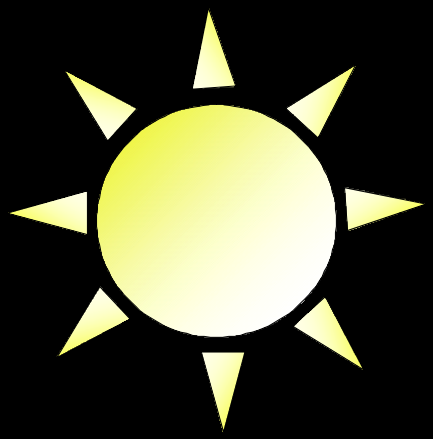
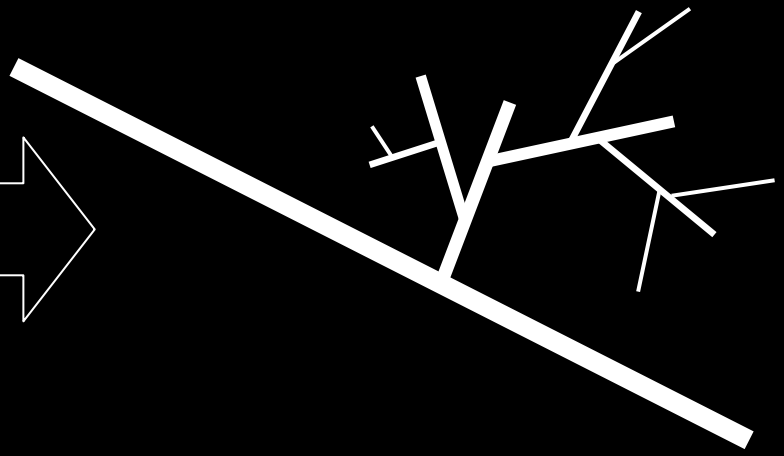
SOLAR RESOURCE



POWER GRID



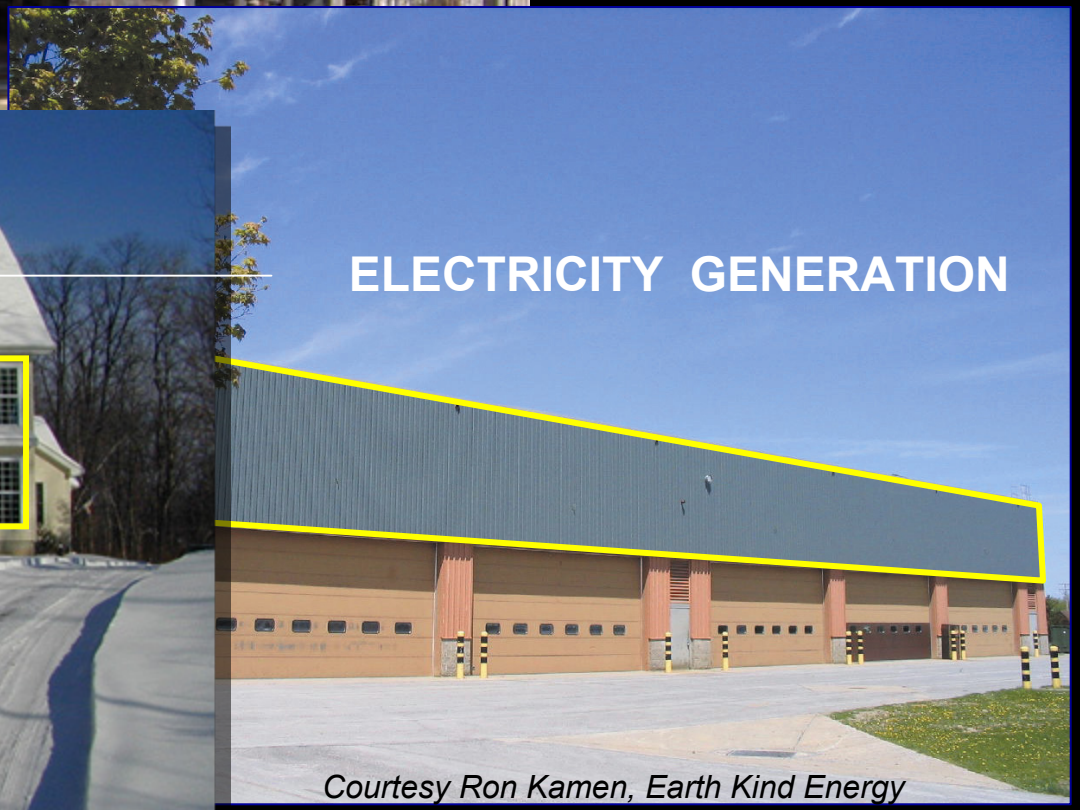
VALUE

COST

End-use-specific Solar

UNIVERSAL SOLAR

Richard Perez



Courtesy Ron Kamen, Earth Kind Energy

End-use-specific Solar

UNIVERSAL SOLAR

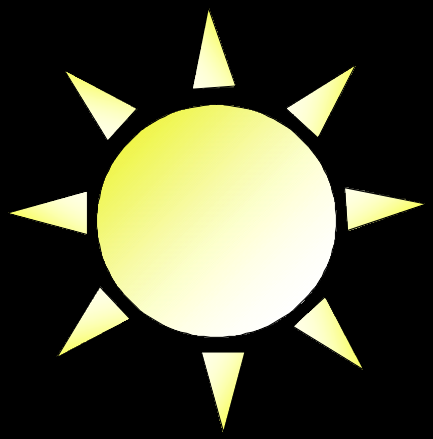
Photovoltaics

PV

Solar Thermal

PV

SOLAR RESOURCE

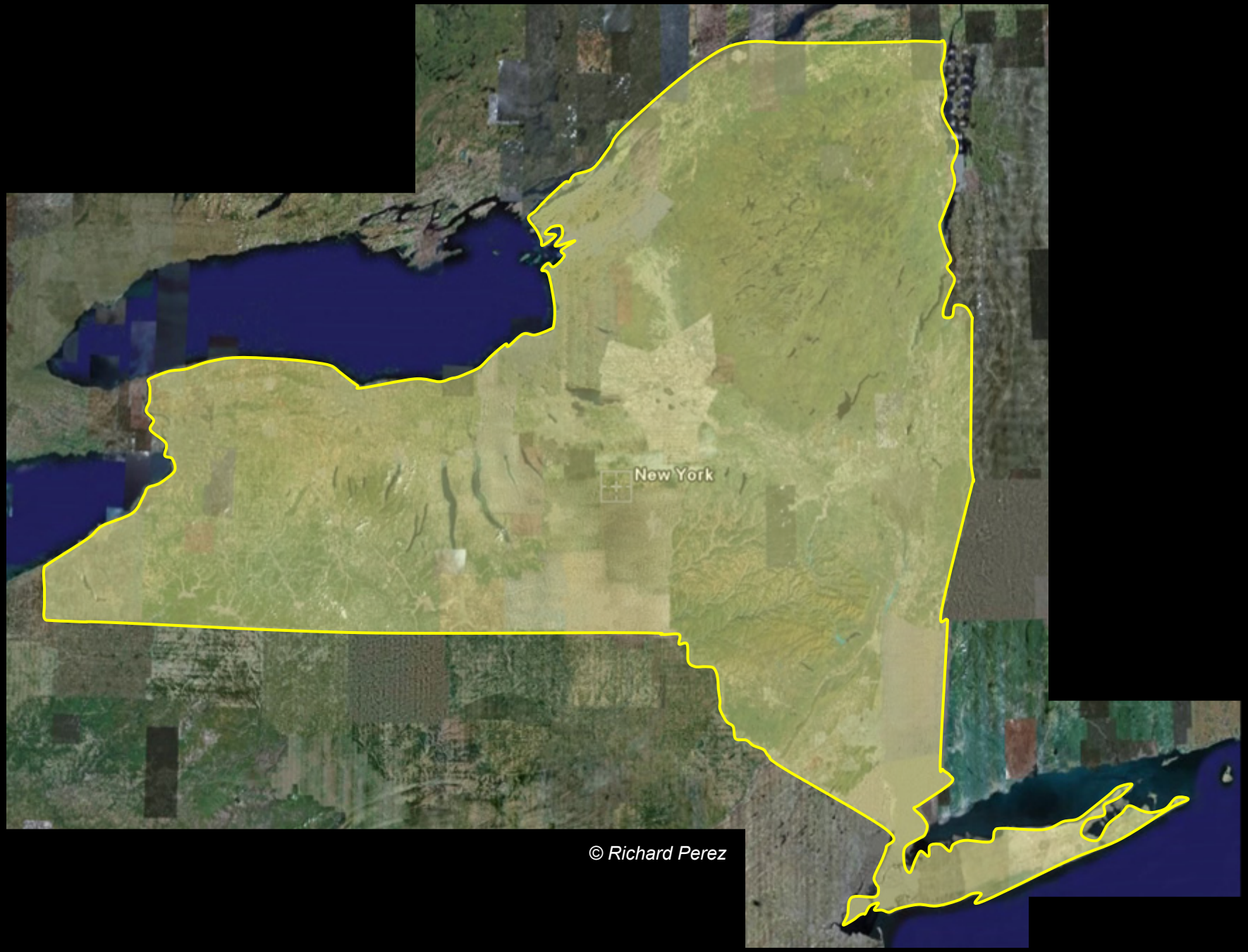


- NOT ENOUGH SPACE,
- NOT ENOUGH SUN,

Each square meter in New York can generate 200 kWh of photovoltaic electricity per year

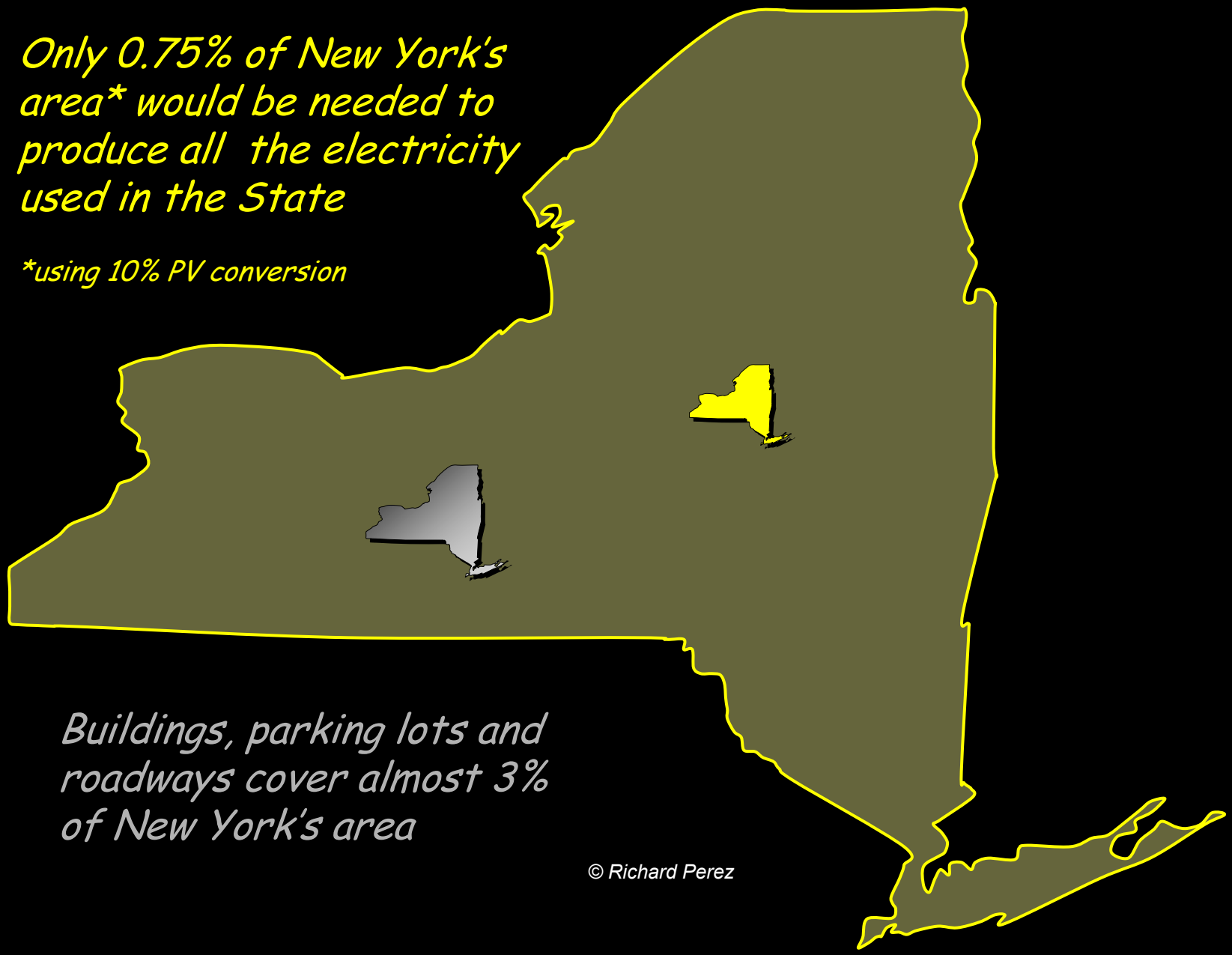
Photograph courtesy of AltPower, Inc.


120 billion kWh / year
More than twice
New York's Consumption
© Richard Perez

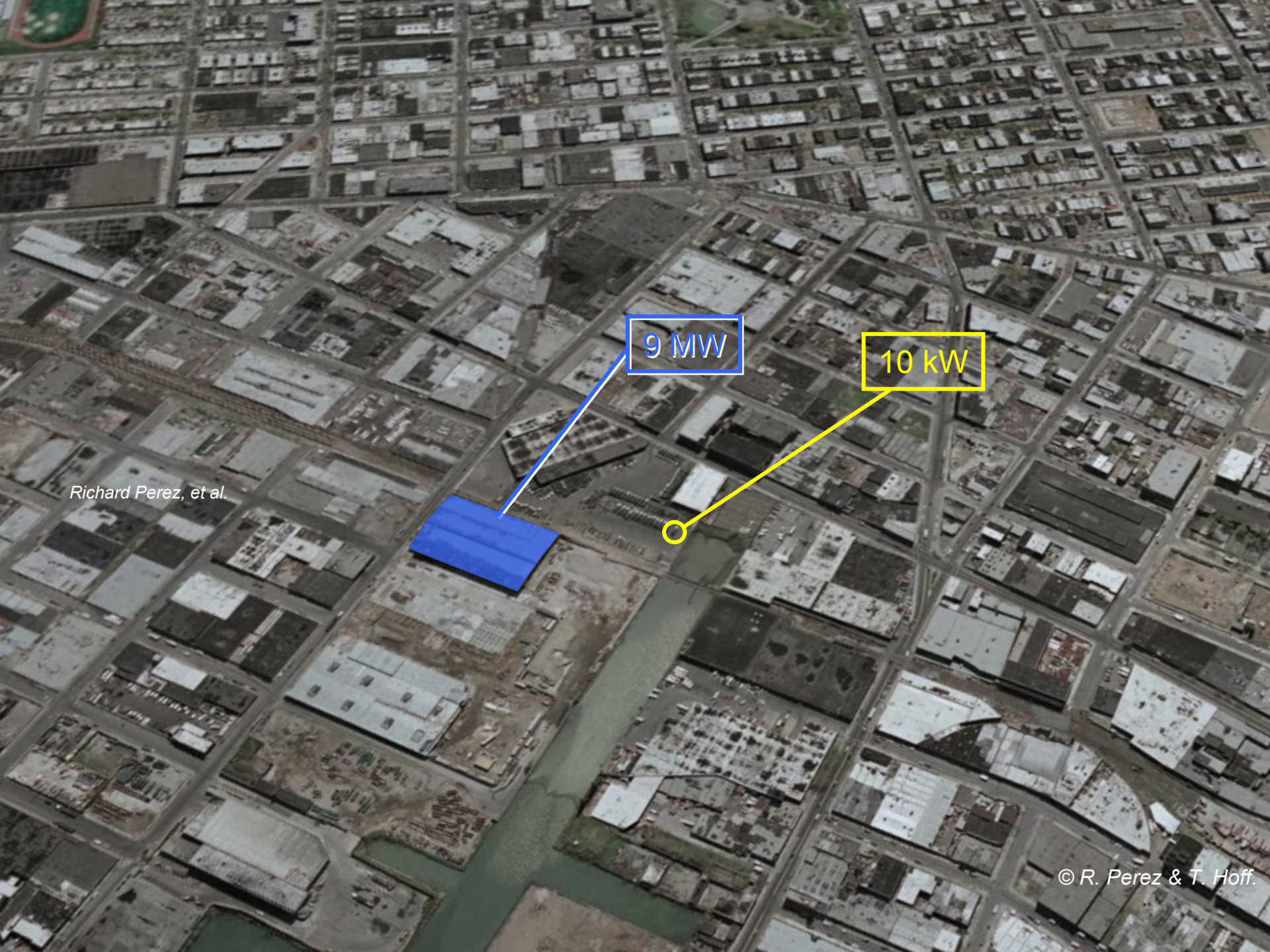


Only 0.75% of New York's area would be needed to produce all the electricity used in the State*

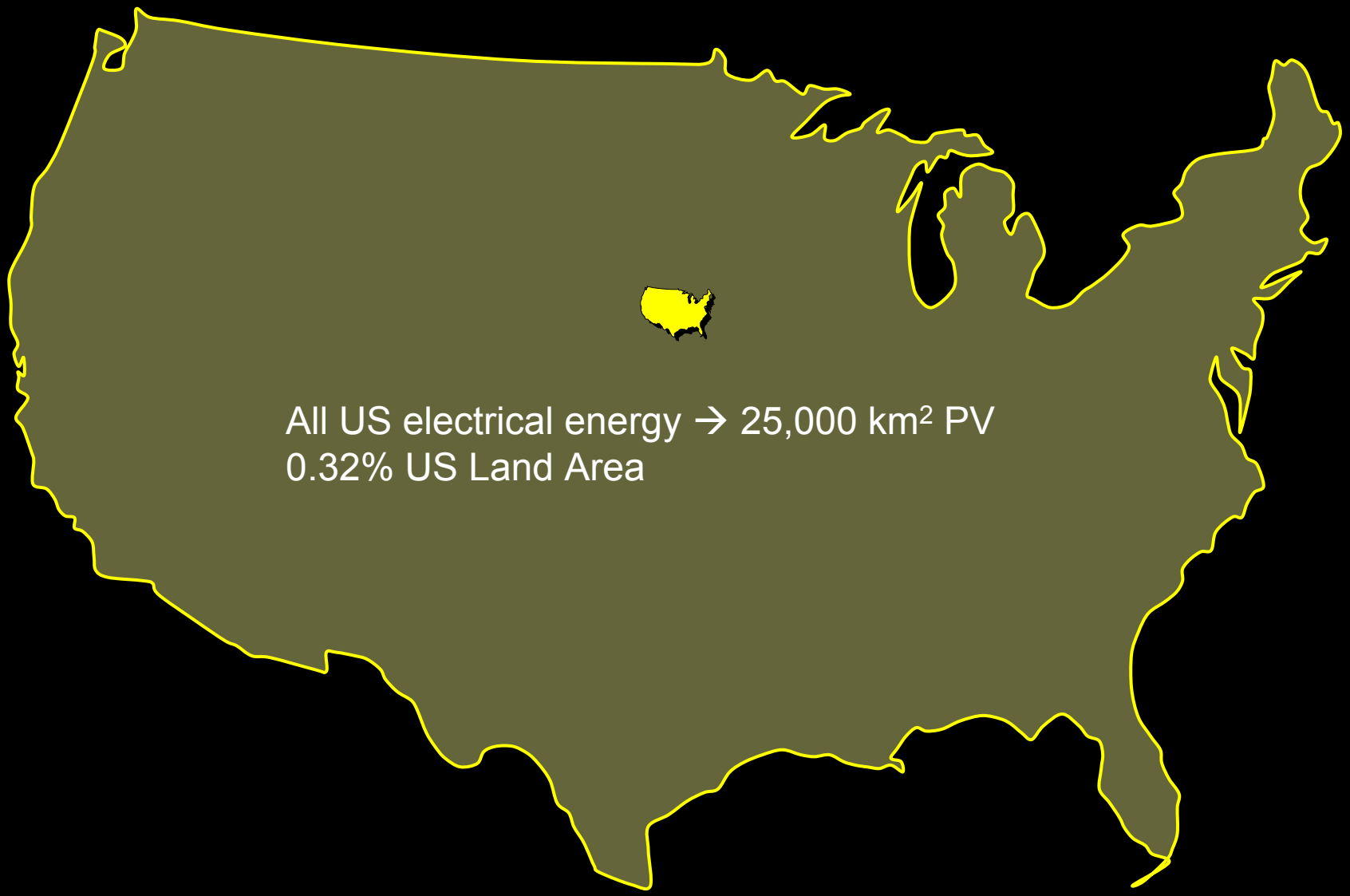
**using 10% PV conversion*



Buildings, parking lots and roadways cover almost 3% of New York's area

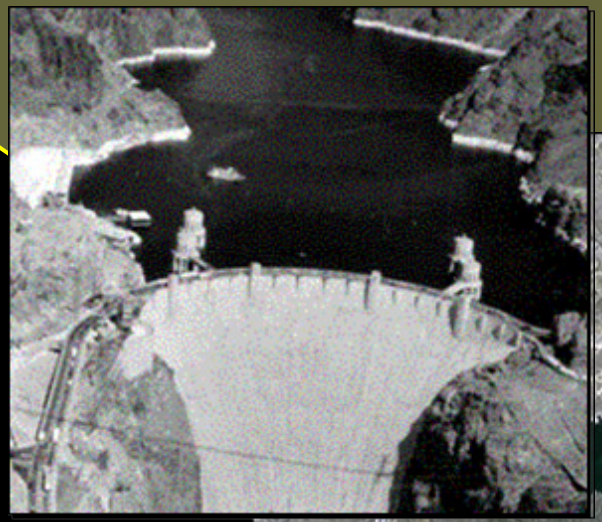

9 MW
10 kW
Richard Perez, et al.
© R. Perez & T. Hoff.


1500 MW
© Richard Perez



7% US electricity

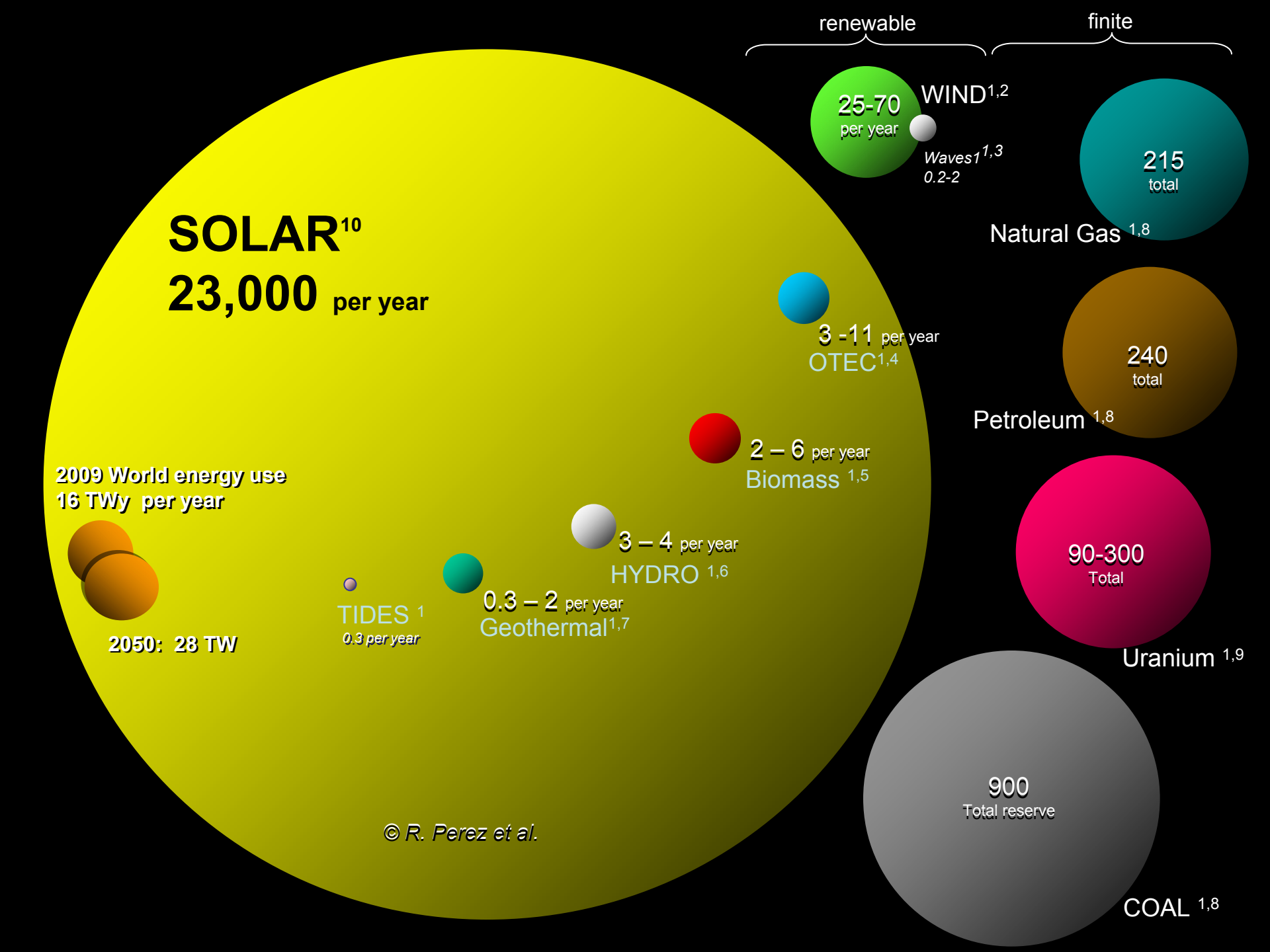
Hydropower artificial lakes > 100,000 km^2

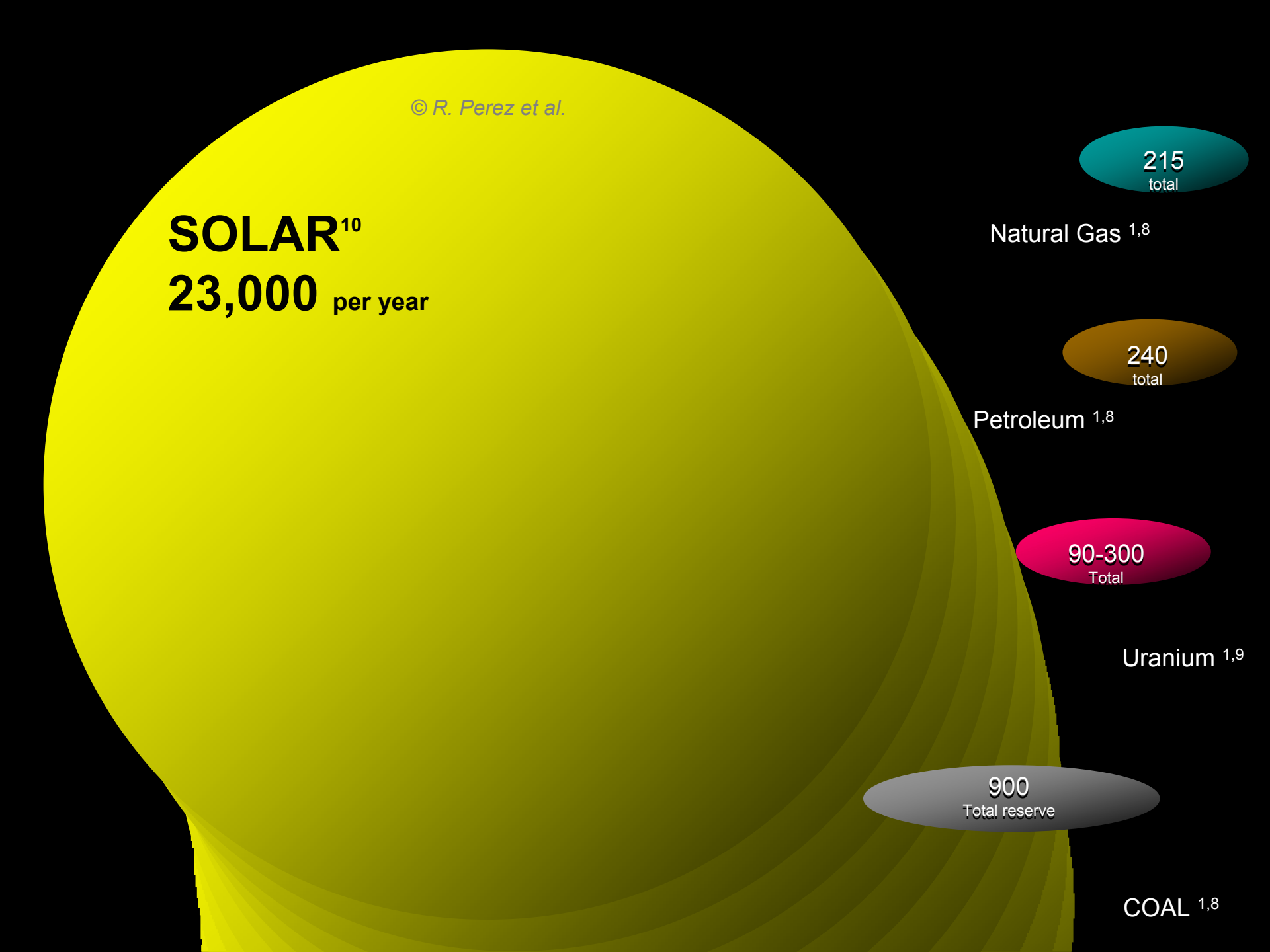


WORLD TOTAL ENERGY USE

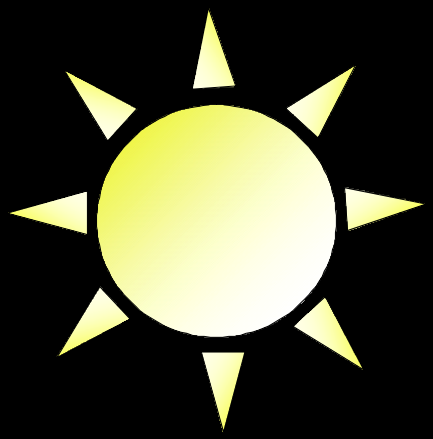
2009: 16 TWy

2050: 28 TWy


renewable
finite
SOLAR[10]
23,000 per year
2009 World energy use
16 TWy per year
2050: 28 TW
25-70
per year
WIND[1,2]
Waves[1,3]
0.2-2
215
total
Natural Gas [1,8]
3 -11 per year
OTEC[1,4]
240
total
Petroleum [1,8]
2 – 6 per year
Biomass [1,5]
3 – 4 per year
HYDRO [1,6]
90-300
Total
Uranium [1,9]
TIDES [1]
0.3 per year
0.3 – 2 per year
Geothermal[1,7]
900
Total reserve
COAL [1,8]
© R. Perez et al.


© R. Perez et al.
SOLAR[10]
23,000 per year
215
total
Natural Gas [1,8]
240
total
Petroleum [1,8]
90-300
Total
Uranium [1,9]
900
Total reserve
COAL [1,8]

SOLAR RESOURCE



- ~~NOT~~ ENOUGH SPACE,
- ~~NOT~~ ENOUGH SUN,
- TOO EXPENSIVE

COST = $50 Trillion

- **TOO EXPENSIVE**

COMPLETE **2050** 100% SWITCH TO SOLAR & RENEWABLES:

CURRENT DEBT ORIGINATED UN THE US, EUROPE & JAPAN (2008)

$58 Trillion

ENOUGH SPACE,
ENOUGH SUN,
…TOO EXPENSIVE…

VALUE

Ralph Izzo, Chairman, PSEG:

"We've got to stop pretending solar power will lower the cost of energy.

It's going to increase the cost and people have got to understand why it is worth more"

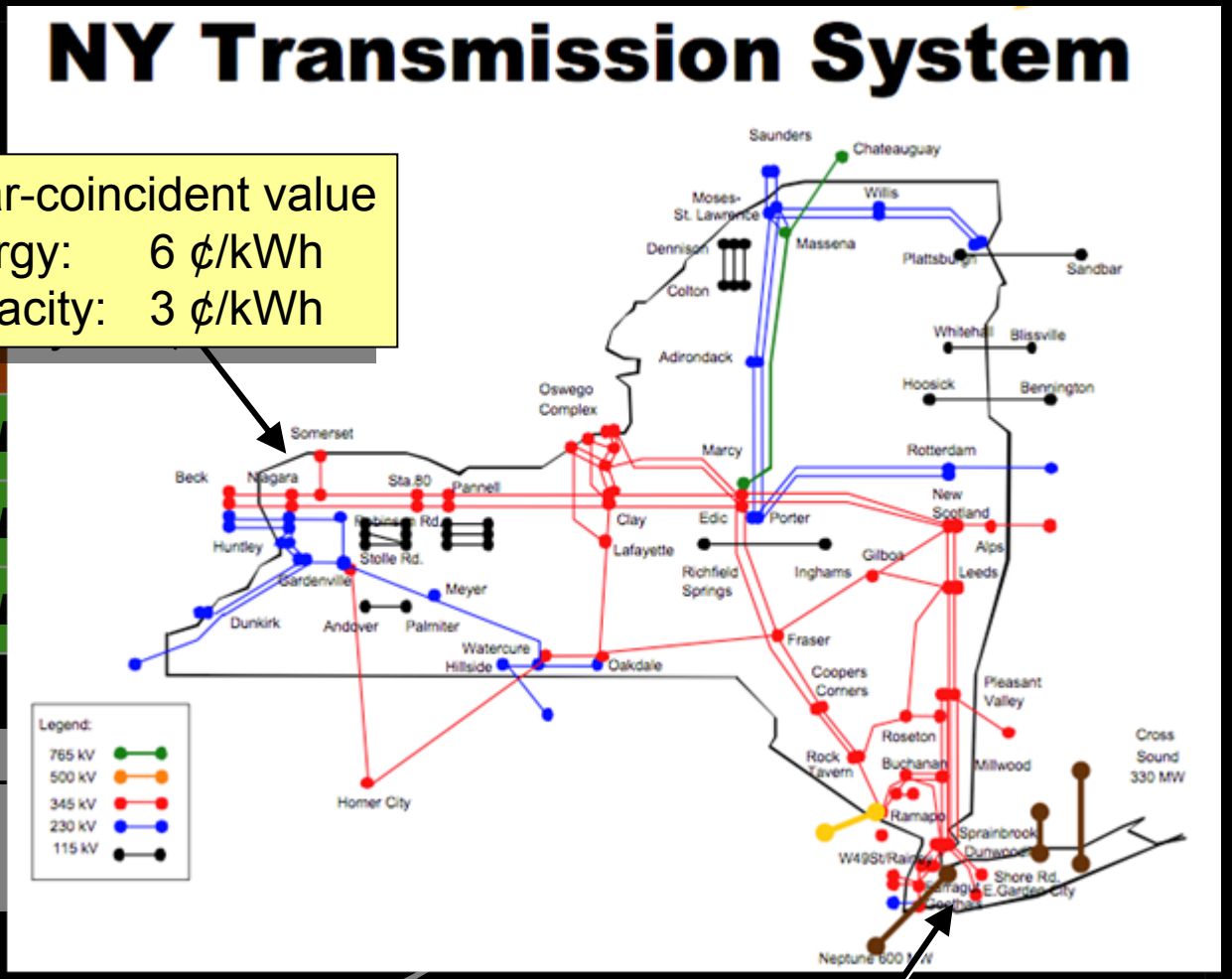
Wall Street Journal 7/31/09

	PV OWNER	UTILITY	CONSTITUENTS
EQUIPMENT	COST		
INCENTIVES	BENEFIT		COST
UTILITY BILLS	BENEFIT	COST	
TAX EFFECTS	BENEFIT		COST

EQUIPMENT
INCENTIVES
UTILITY BILLS
TAX EFFECTS

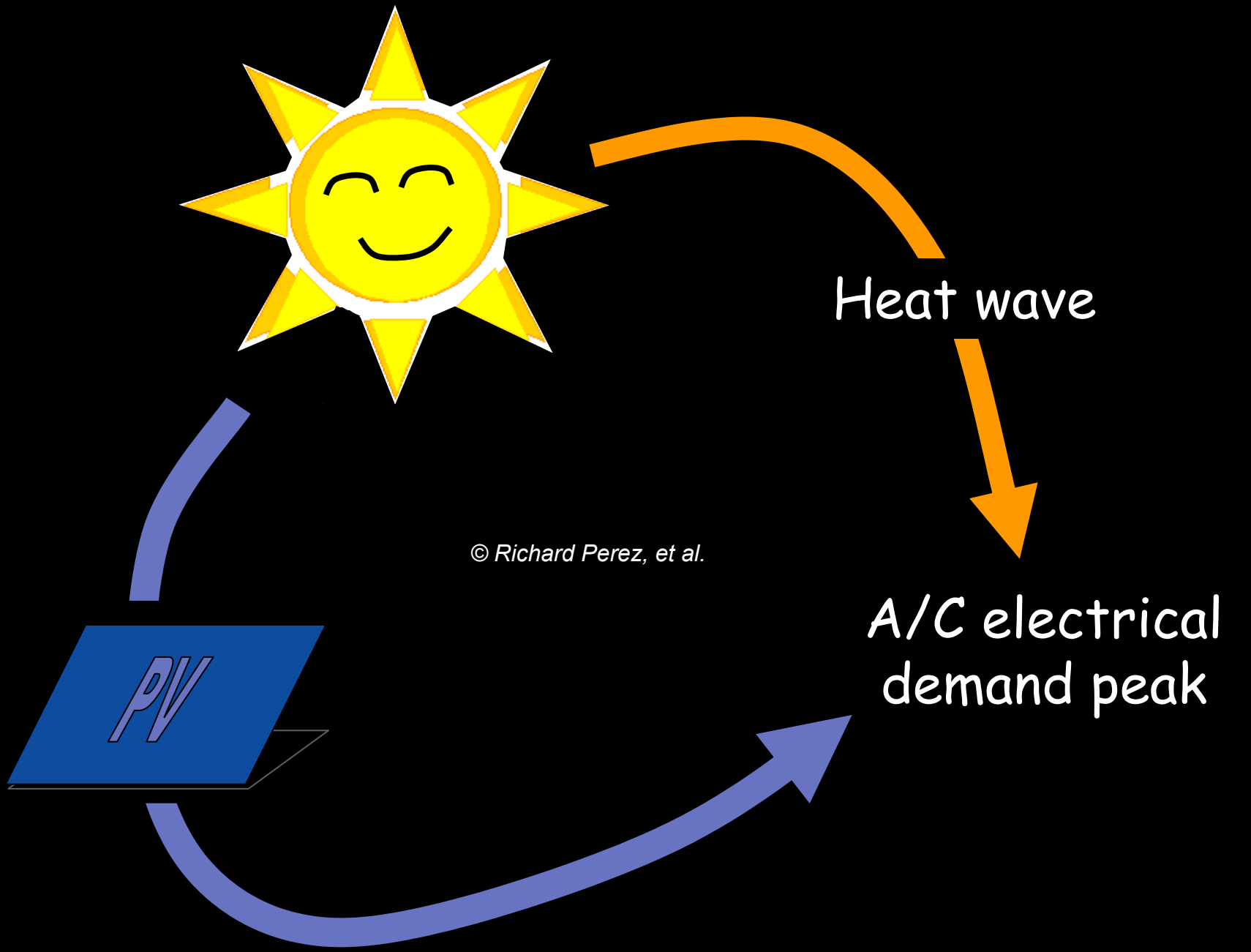
TRANSMISSION LEVEL
Energy
Capacity

Solar-coincident value
Energy: 6 ¢/kWh
Capacity: 3 ¢/kWh

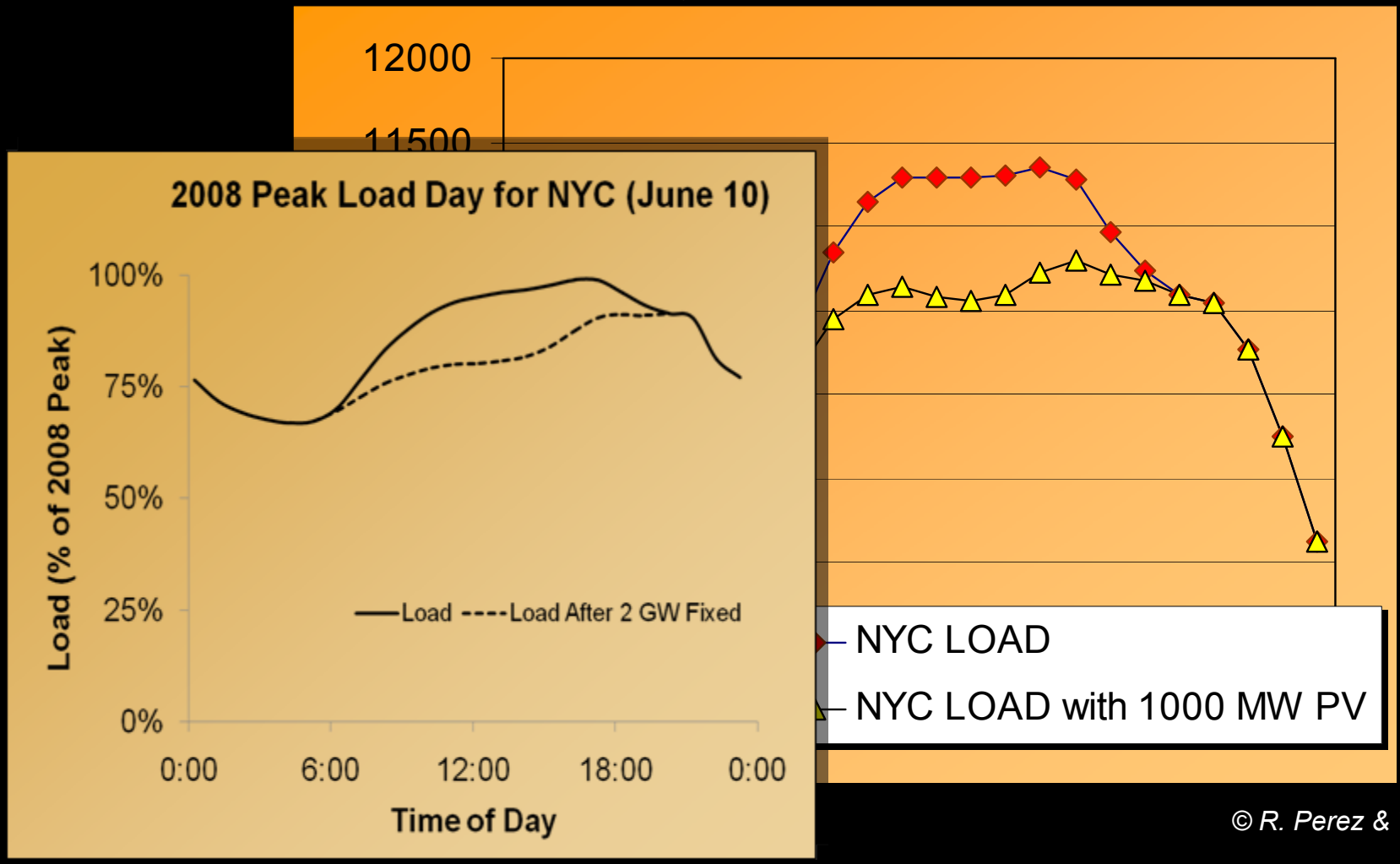


Mean 24 hour value
Energy: 5 ¢/kWh
Capacity: 0 ¢/kWh for solar

Energy: 11 ¢/kWh
Capacity: 5 ¢/kWh


Heat wave
A/C electrical demand peak
PV
© Richard Perez, et al.

Summer 2006 peak demand day New York City



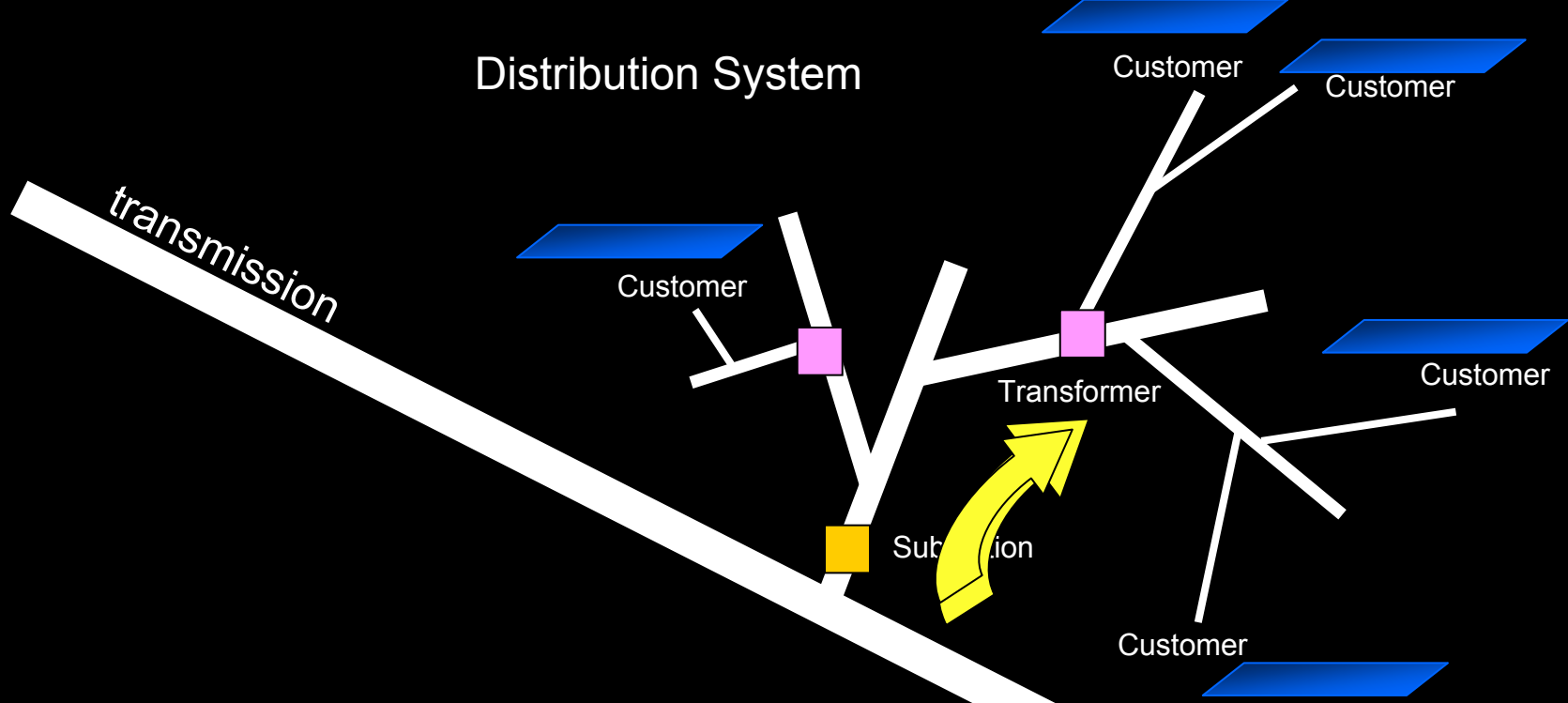
	PV OWNER	UTILITY	CONSTITUENTS
EQUIPMENT	COST	BENEFIT	BENEFIT
INCENTIVES	BENEFIT		COST
UTILITY BILLS	BENEFIT	COST	
TAX EFFECTS	BENEFIT		COST

TRANSMISSION LEVEL

Energy
Capacity

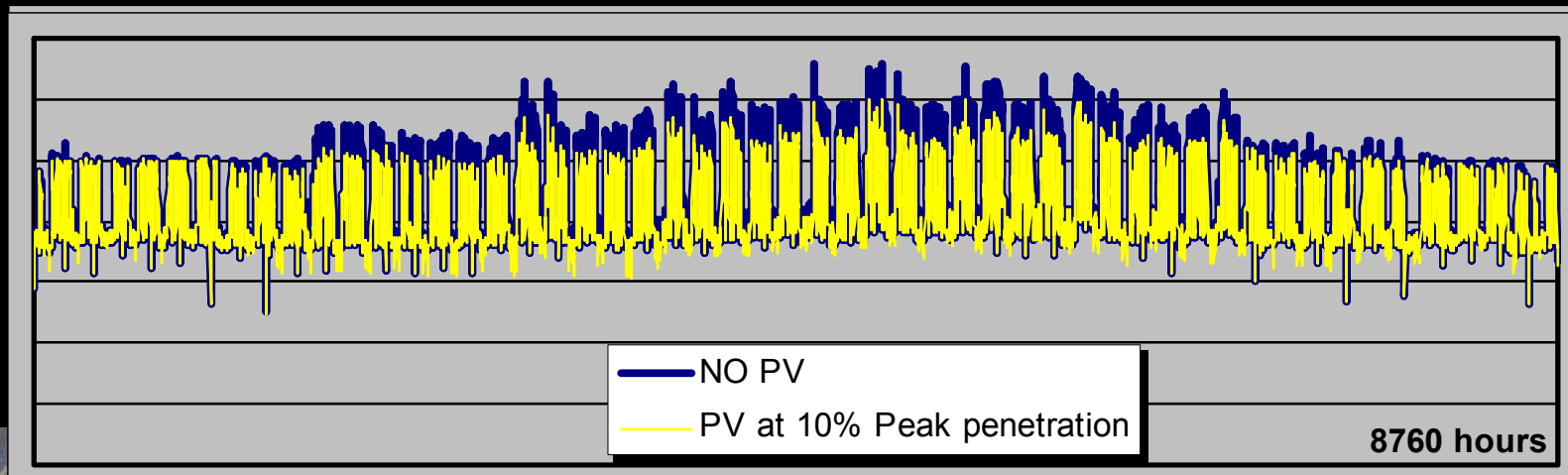
15 ¢/kWh
utility

Distribution System

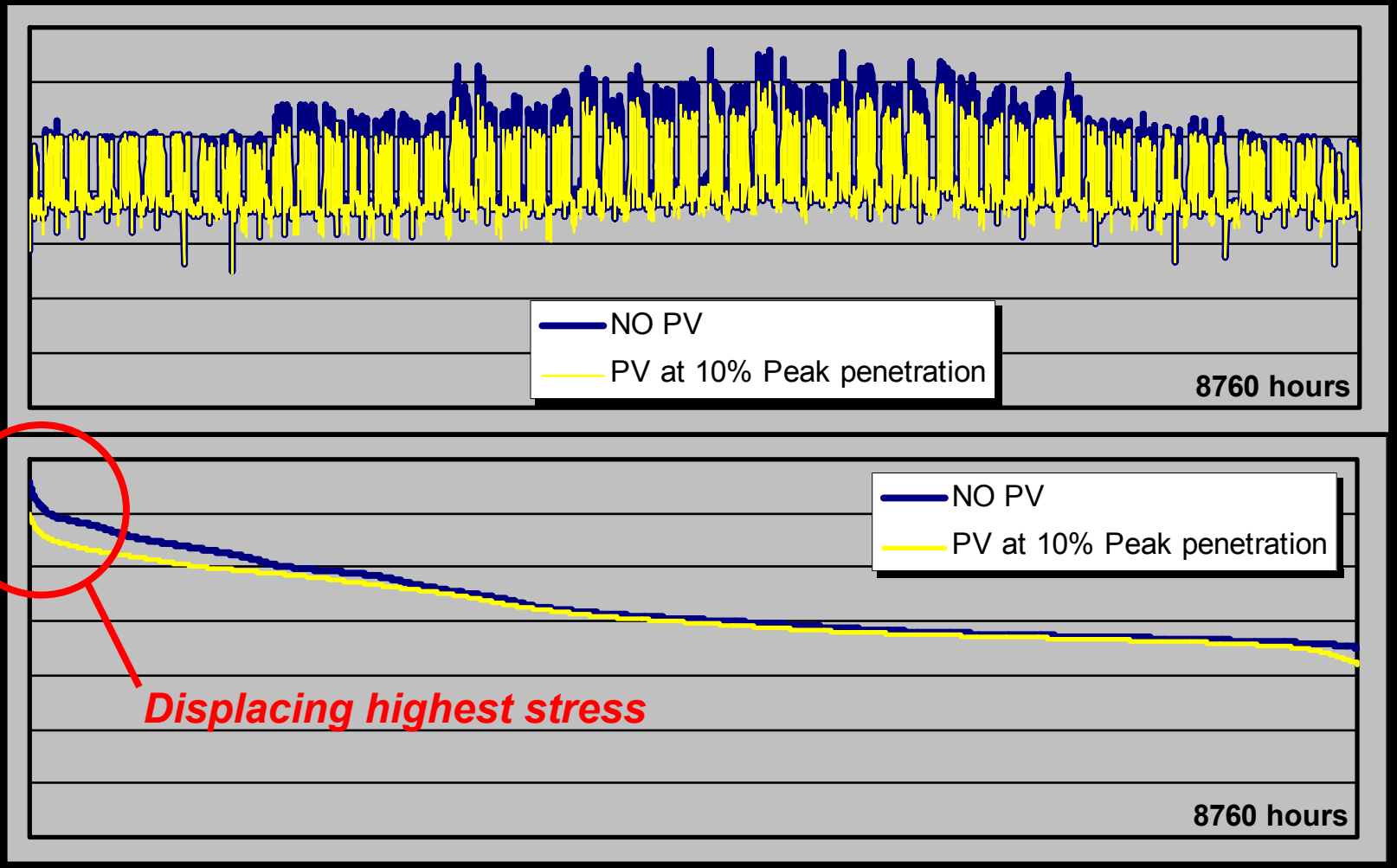


TRANSMISSION LEVEL		
	Energy Capacity	15 ¢/kWh *utility*
DISTRIBUTION LEVEL		
	Capacity	
	Loss savings	

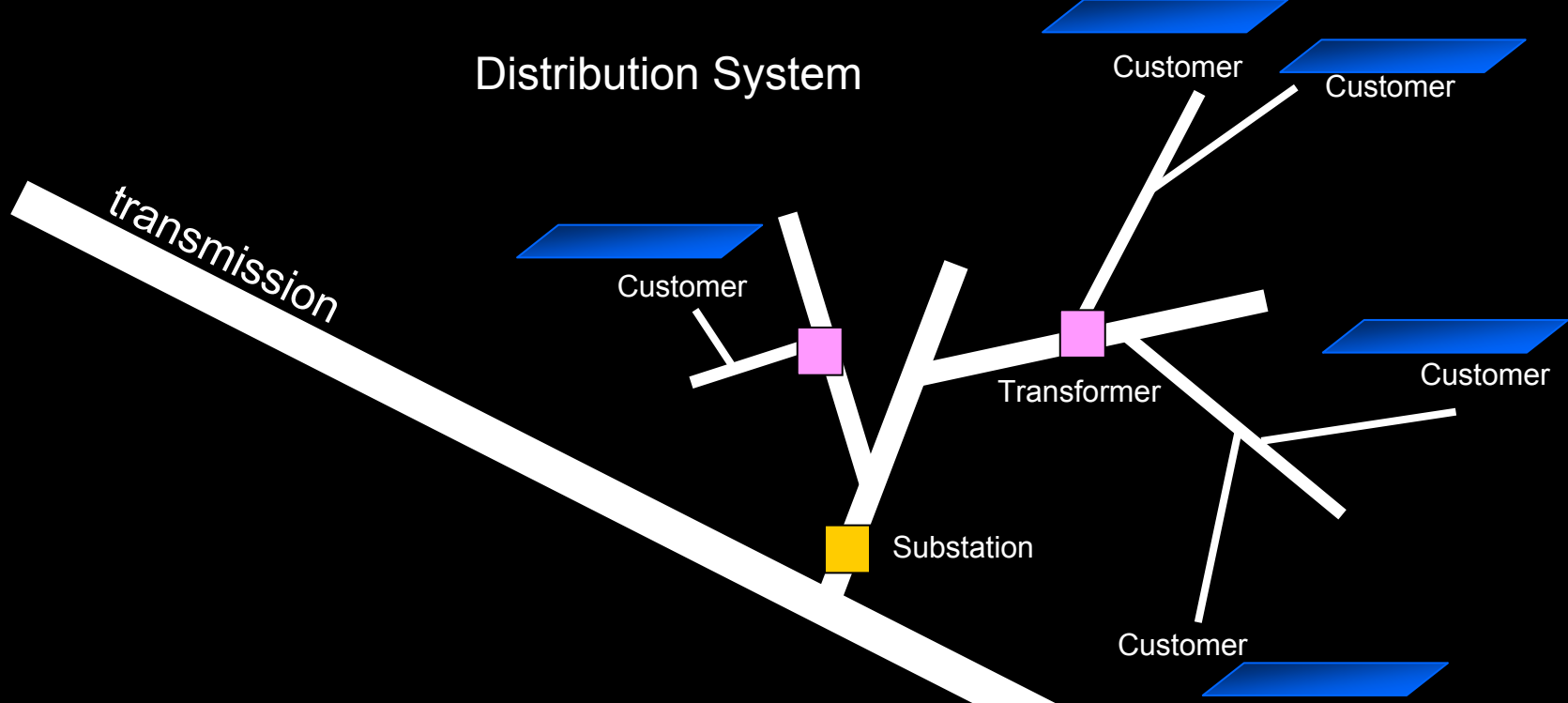
ELECTRICAL DEMAND THROUGHOUT ONE YEAR



PV IMPACT AT 10% CAPCITY PENETRATION



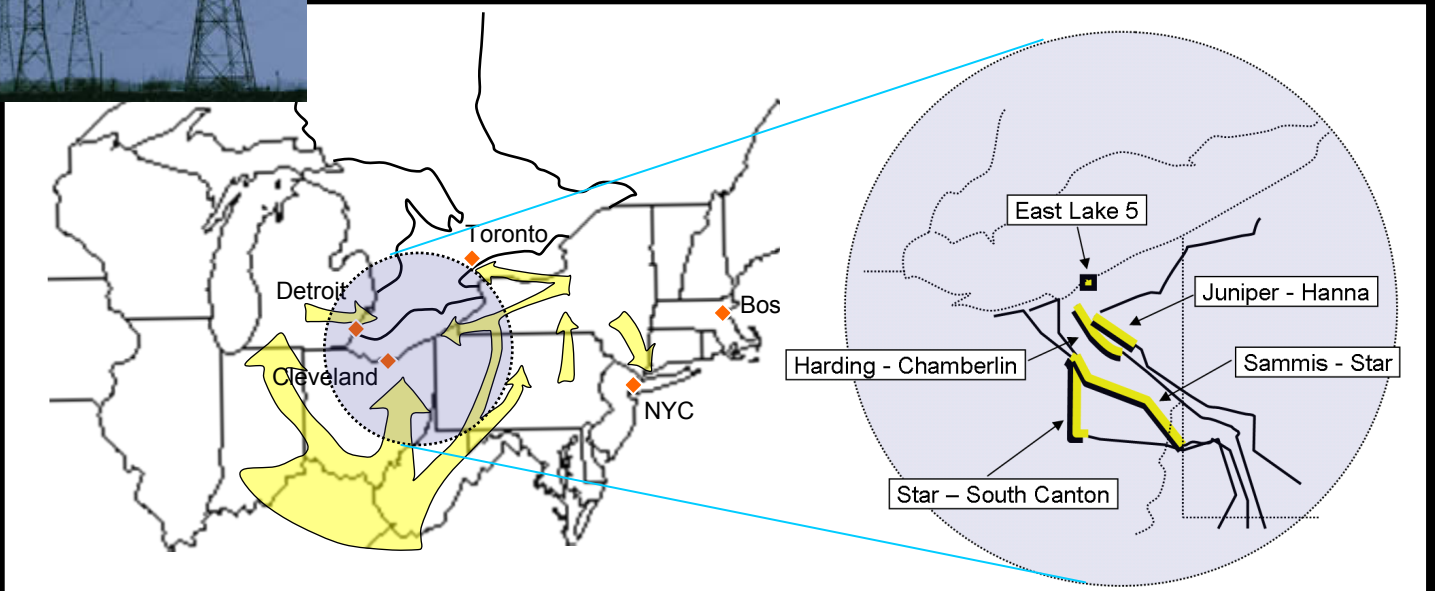
Distribution System



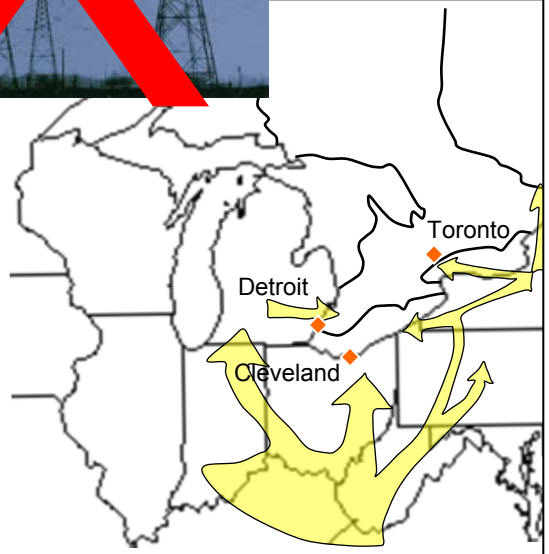
TRANSMISSION LEVEL		
	Energy Capacity	15 ¢/kWh *utility*
DISTRIBUTION LEVEL		
	Capacity Loss savings	1-6 ¢/kWh *utility*

TRANSMISSION LEVEL		
	Energy Capacity	15 ¢/kWh *utility*
DISTRIBUTION LEVEL		
	Capacity Loss savings	1-6 ¢/kWh *utility*
GRID SECURITY		

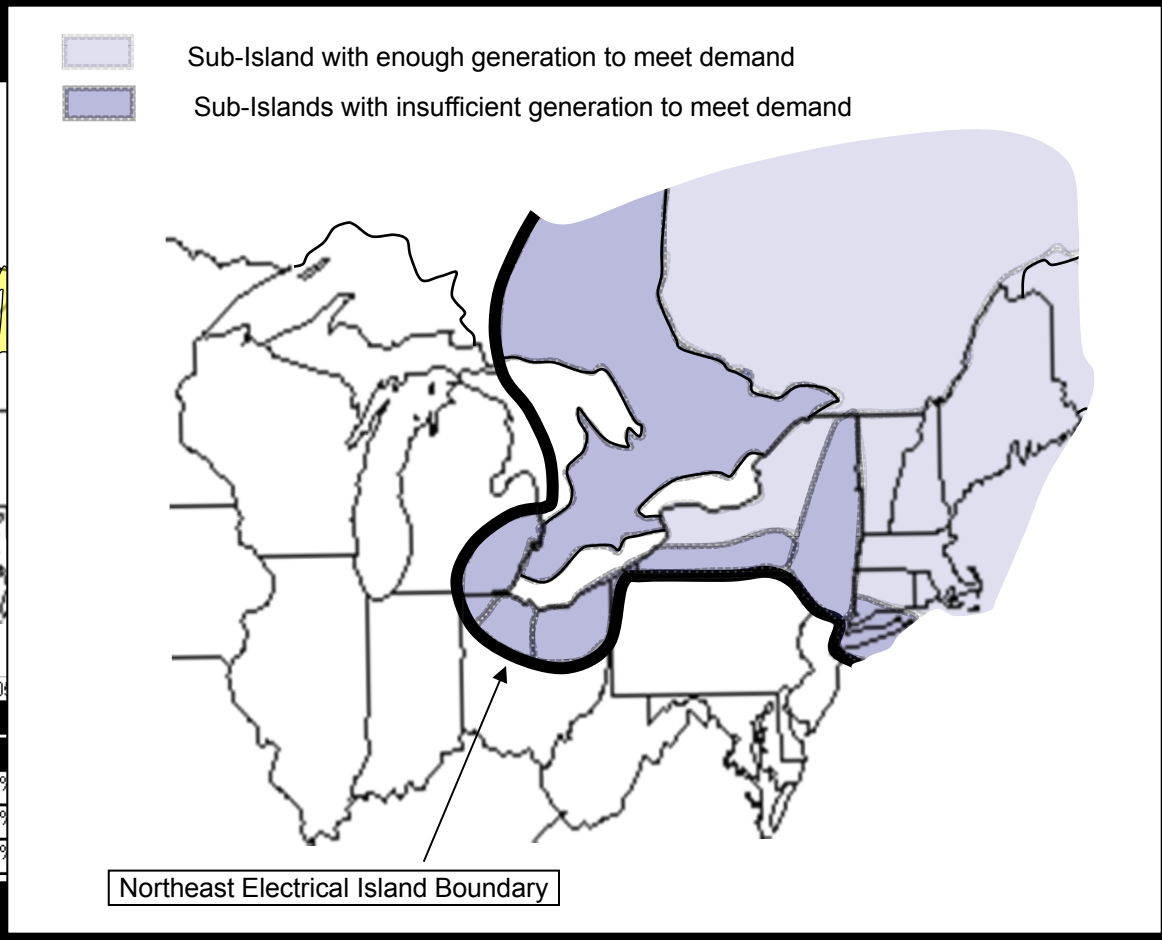
**Gellings, C. W., and K. Yeager, (2004): Transforming the electric infrastructure. Physics Today, Dec. 2004.*



	Before 1:31 PM	1:31 PM	3:05 PM	3:32 PM	3:41 PM	4:05 PM	Cause
East Lake 5 Plant	100% (600MW)	Failed	Failed	Failed	Failed	Failed	Exceeding MVAR limit
Harding-Chamberlain	35% (400MW)	45% (500MW)	Failed	Failed	Failed	Failed	Tree Contact
Juniper-Hanna	55% (800MW)	70% (1 GW)	80% (1.2 GW)	Failed	Failed	Failed	Tree Contact
Star-South Canton	65% (650MW)	80% (800MW)	90% (900MW)	120% (1.2 GW)	Failed	Failed	Overaload
Star-Sammis	55% (650MW)	60% (700MW)	65% (800MW)	85% (1 GW)	120% (1.4 GW)	Failed	Overaload



	Before 1:31 PM	1:31 PM	3:0
East Lake 5 Plant	100% (600MW)	Failed	
Harding-Chamberlain	35% (400MW)	45% (500MW)	
Juniper-Hanna	55% (800MW)	70% (1 GW)	80%
Star-South Canton	65% (650MW)	80% (800MW)	90%
Star-Sammis	55% (650MW)	60% (700MW)	65%



NYC $1 Billion

(Reuters)

$1.1 Billion

(The Guardian)

US-Can $6.8 - $10.3 B

(ICF Consulting)

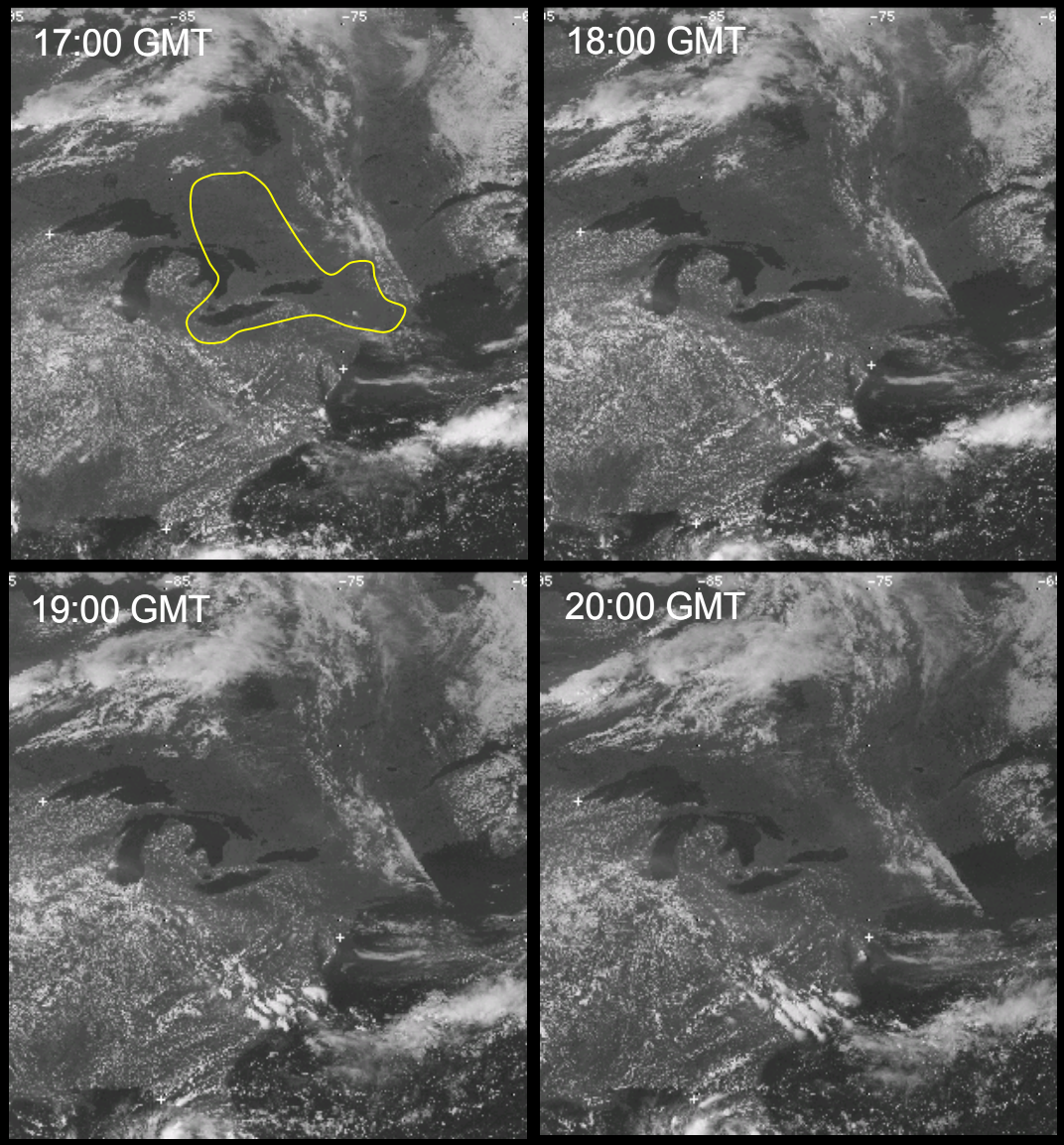

PV

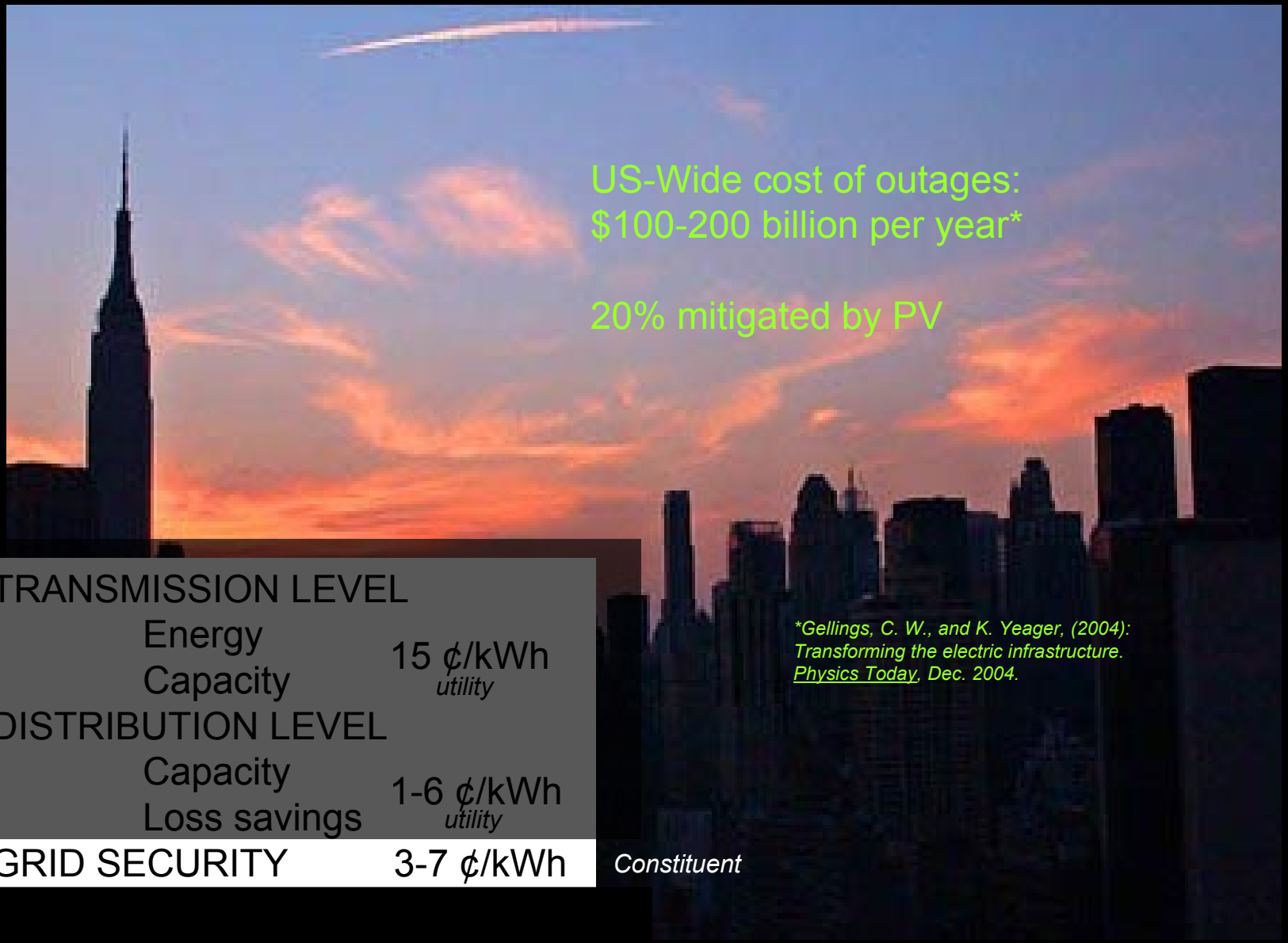
?

As little as 500 MW of PV dispersed around the major northeastern cities would have prevented the blackout

An investment of $ 3 billion

Outage cost $ 8 billion

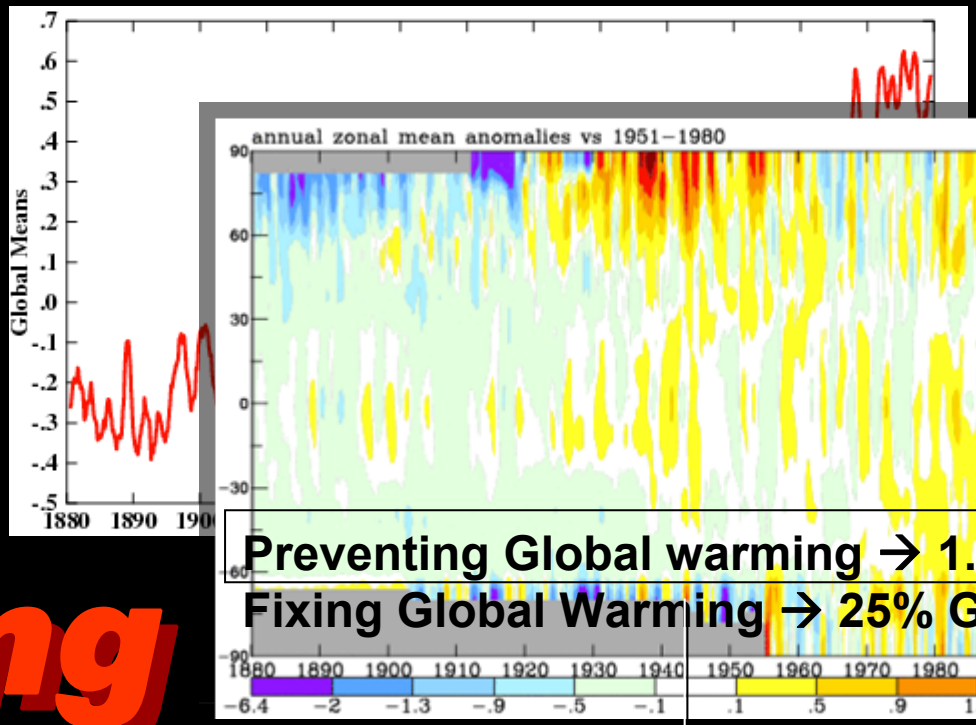




TRANSMISSION LEVEL		
	Energy Capacity	15 ¢/kWh *utility*
DISTRIBUTION LEVEL		
	Capacity Loss savings	1-6 ¢/kWh *utility*
GRID SECURITY	3-7 ¢/kWh	*Constituent*

**Gellings, C. W., and K. Yeager, (2004): Transforming the electric infrastructure. Physics Today, Dec. 2004.*

Global Warming



Preventing Global warming → 1.5% GDP

Fixing Global Warming → 25% GDP

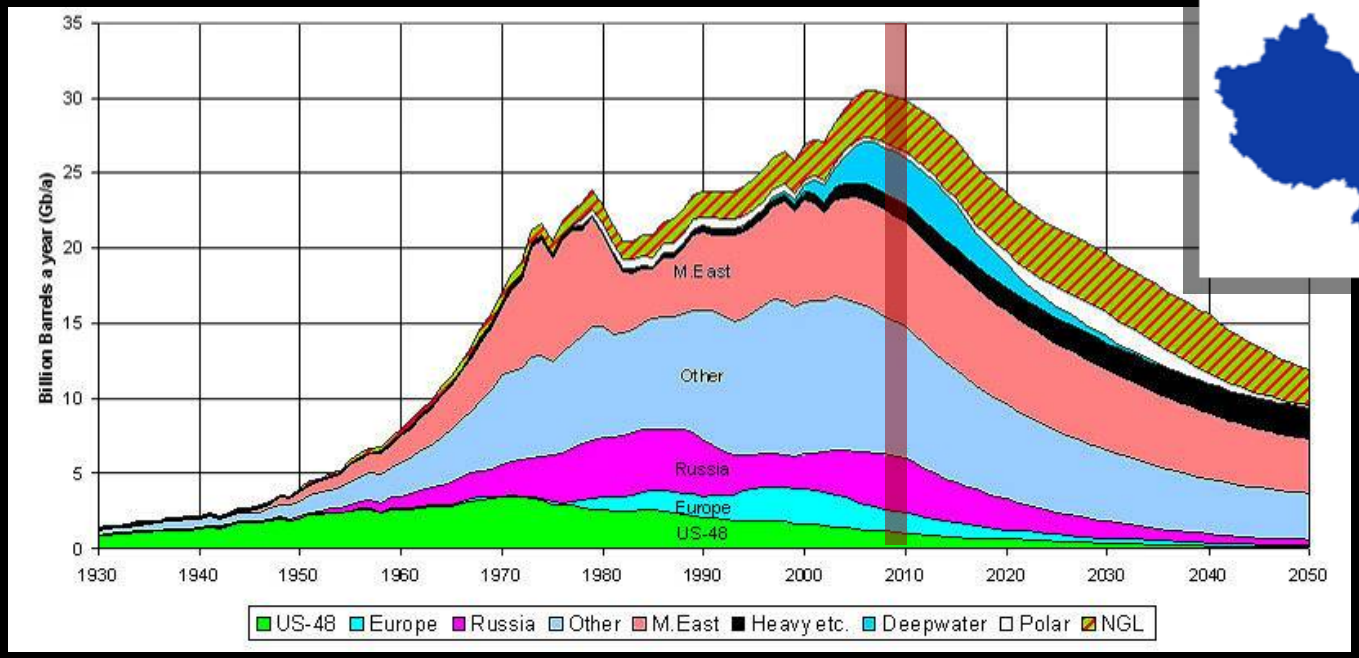
TRANSMISSION LEVEL		
	Energy Capacity	15 ¢/kWh *utility*
DISTRIBUTION LEVEL		
	Capacity Loss savings	1-6 ¢/kWh *utility*
GRID SECURITY		3-7 ¢/kWh
ENVIRONMENTAL COMPLIANCE		

PV = 10% of solution

Constituent	
	250 cents per kWh**
	2 cents per kWh est, @ $40/metric ton CO2*

* Based upon current NYS generation mix

** based upon 2010 PV industry size



TRANSMISSION LEVEL		
Energy Capacity	15 ¢/kWh *utility*	
DISTRIBUTION LEVEL		
Capacity Loss savings	1-6 ¢/kWh *utility*	
GRID SECURITY	3-7 ¢/kWh	*Constituent*
ENVIRONMENTAL COMPLIANCE	2–100+ ¢/kWh	*Constituent*
FUEL PRICE RISK MITIGATION	5-25+ ¢/kWh	*Constituent/utility*

Hedging $500/bbl oil in 2040:

NPV = 25 cents per kWh est.

Each megawatt (MW) of photovoltaic (PV) panels **manufactured** in the US employs 14 people.

Each MW of PV **installed on homes** in the US employs 14.3 people.

Each MW of PV **installed on commercial buildings** employs 9 people.

Each MW of PV **maintained** employs .3 people.

TRANSMISSION LEVEL		
Energy	15 ¢/kWh	*utility*
Capacity		
DISTRIBUTION LEVEL		
Capacity	1-6 ¢/kWh	*utility*
Loss savings		
GRID SECURITY	3-7 ¢/kWh	*Constituent*
ENVIRONMENTAL COMPLIANCE	2–100+ ¢/kWh	*Constituent*
FUEL PRICE RISK MITIGATION	5-25+ ¢/kWh	*Constituent/utility*
ECONOMIC GROWTH	2-3+ ¢/kWh	*Constituent*

PV VALUE: 30–100's ¢/kWh

PV COST W/O INCENTIVES TODAY: 30-45 ¢/kWh

TRANSMISSION LEVEL		
	Energy Capacity	15 ¢/kWh *utility*
DISTRIBUTION LEVEL		
	Capacity Loss savings	2-6 ¢/kWh *utility*
GRID SECURITY	3-7 ¢/kWh	*Constituent*
ENVIRONMENTAL COMPLIANCE	2–100+ ¢/kWh	*Constituent*
FUEL PRICE RISK MITIGATION	5-25+ ¢/kWh	*Constituent/utility*
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PV VALUE: 30–100's ¢/kWh

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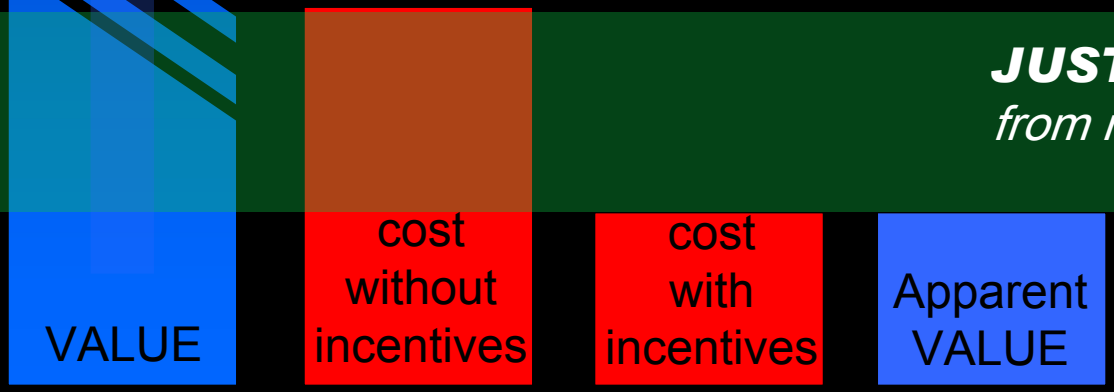
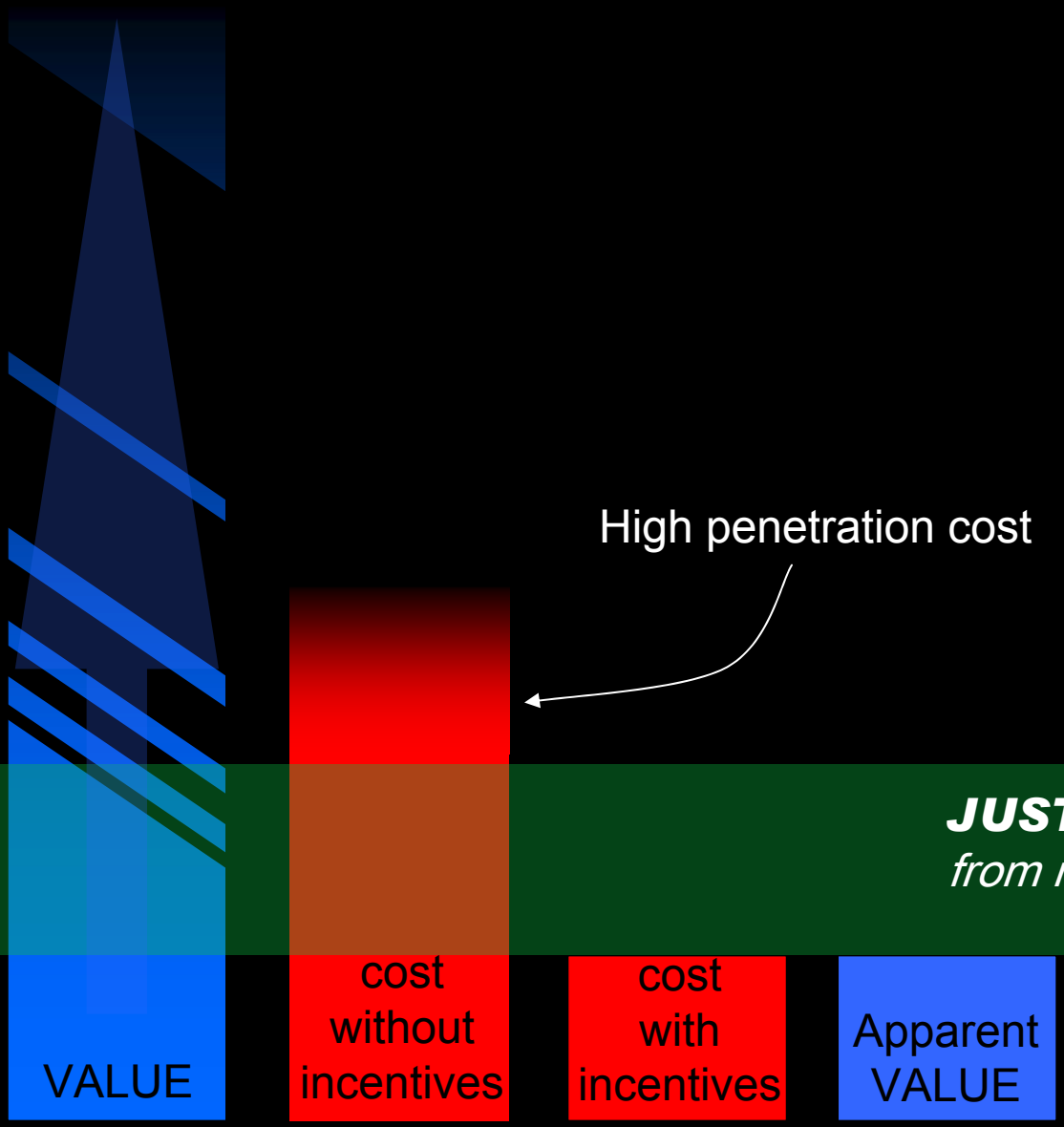
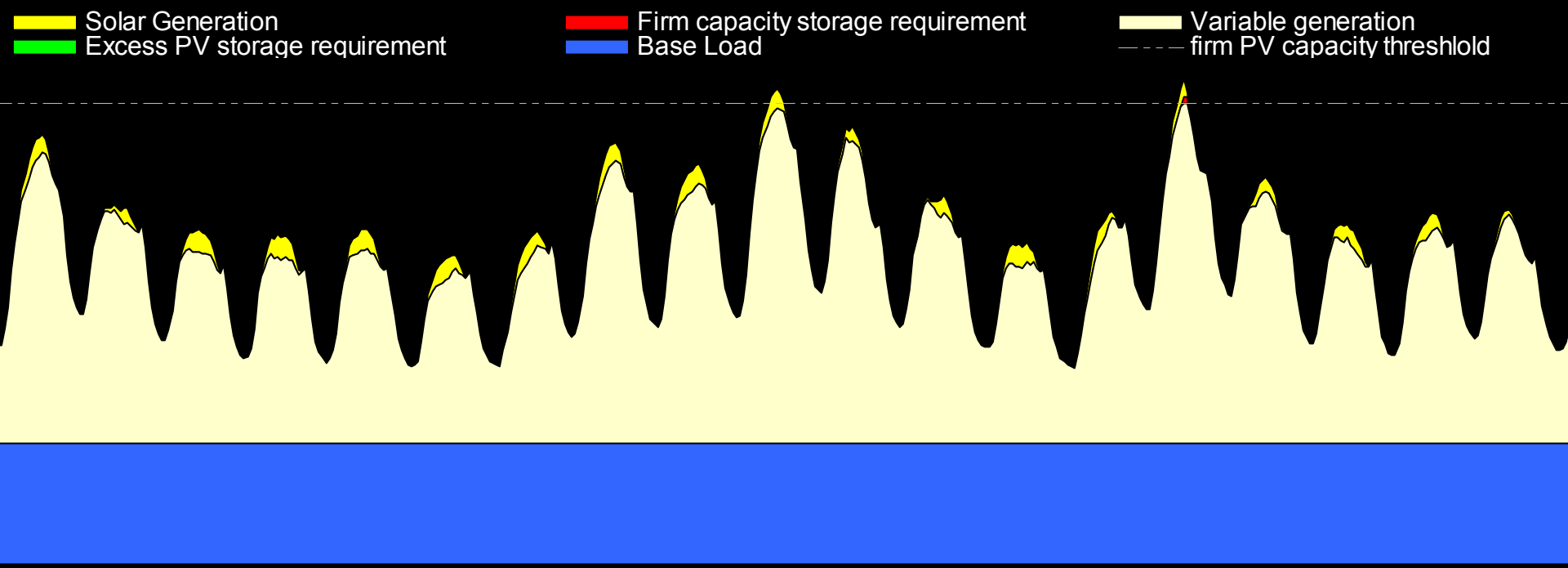


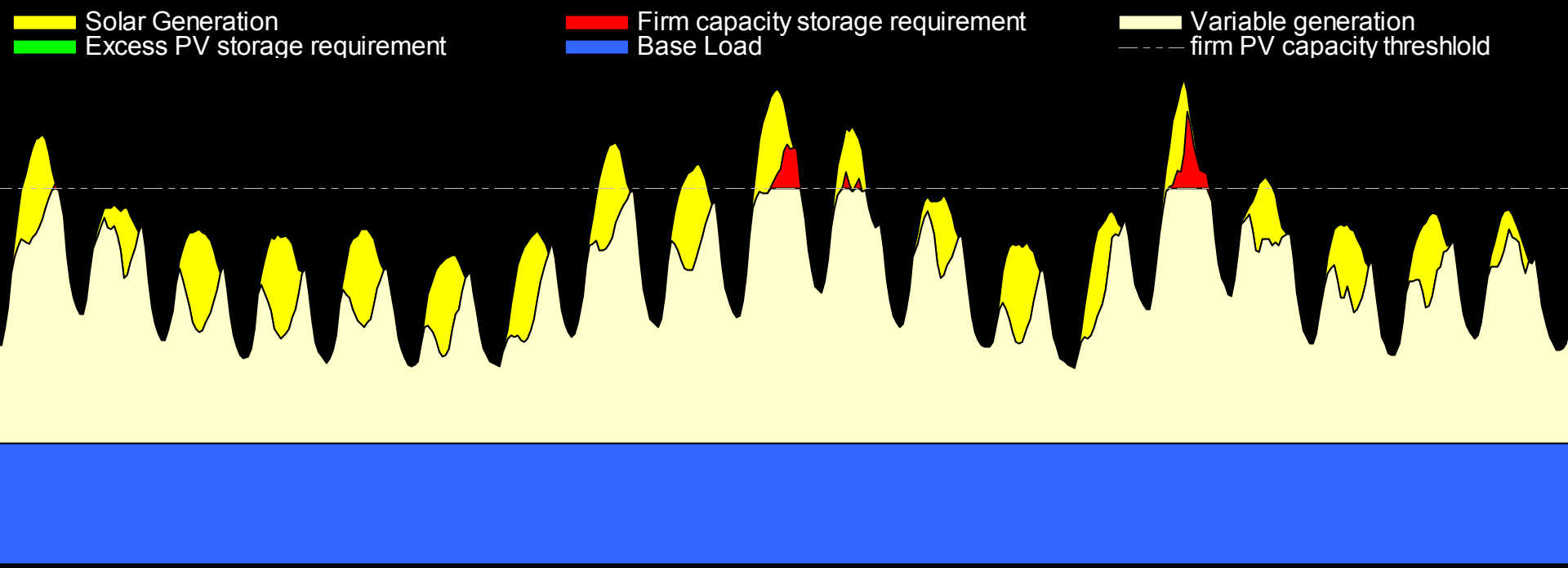
JUSTIFY INCENTIVES
from ratepayers & taxpayers

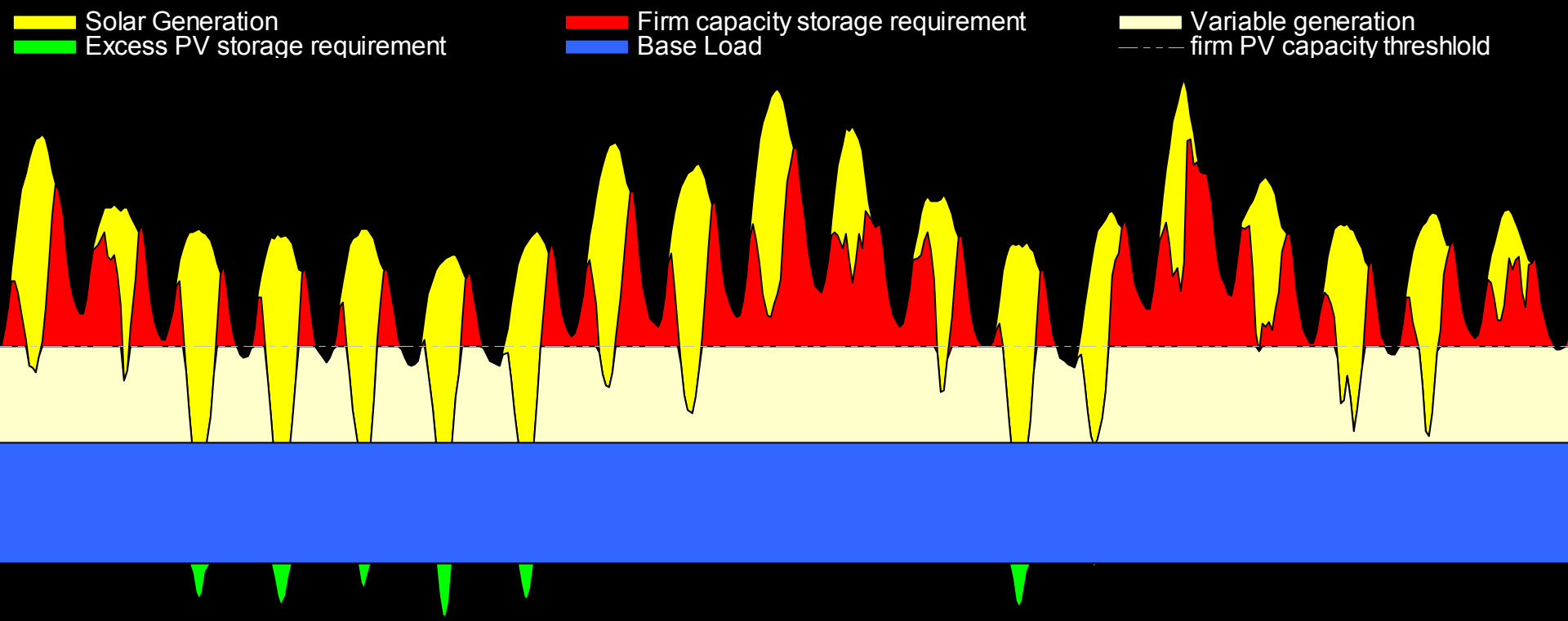
		ratepayers	taxpayers
	PV OWNER	**UTILITY**	**CONSTITUENTS**
EQUIPMENT	**COST**	**BENEFIT**	**BENEFIT**
INCENTIVES	**BENEFIT**		**COST**
UTILITY BILLS	**BENEFIT**	**COST**	
TAX EFFECTS	**BENEFIT**		**COST**

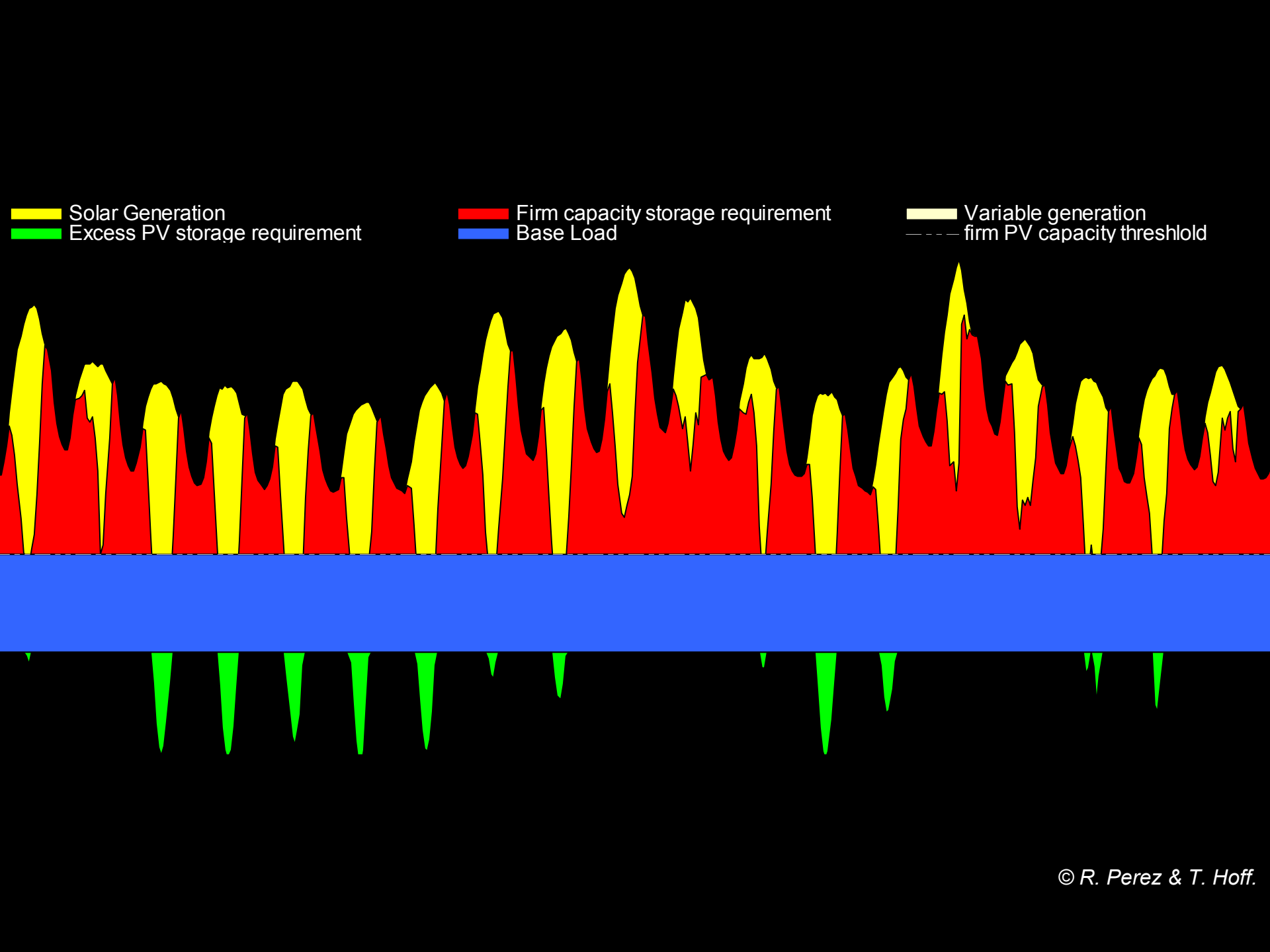
Ratepayers = Taxpayer = You and me

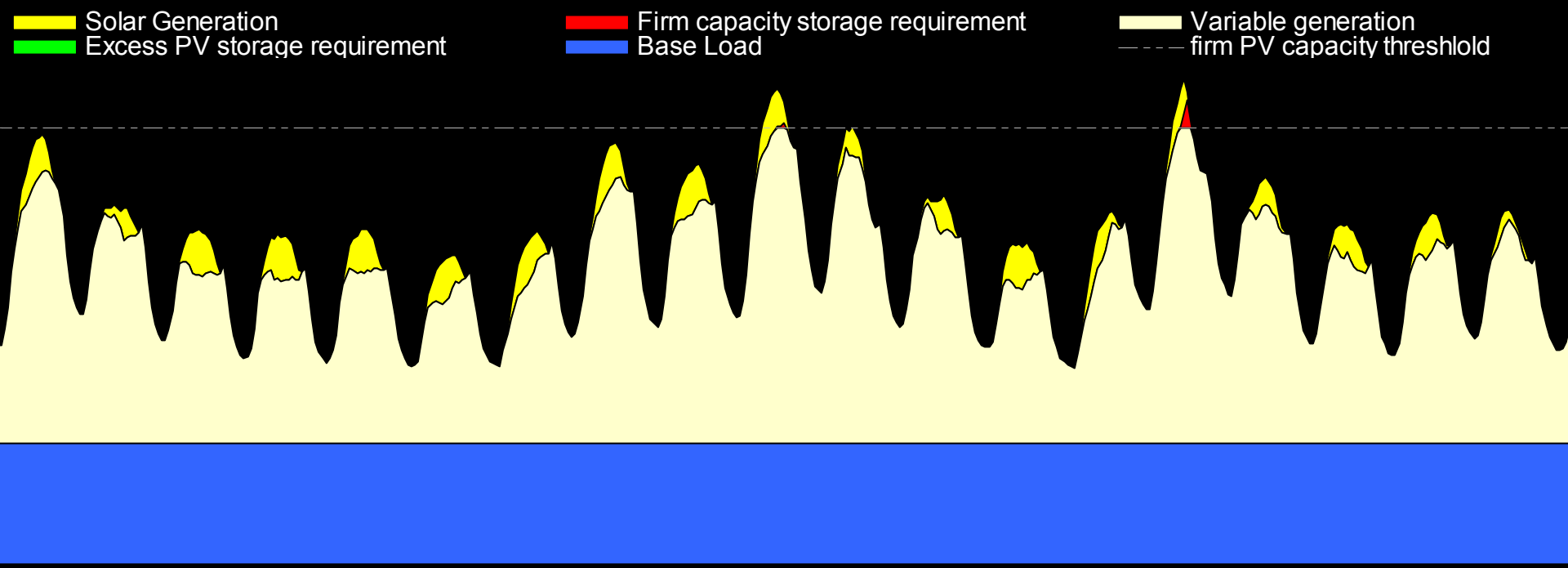




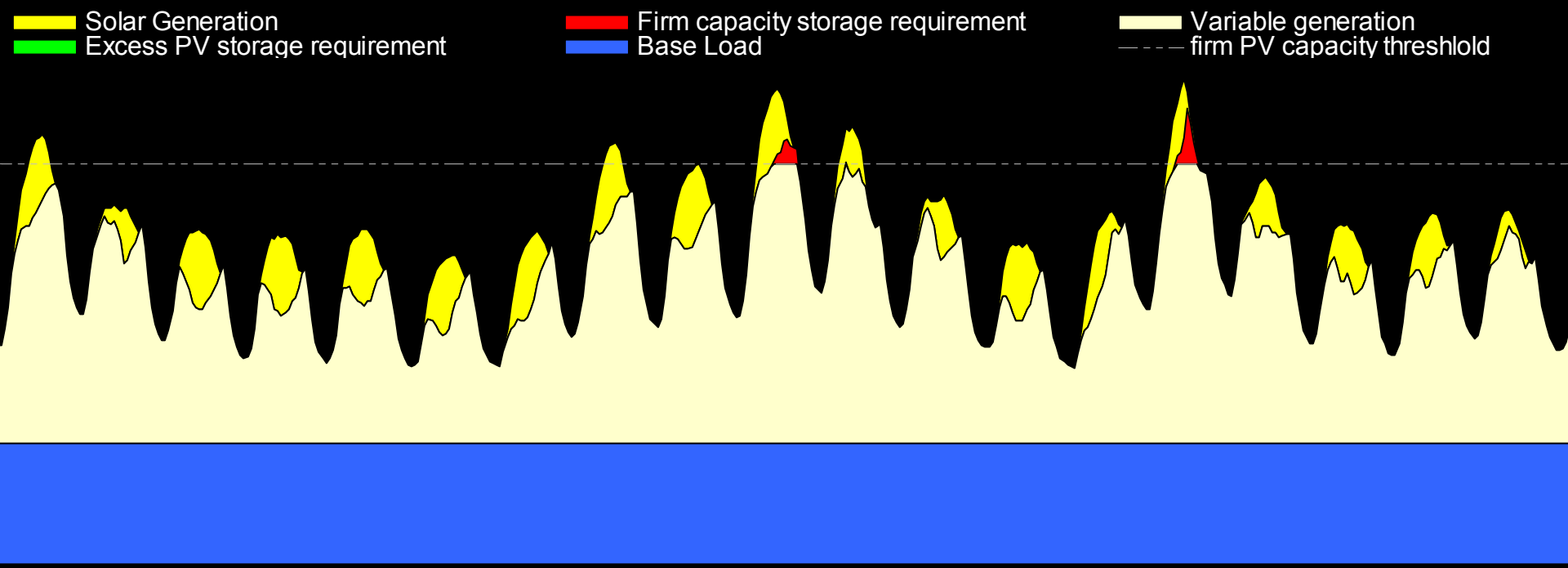




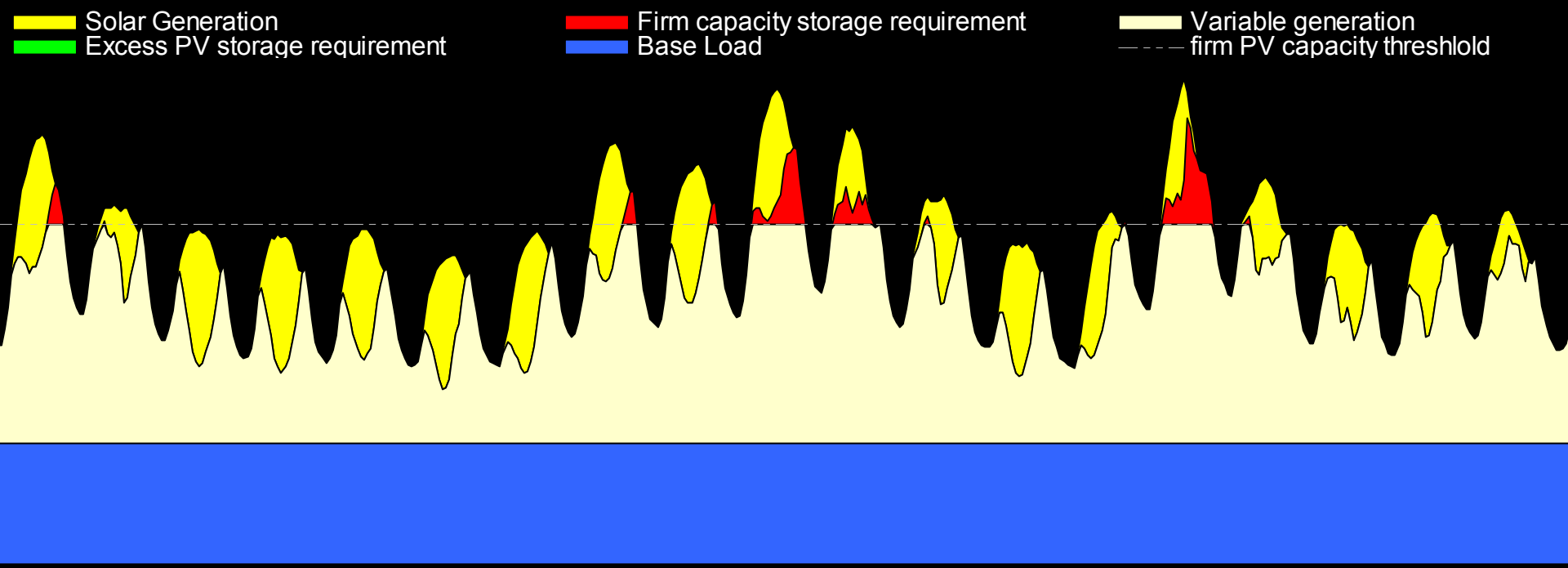

Solar Generation
Excess PV storage requirement
Firm capacity storage requirement
Base Load
Variable generation
firm PV capacity threshlold
© R. Perez & T. Hoff.



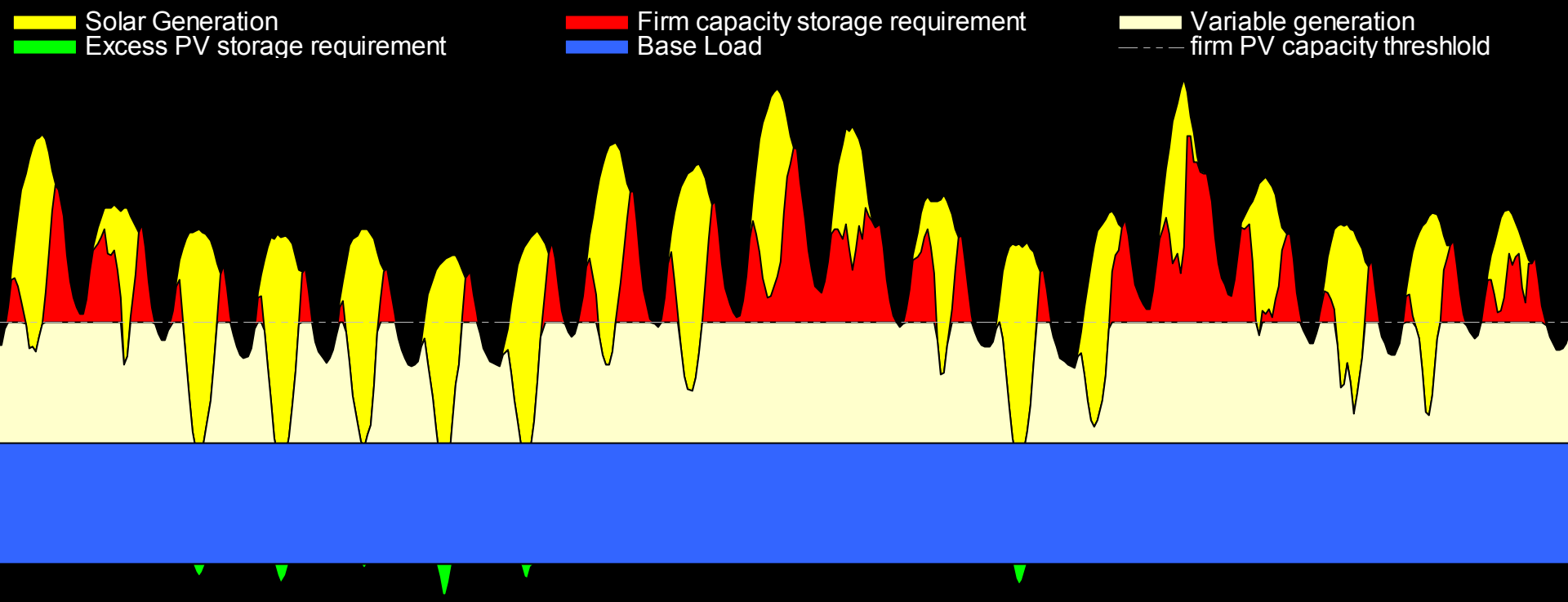
10% Solar Penetration cost: 1.5 cent per kWh



20% Solar Penetration cost: 3.5 cents per kWh



30% Solar Penetration cost: 7 cents per kWh

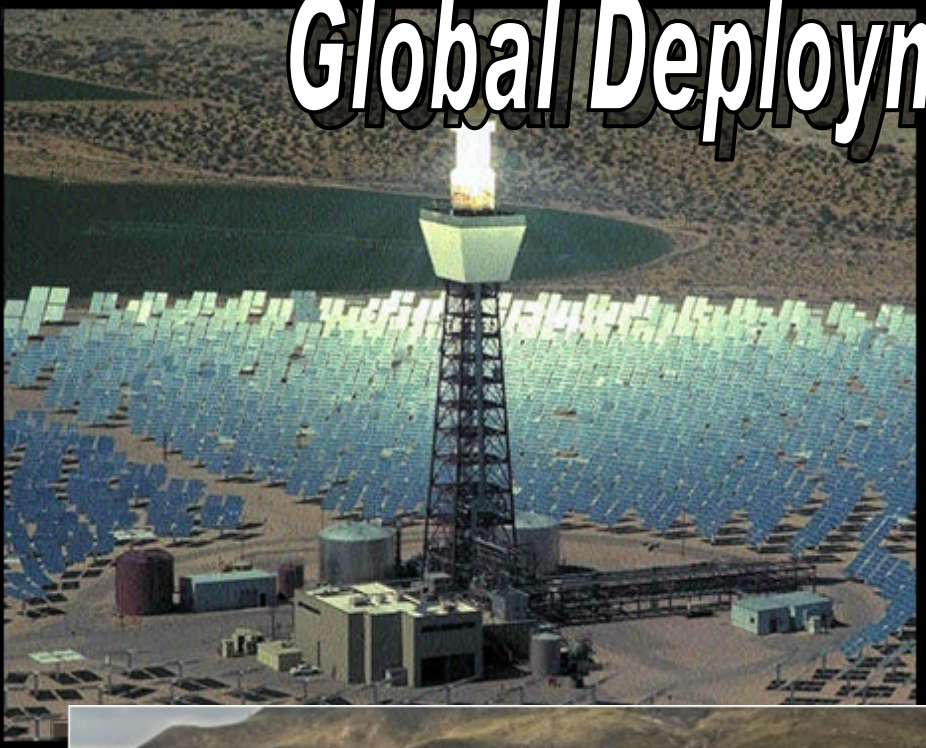


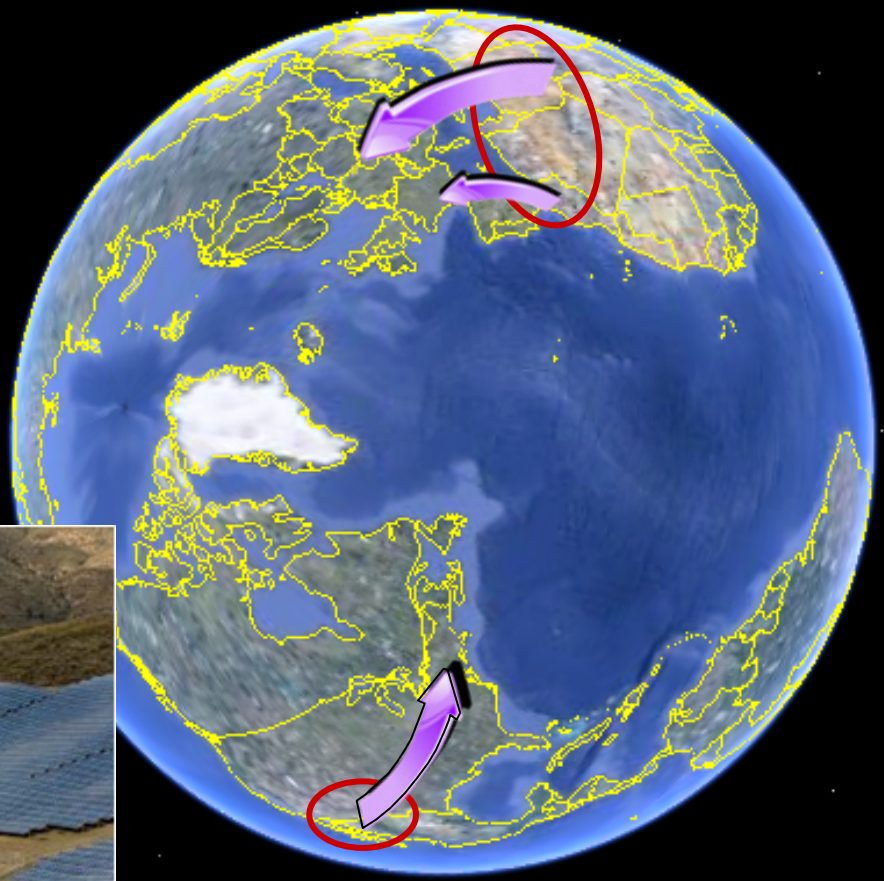
50% Solar Penetration cost: 19 cents per kWh

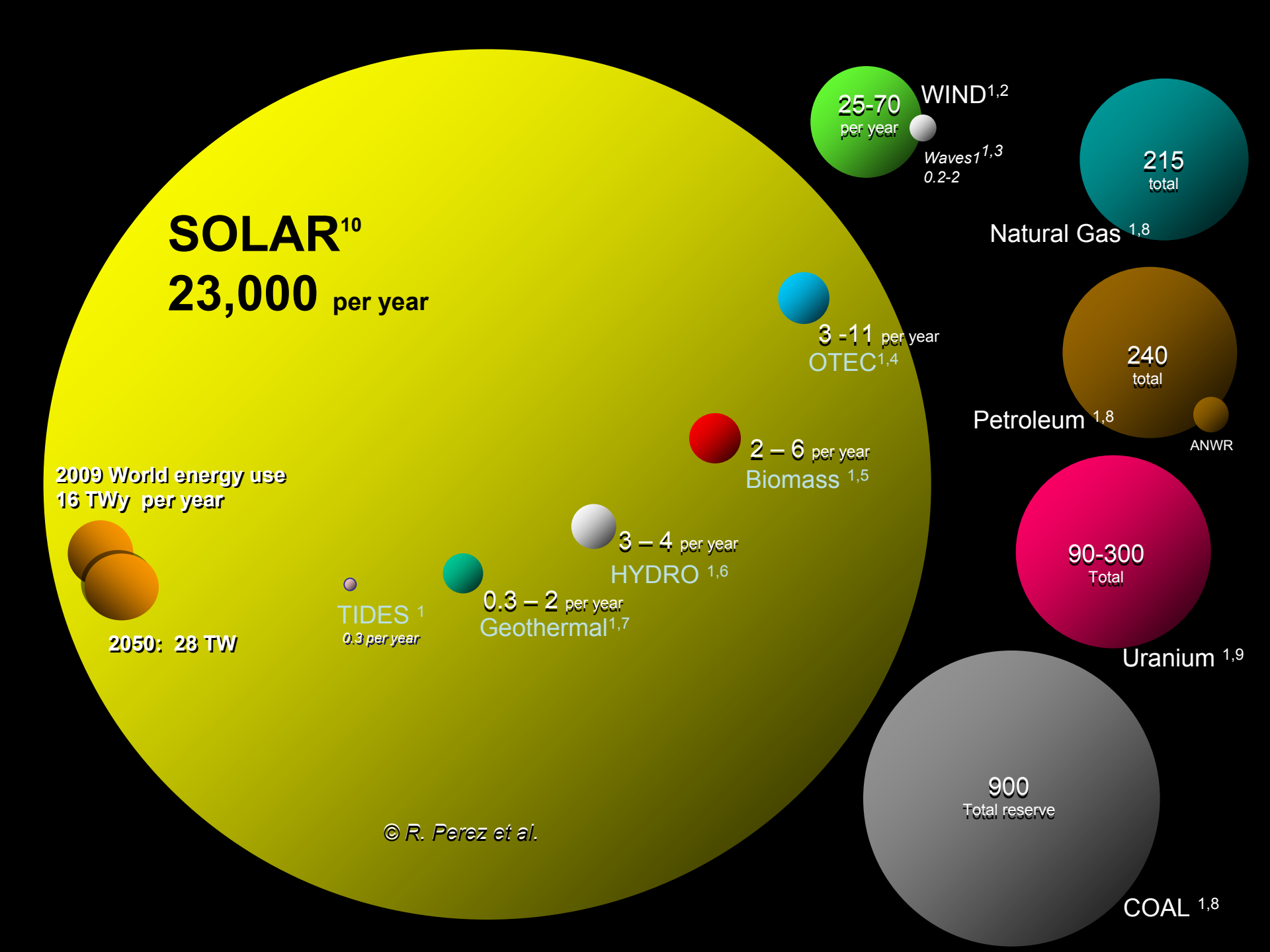
High-Value Local Deployment

up to 30-35% penetration

Global Deployment >35% penetration






SOLAR[10]
23,000 per year
2009 World energy use
16 TWy per year
2050: 28 TW
25-70
per year
WIND[1,2]
Waves[1,3]
0.2-2
215
total
Natural Gas [1,8]
3 -11 per year
OTEC[1,4]
240
total
Petroleum [1,8]
ANWR
2 – 6 per year
Biomass [1,5]
3 – 4 per year
HYDRO [1,6]
90-300
Total
Uranium [1,9]
TIDES [1]
0.3 per year
0.3 – 2 per year
Geothermal[1,7]
900
Total reserve
COAL [1,8]
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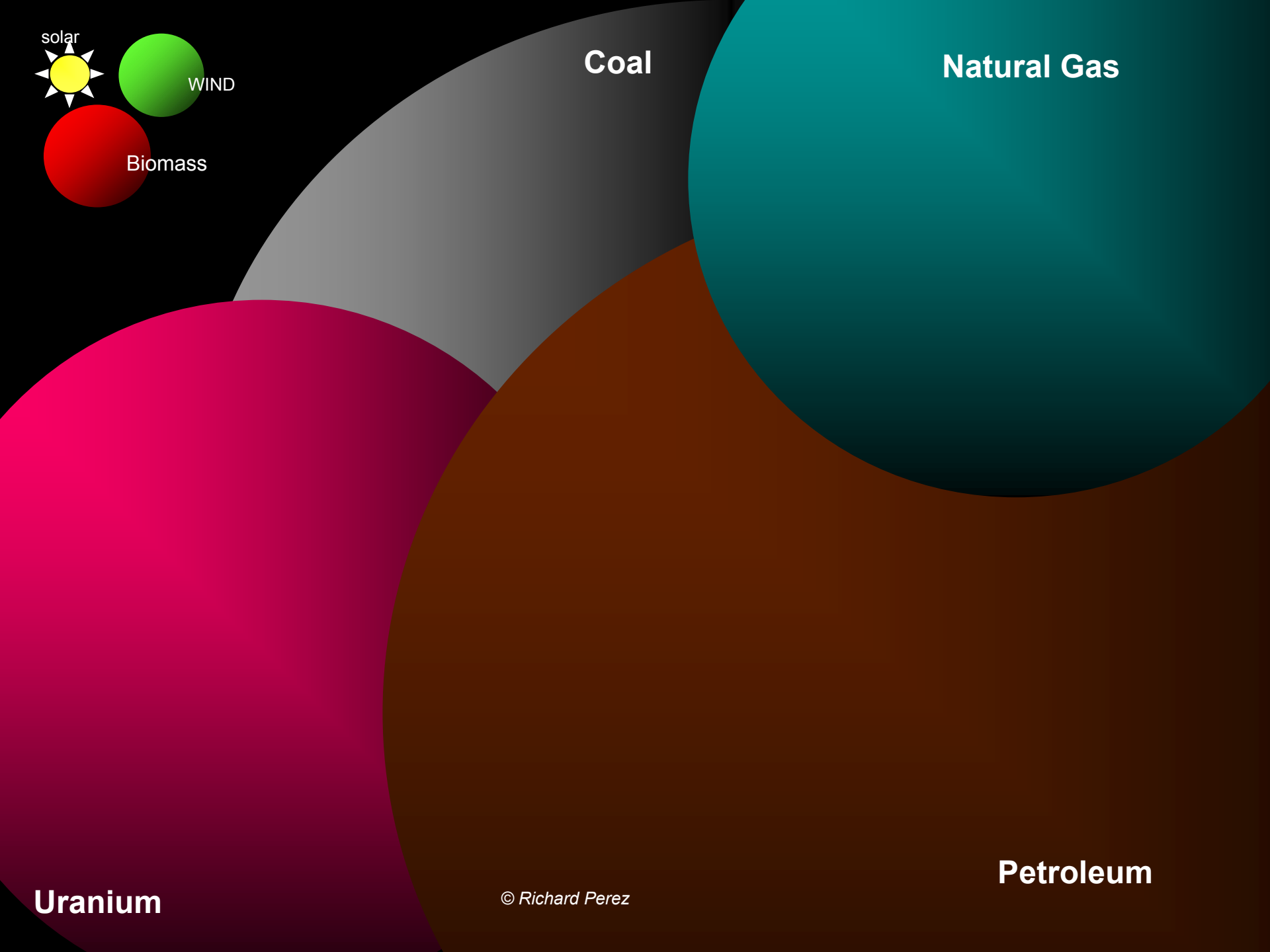
solar
WIND
Biomass
Coal
Natural Gas
Uranium
Petroleum
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