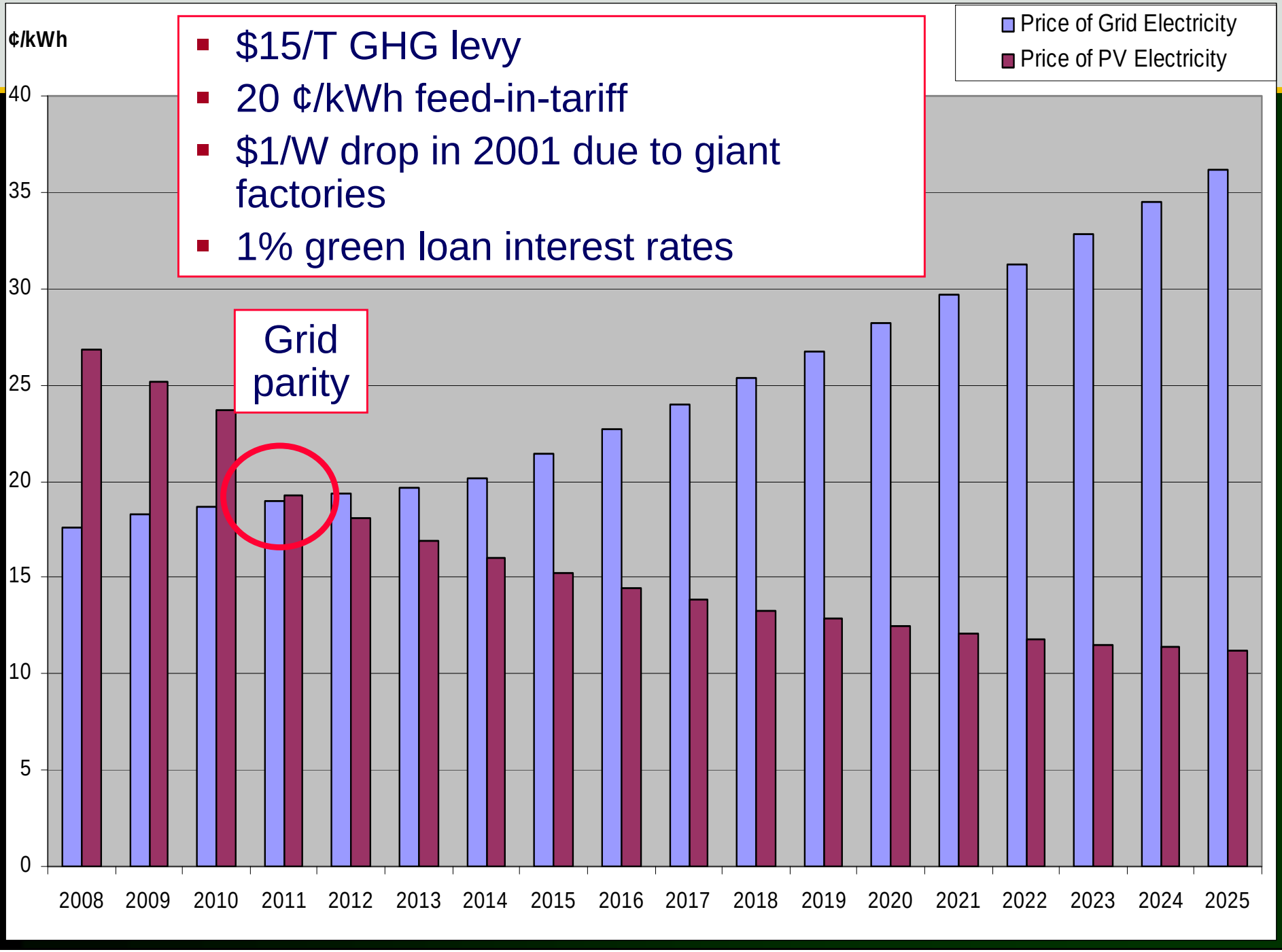
Effect of Interest Rates on PV Energy Pricing



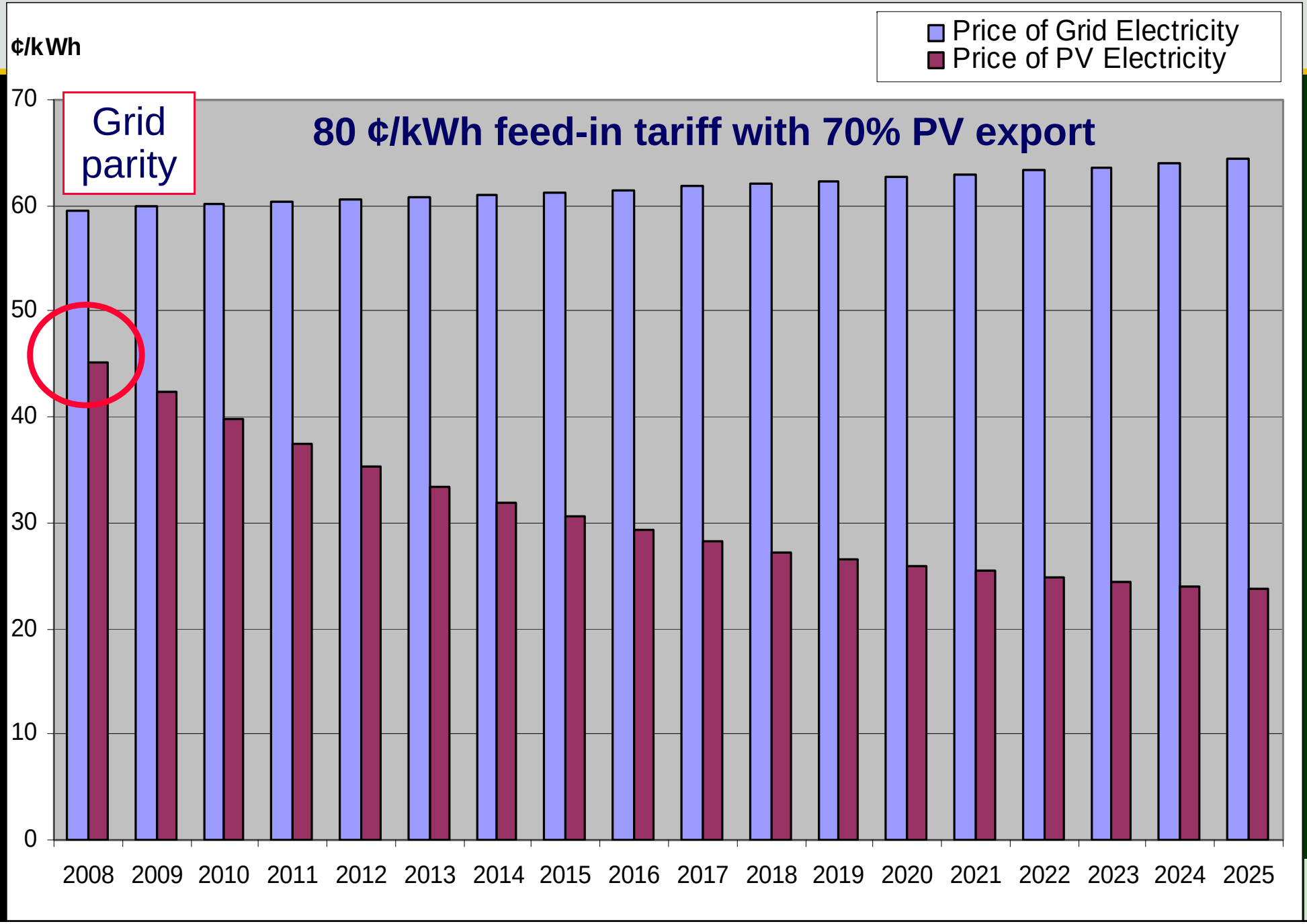
Grid Parity in 2022



Grid Parity in 2011



Grid Parity Today, ROI 4%



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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 previous consistent interest by governments in developing policies and technology assistance programmes
- Regulatory barriers – slowly being resolved

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

Benjamin Franklin

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Organisational Questions

- Policies are answers to organisation questions…

  The changes to achieve this relate to how we want to organise ourselves, they are not technical.

- How do we want to organise ourselves as a society?
  - Do we want to continue to subsidise fossil fuels with our health care budgets?
  - Do we want to value the environment, and thus put a money value on it?
  - Do we want to encourage massive amounts of personal distributed generation?

How do we want to organise ourselves?

- **Socialism** collapsed
  because it did not allow the market to tell the economic truth.

- **Capitalism** is heading the direction of collapsing
  because it does not allow the market to tell the ecological truth.

Øystein Dahle
Exxon Norway

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Government Response to our Solar Resource

Policies that facilitate	Now the new micro-generation regulation
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 !!

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Government Policies

their policies need to facilitate change instead of blocking change…

- **Value** the environment, and so place a value on it…
- **Allow** full cost recovery of all electricity fed into the grid
- **Value** increasing Canada's solar industrial capacity
- **Mandate** full-cost accounting for all energy sources
- **Remove** fossil fuel subsidies
- **Require** fossil fuels to pay for their environmental damage
- **Provide** ultra-low interest green loans

Characteristics of Solar Electricity…

- 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

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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.

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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

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