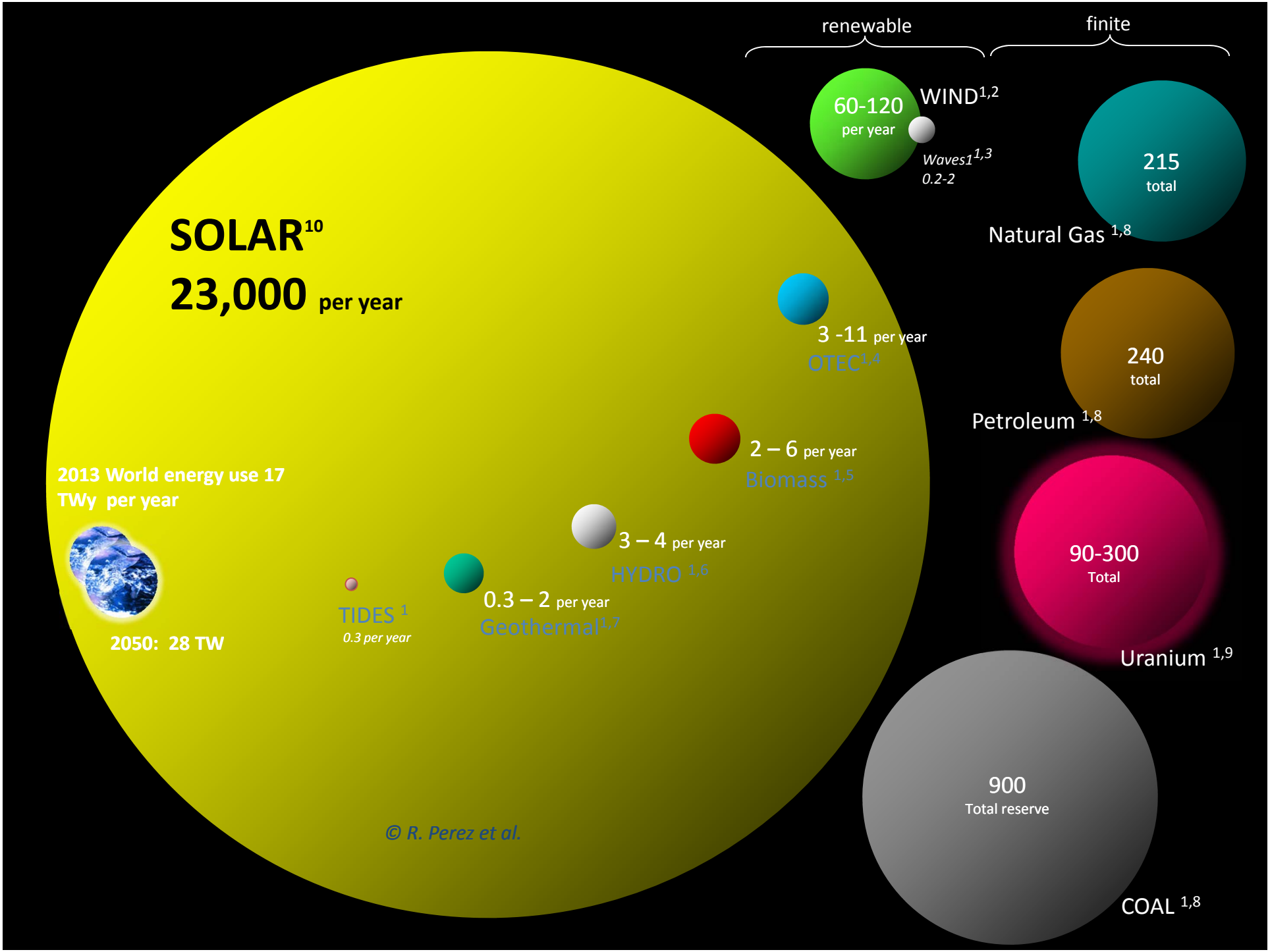
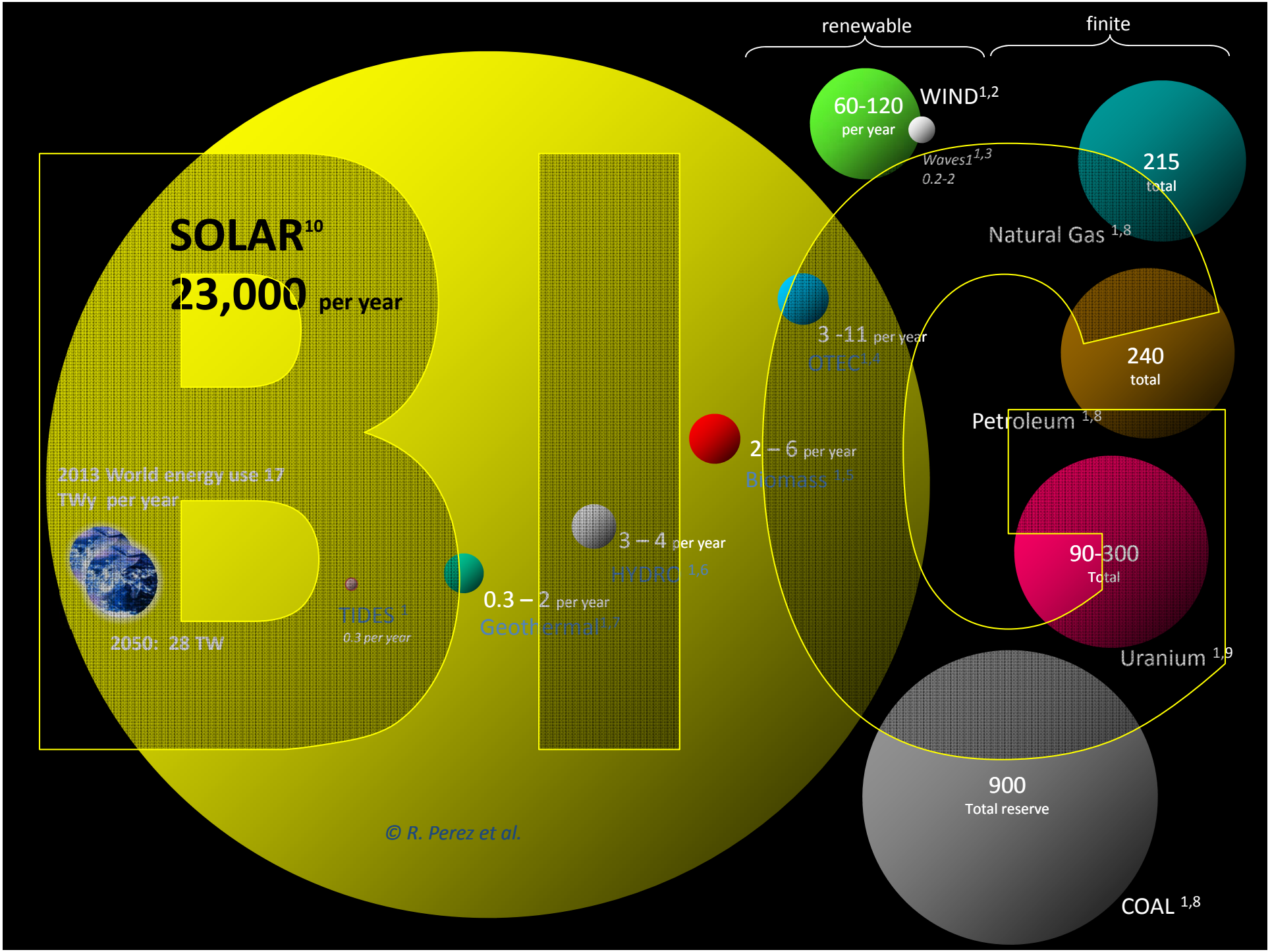
BE14, BOSTON 3/6, 2014

PV GENERATION
The Value Proposition

Richard Perez, ASRC

- Vast resource


renewable
finite
60-120
per year
WIND[1,2]
Waves1[1,3]
0.2-2
215
total
Natural Gas [1,8]
SOLAR[10]
23,000 per year
3 -11 per year
OTEC[1,4]
240
total
Petroleum [1,8]
2 – 6 per year
Biomass [1,5]
2013 World energy use 17
TWy per year
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]
2050: 28 TW
900
Total reserve
COAL [1,8]
© R. Perez et al.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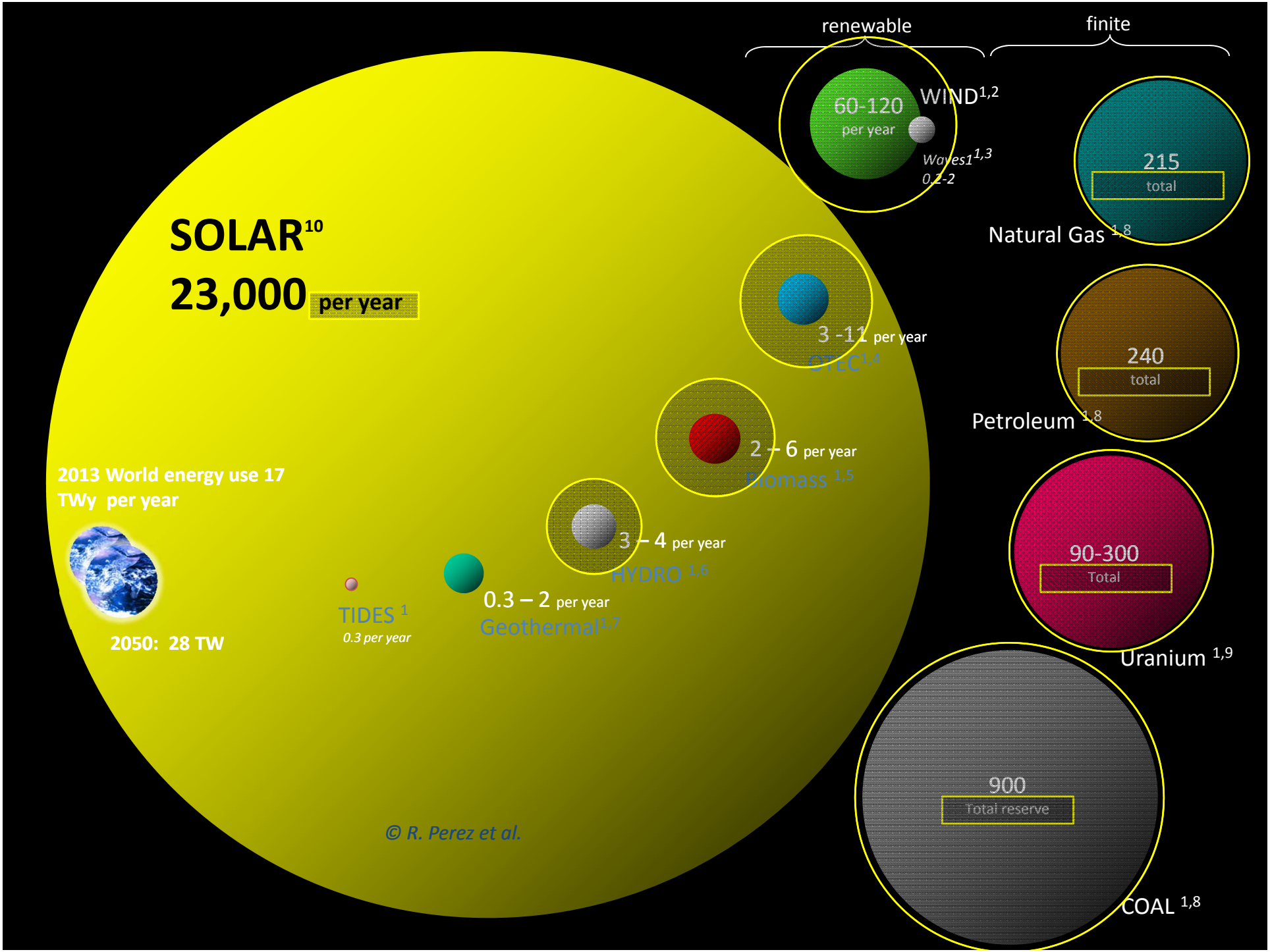
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finite
SOLAR[10]
23,000 per year
2013 World energy use 17 TWy per year
2050: 28 TW
60-120 per year
WIND[1,2]
Waves[1,3] 0.1-2
3 -11 per year
OTEC[1,4]
2 – 6 per year
Biomass [1,5]
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HYDRO [1,6]
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Geothermal[1,7]
TIDES [1]
0.3 per year
215 total
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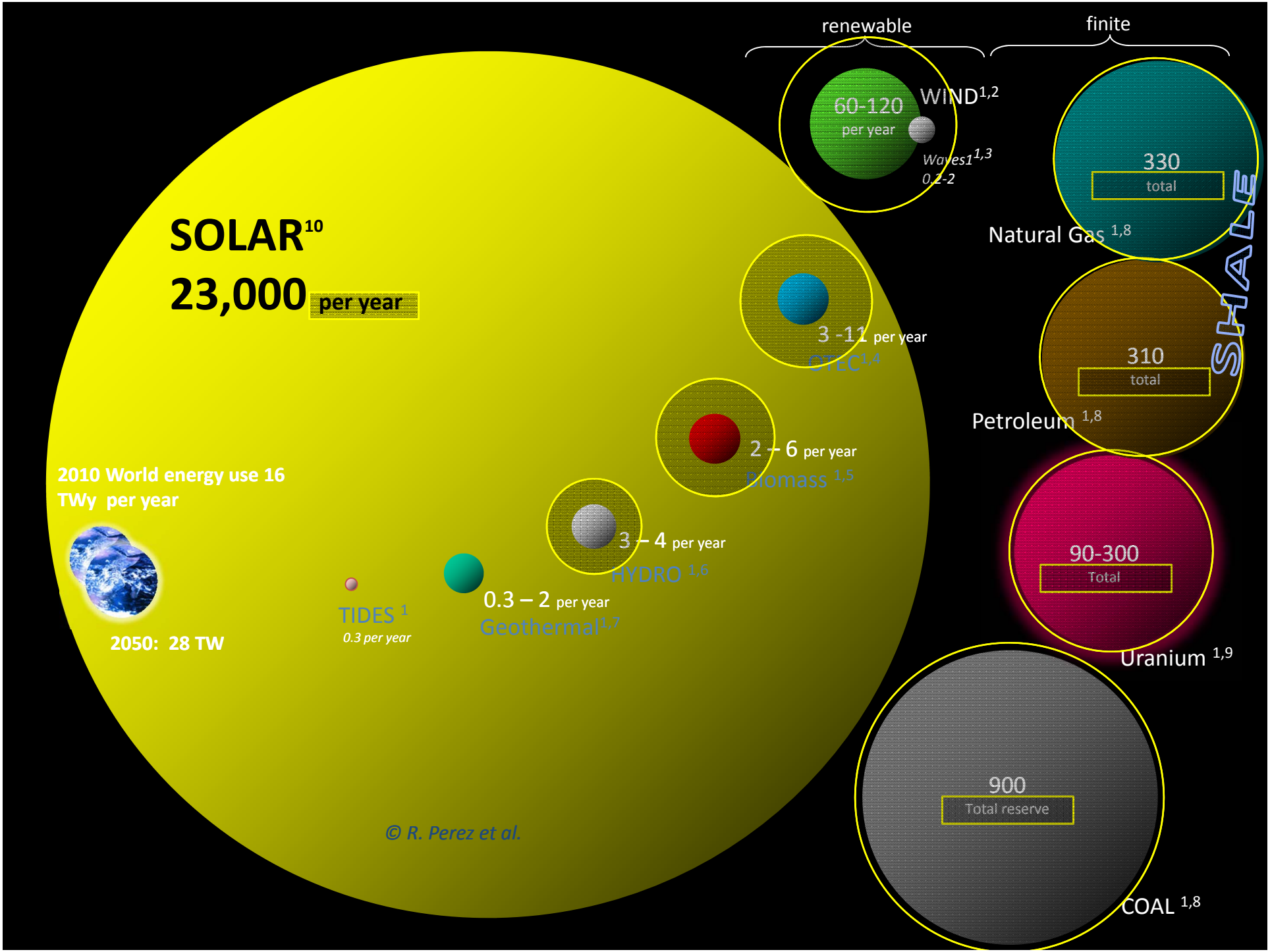
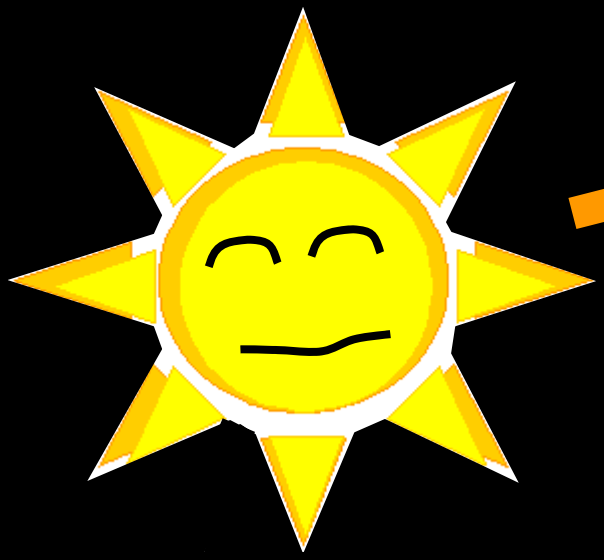
240 total
Petroleum [1,8]
90-300 Total
Uranium [1,9]
900 Total reserve
COAL [1,8]
© R. Perez et al.

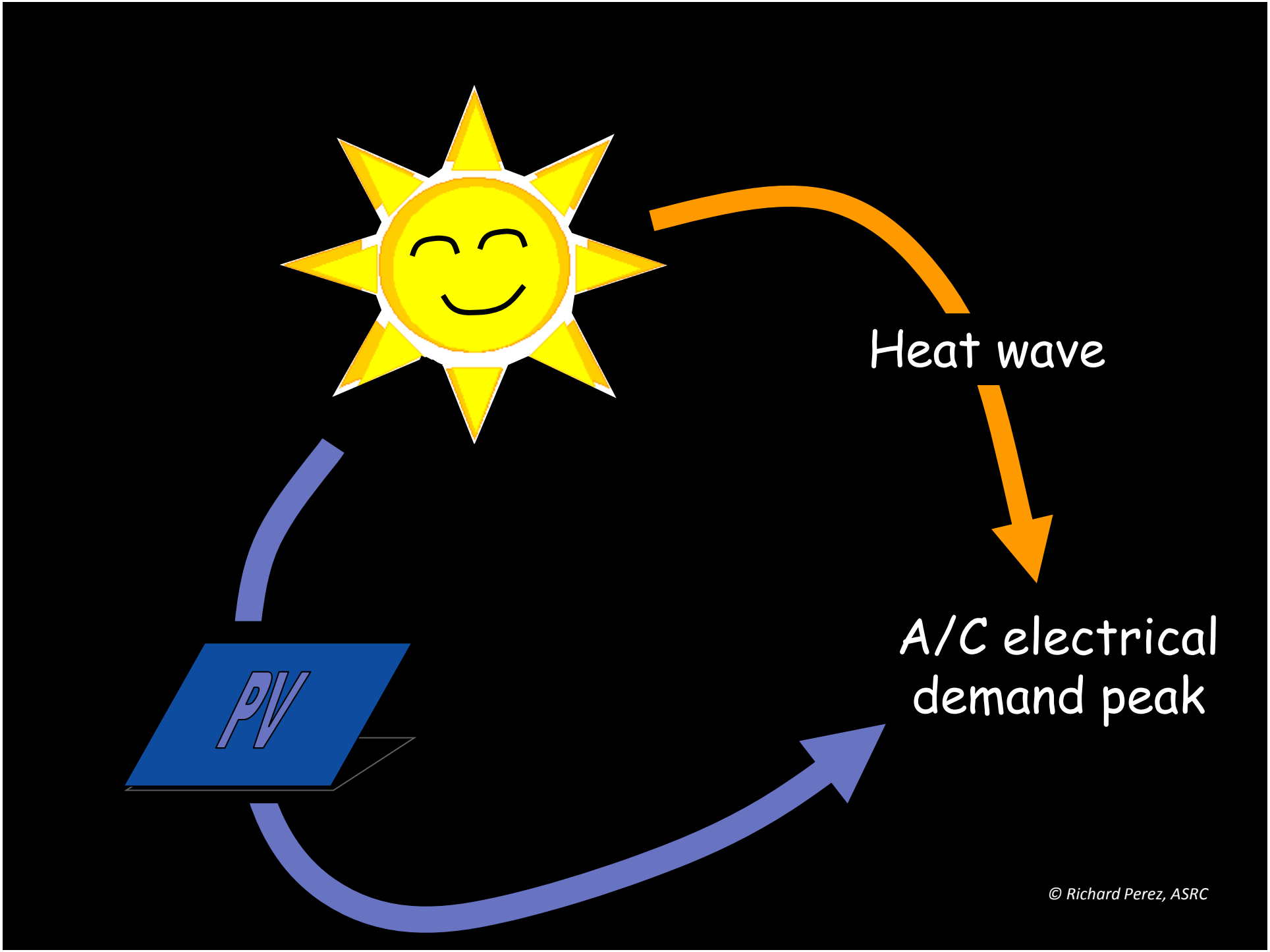

renewable
finite
SOLAR[10]
23,000 per year
60-120
per year
WIND[1,2]
Waves[1,3]
0.2-2
330
total
Natural Gas [1,8]
SHALE
3 -11 per year
OTEC[1,4]
310
total
Petroleum [1,8]
2 – 6 per year
Biomass [1,5]
2010 World energy use 16
TWy per year
3 – 4 per year
HYDRO [1,6]
90-300
Total
Uranium [1,9]
TIDES [1]
0.3 per year
0.3 – 2 per year
Geothermal[1,7]
2050: 28 TW
900
Total reserve
COAL [1,8]
© R. Perez et al.

- Vast resource
- Built-in smart grid capability



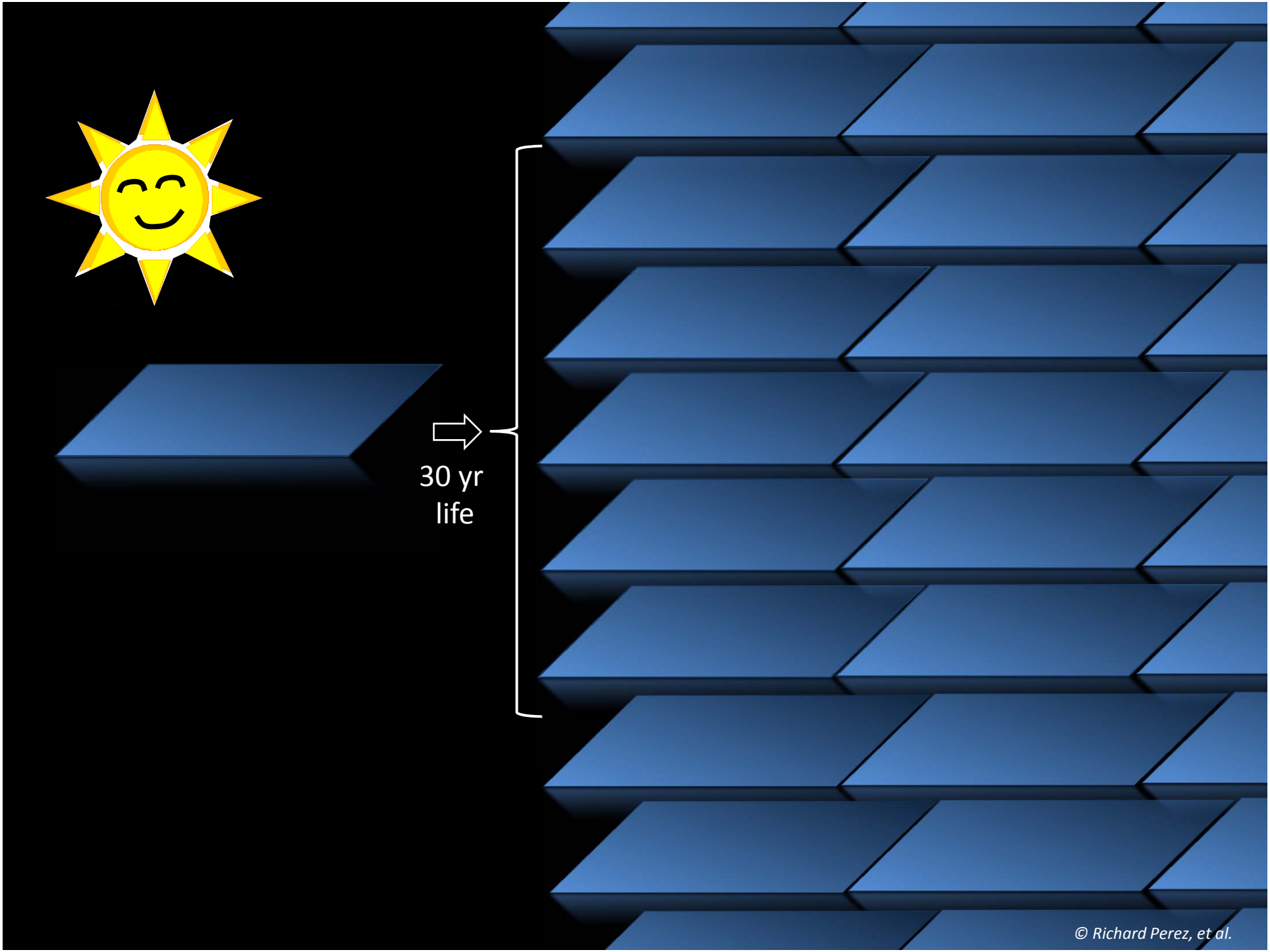
Heat wave

A/C electrical demand peak

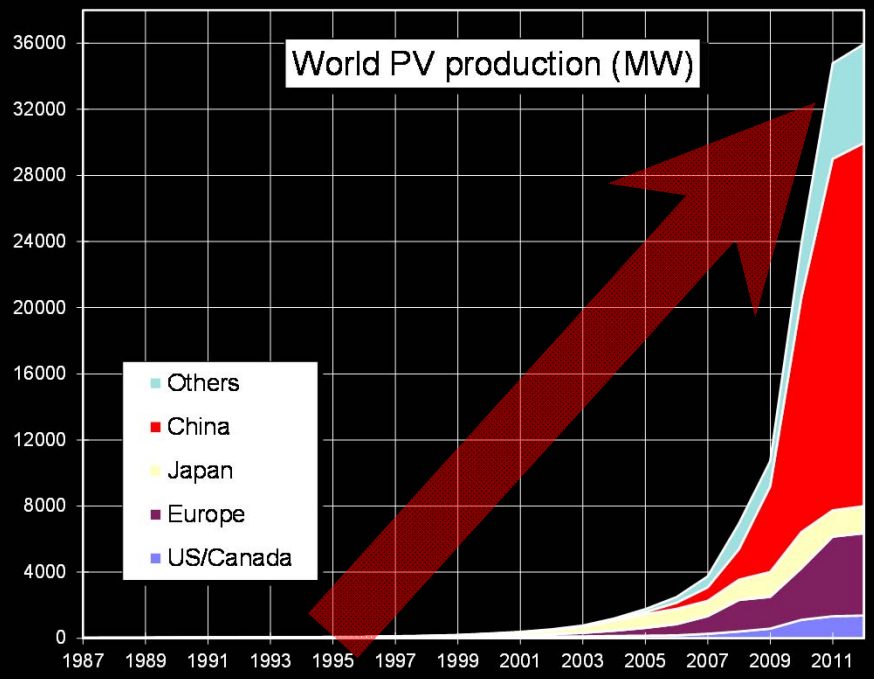

Heat wave
A/C electrical demand peak
PV
© Richard Perez, ASRC


100°F
80°F
60°F
40°F
20°F
© Richard Perez, ASRC

- Vast resource
- Built-in smart grid capability
- Energy breeder

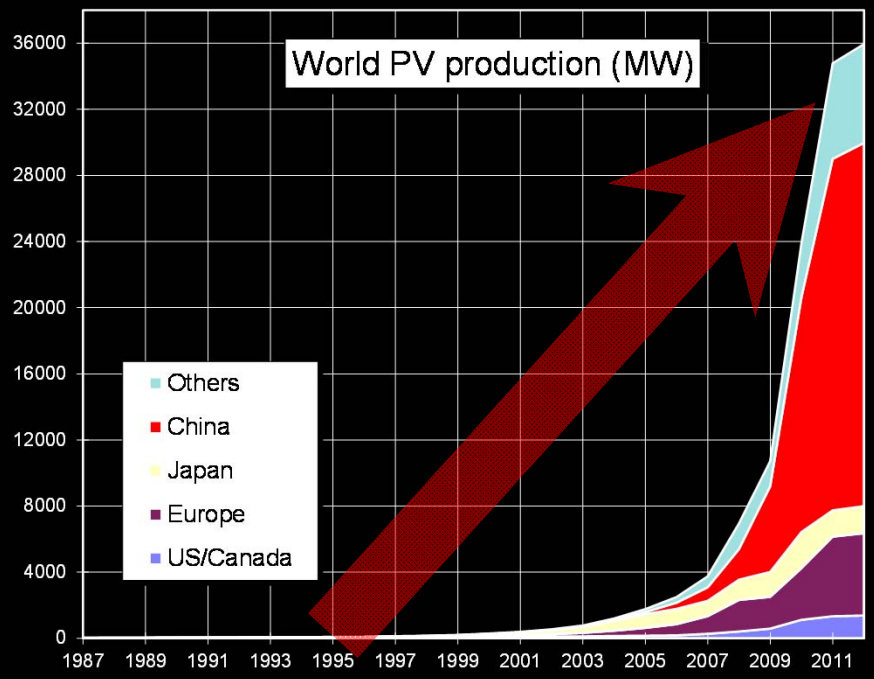

30 yr
life
© Richard Perez, et al.

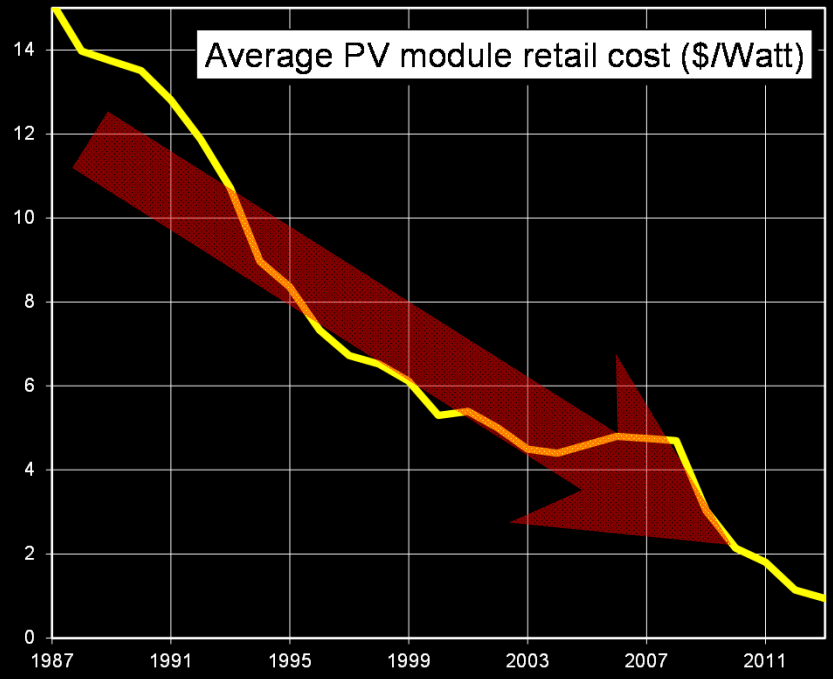
- Vast resource
- Built-in smart grid capability
- Energy breeder
- Industry & markets grow fast



PHOTOVOLTAIC TENDENCIES

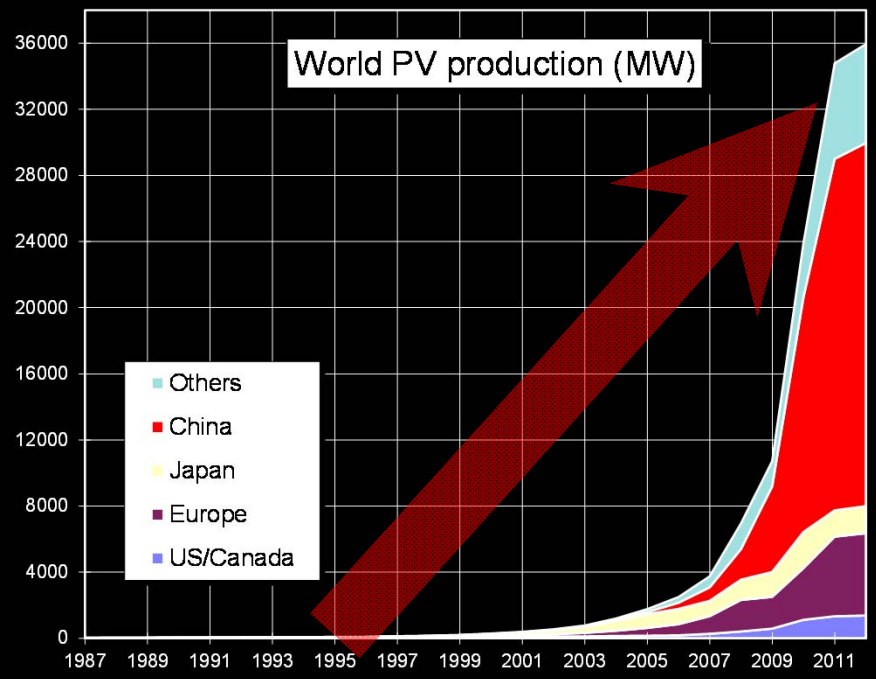
- **PRODUCTION**
- **COST**
- **EFFICIENCY**

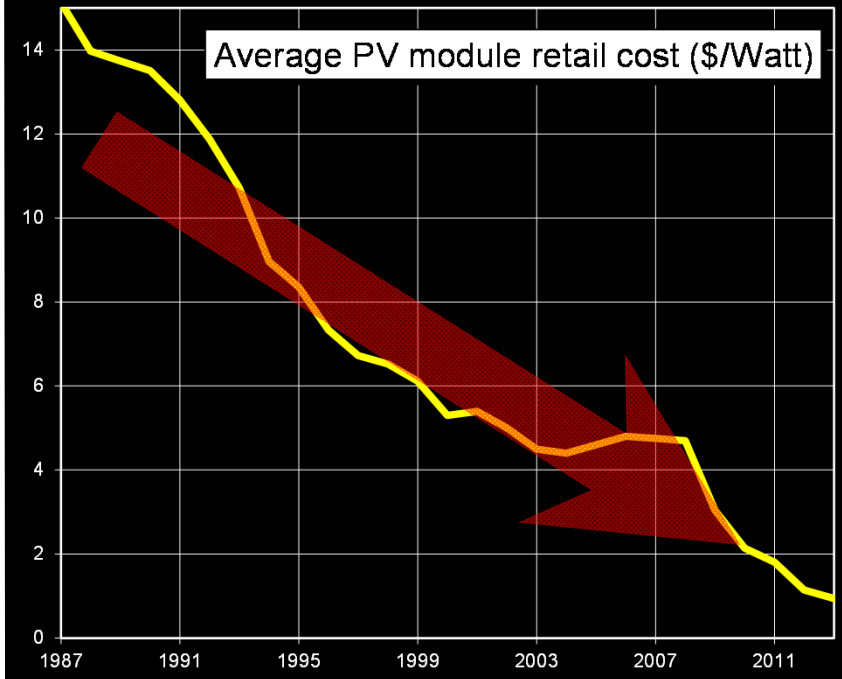




PHOTOVOLTAIC TENDENCIES

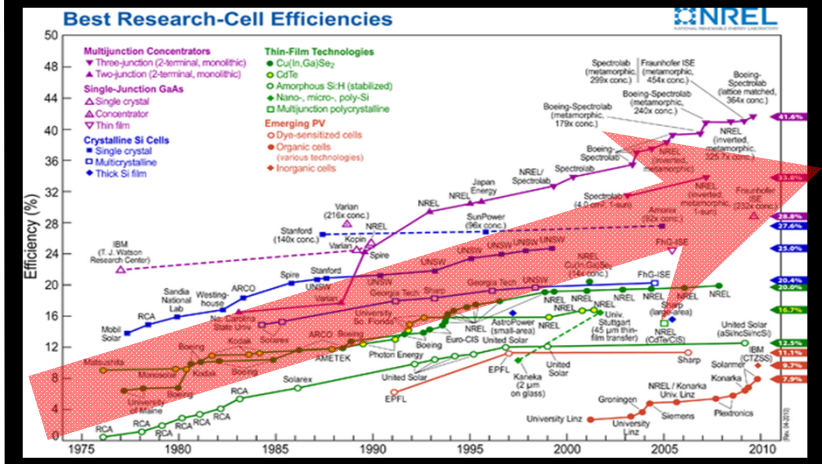
- **PRODUCTION**
- **COST**
- **EFFICIENCY**





PHOTOVOLTAIC TENDENCIES

- ➡ - PRODUCTION
- ➡ - COST
- ➡ - EFFICIENCY



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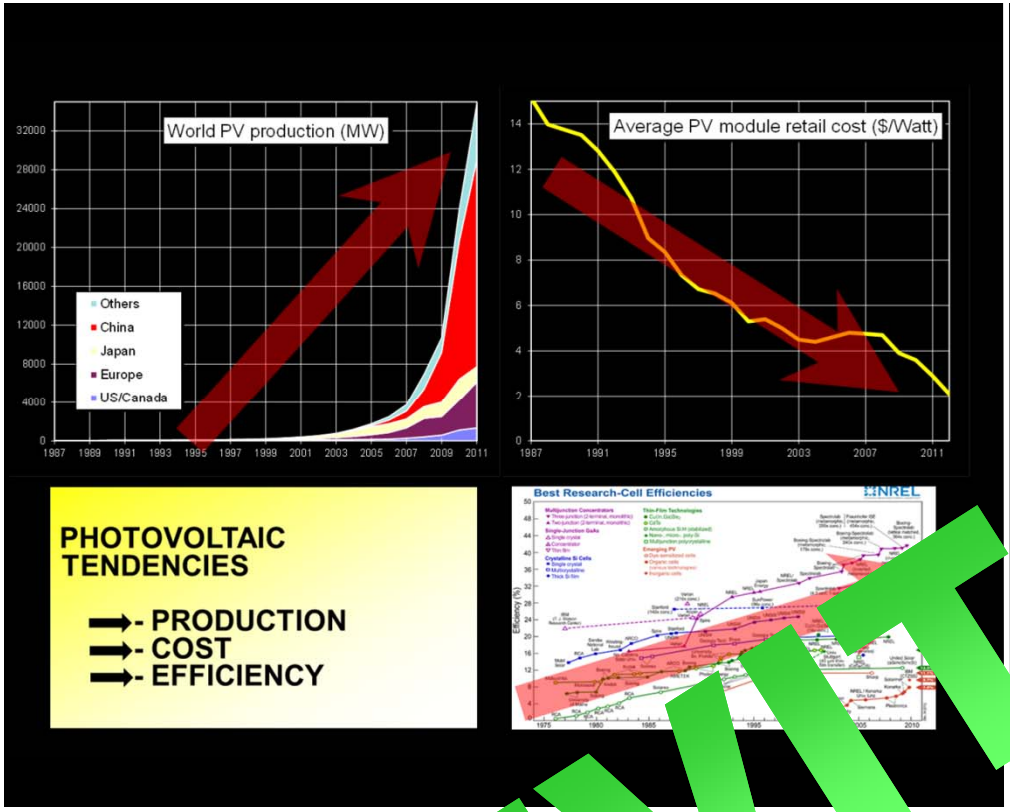
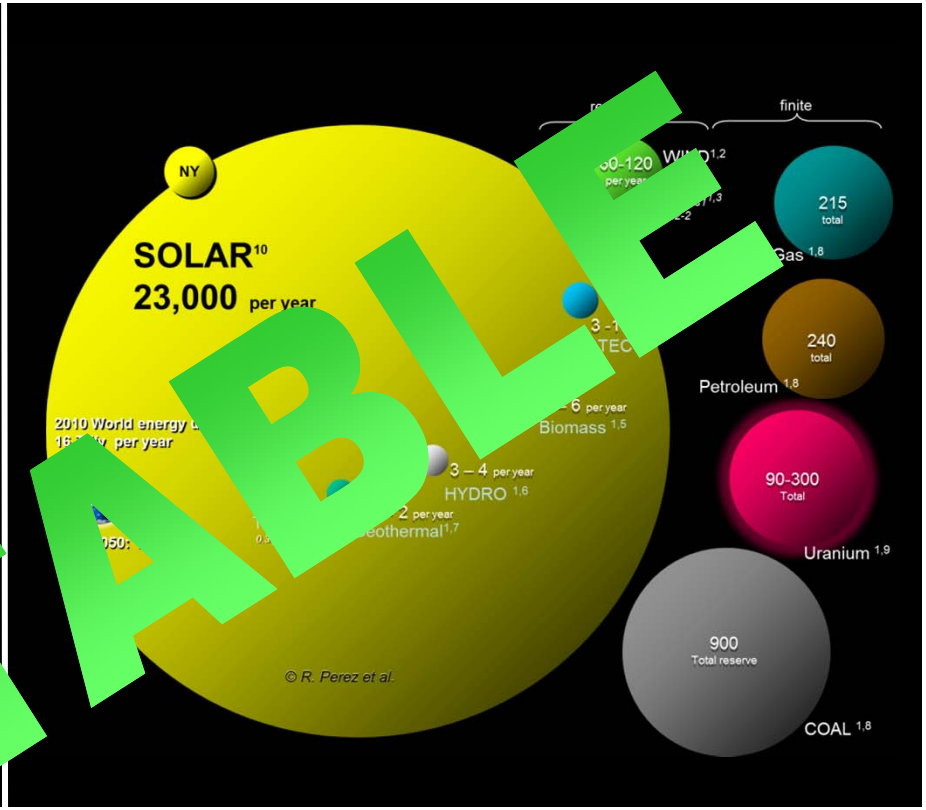
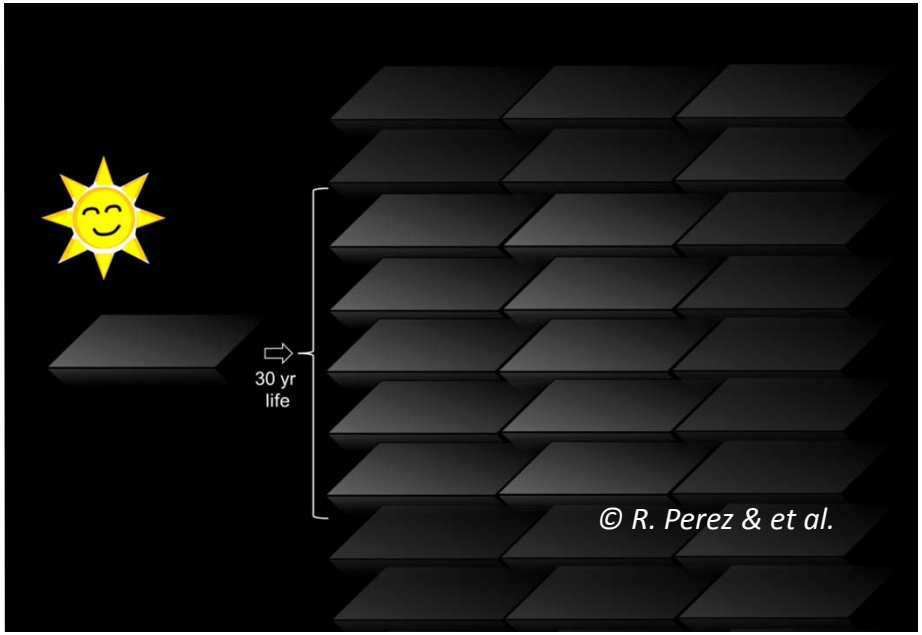

World PV production (MW)
Others
China
Japan
Europe
US/Canada
Average PV module retail cost ($/Watt)
PHOTOVOLTAIC TENDENCIES
➡- PRODUCTION
➡- COST
➡- EFFICIENCY
Best Research-Cell Efficiencies
NREL

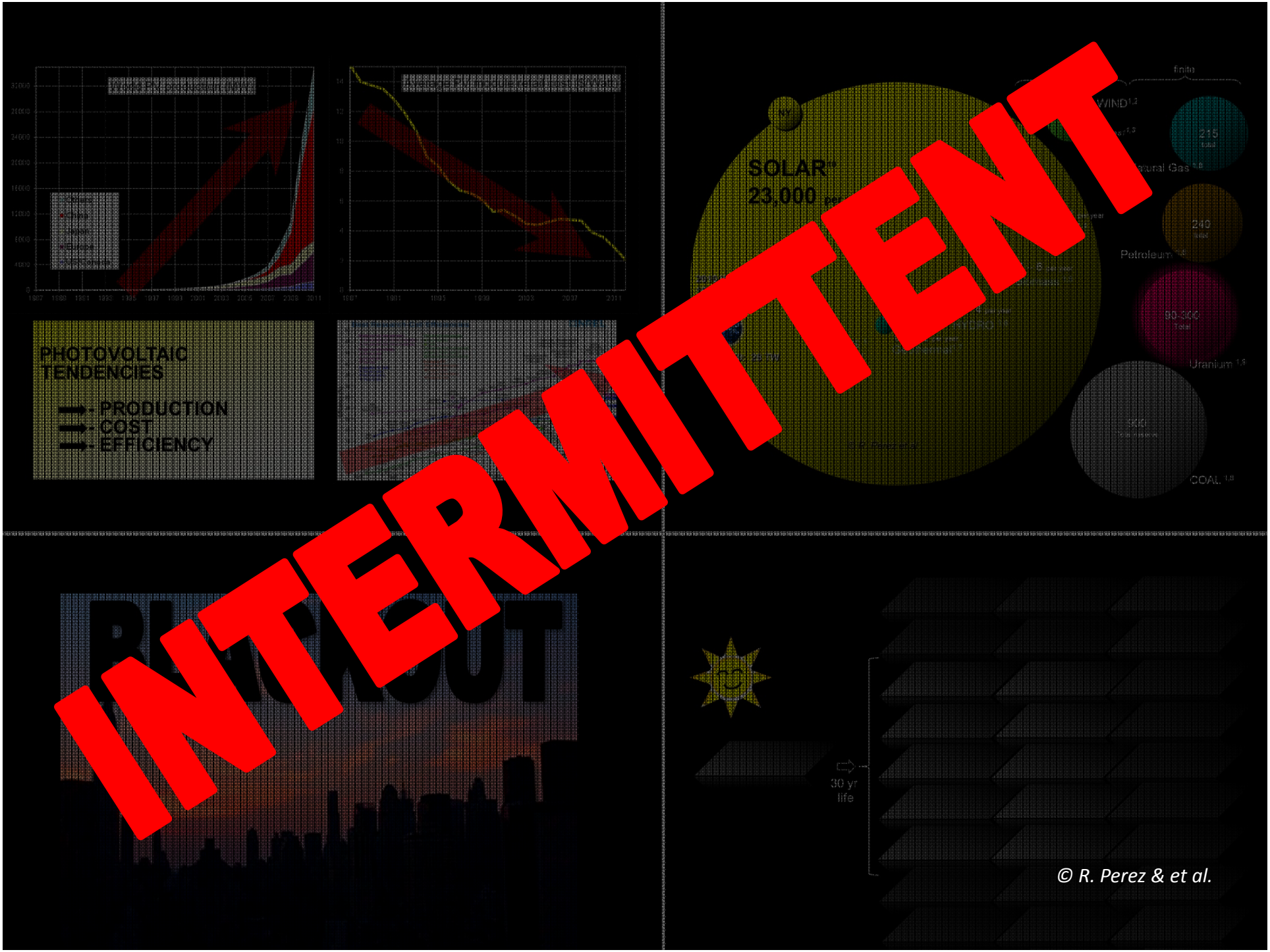

finite
NY
SOLAR[10]
23,000 per year
2010 World energy
per year
215
total
Gas 1,8
240
total
Petroleum 1,8
6 per year
Biomass 1,5
3 – 4 per year
HYDRO 1,6
2 per year
Geothermal 1,7
90-300
Total
Uranium 1,9
900
Total reserve
COAL 1,8
© R. Perez et al.


BLACKOUT

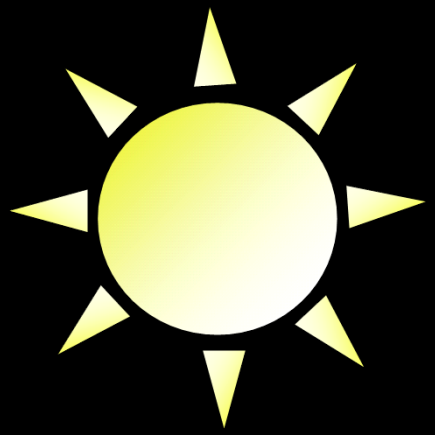

30 yr life
© R. Perez & et al.

INEVITABLE

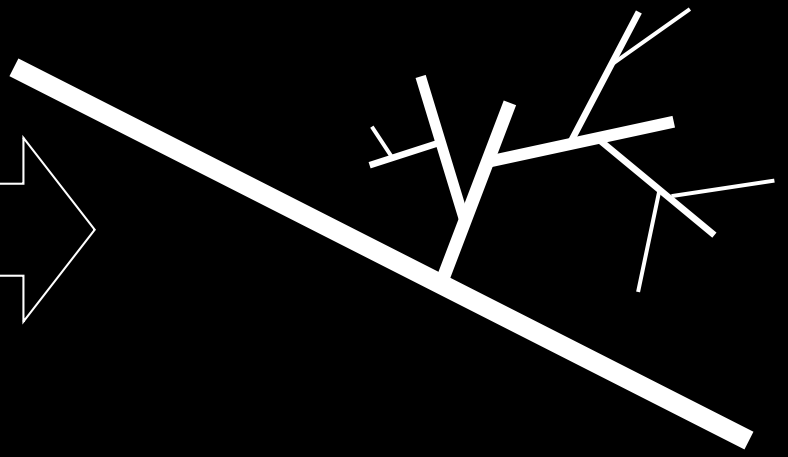

PHOTOVOLTAIC
TENDENCIES
- PRODUCTION
- COST
- EFFICIENCY
SOLAR
23,000
finite
215
240
30-300
Petroleum
Uranium
COAL
30 yr
life
TOO EXPENSIVE


PHOTOVOLTAIC
TENDENCIES
PRODUCTION
COST
EFFICIENCY
SOLAR
23,000
WIND
Petroleum
Uranium
COAL
30 yr
life
INTERMITTENT
© R. Perez & et al.

SOLAR



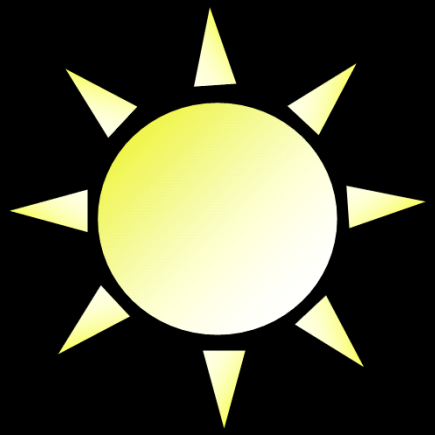
POWER GRID

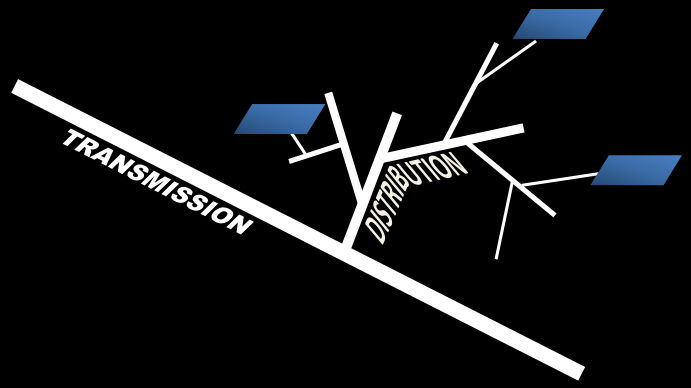


VALUE

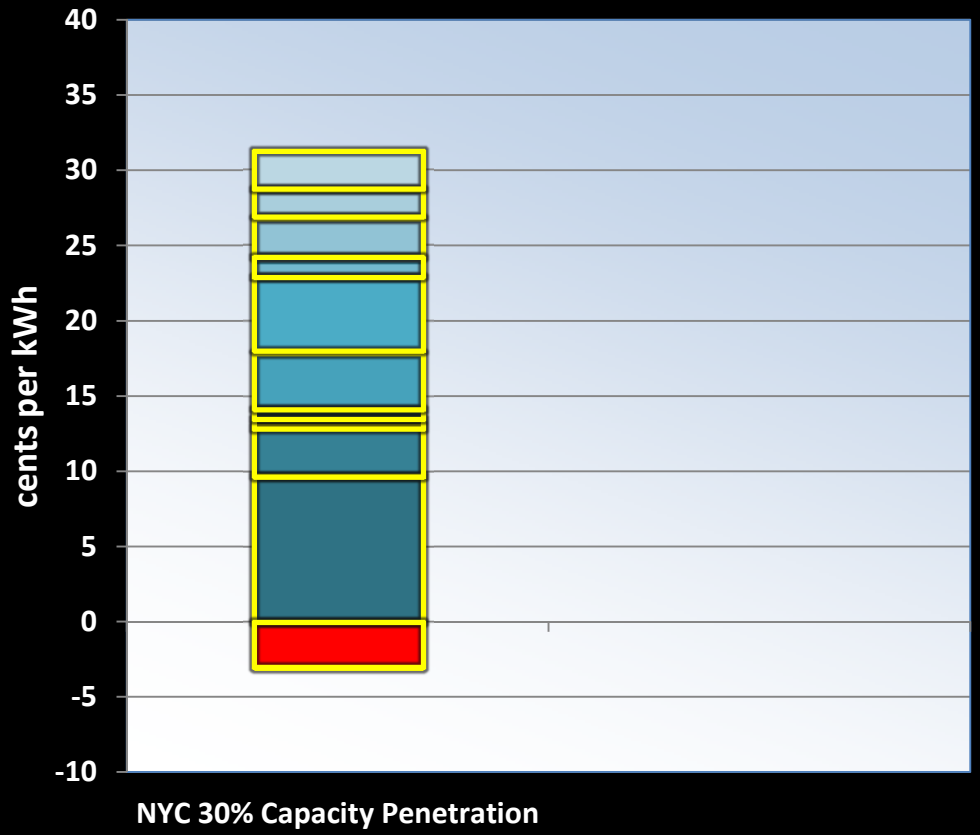
Remuneration

COST

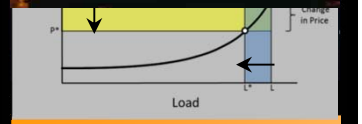


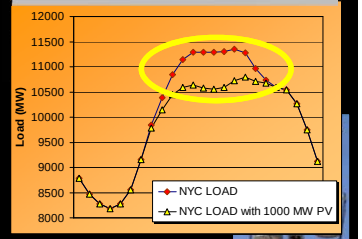


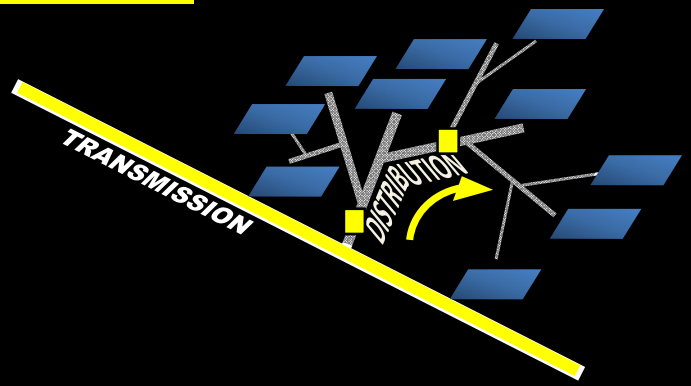
VALUE



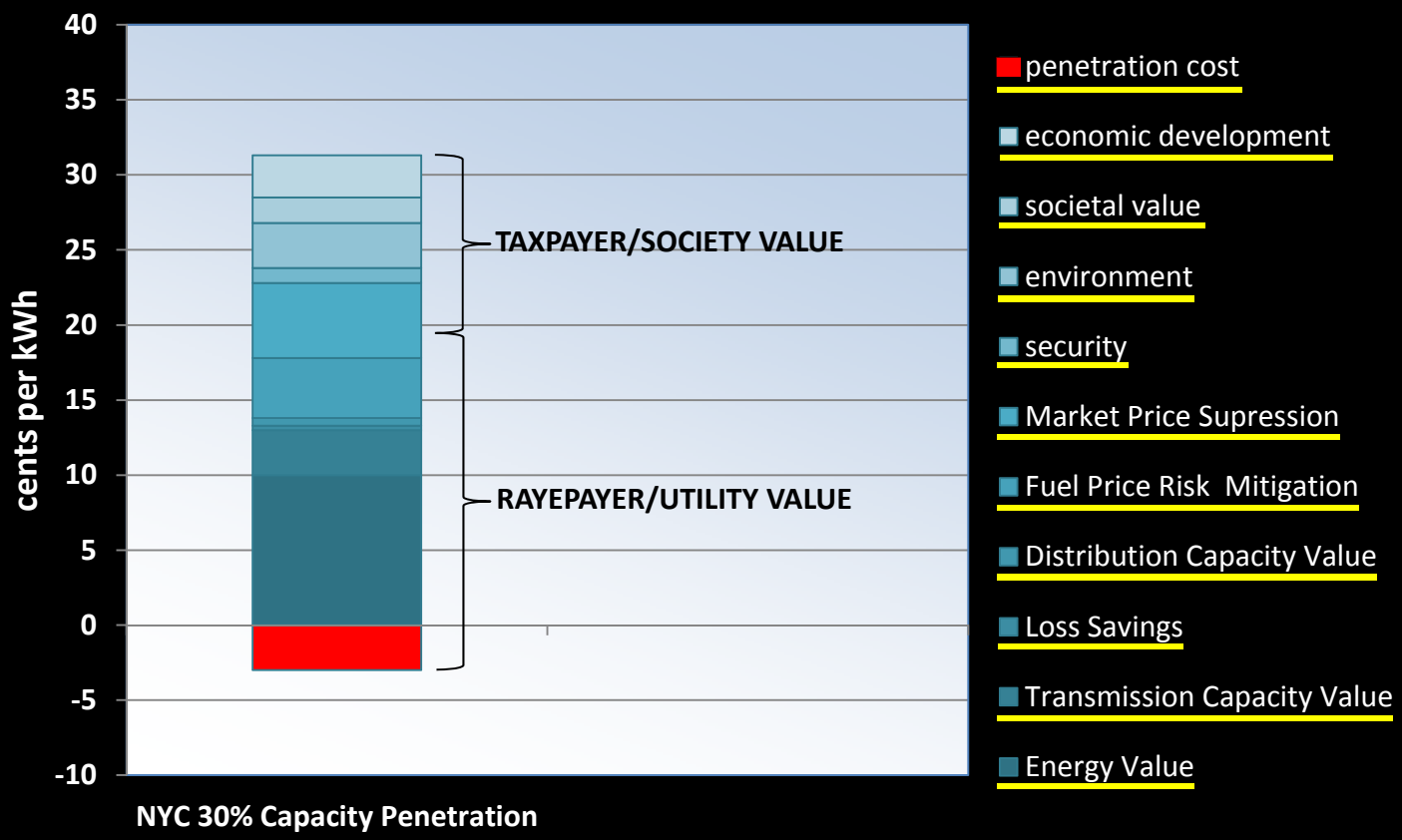
- penetration cost
- economic development
- societal value
- environment
- security
- Market Price Supression
- Fuel Price Risk Mitigation
- Distribution Capacity Value
- Loss Savings
- Transmission Capacity Value
- Energy Value

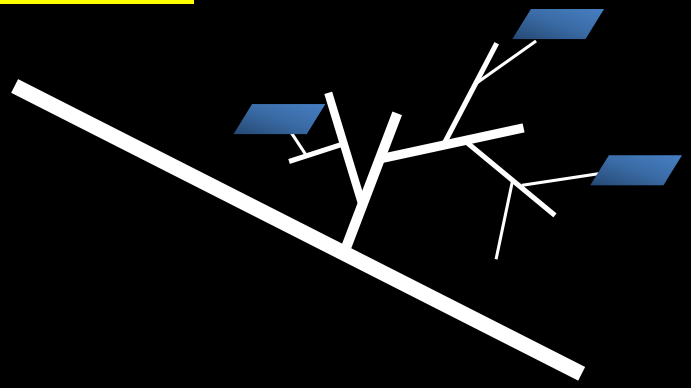




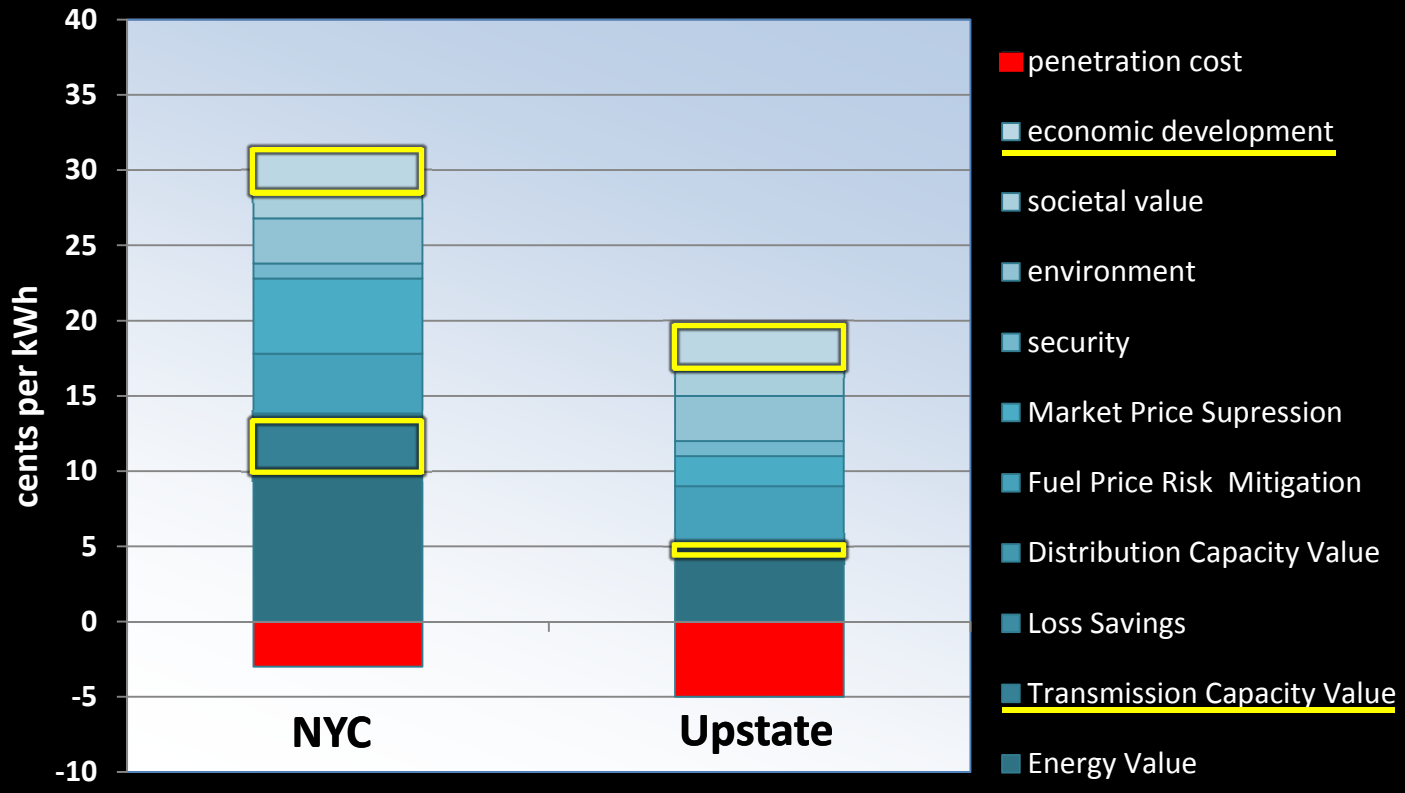


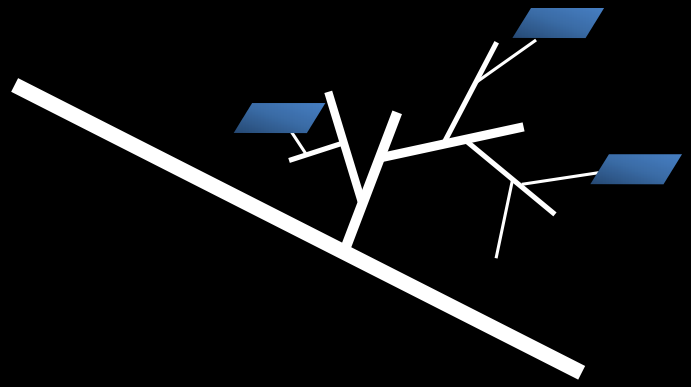
VALUE ACCRUES TO TWO STAKEHOLDERS



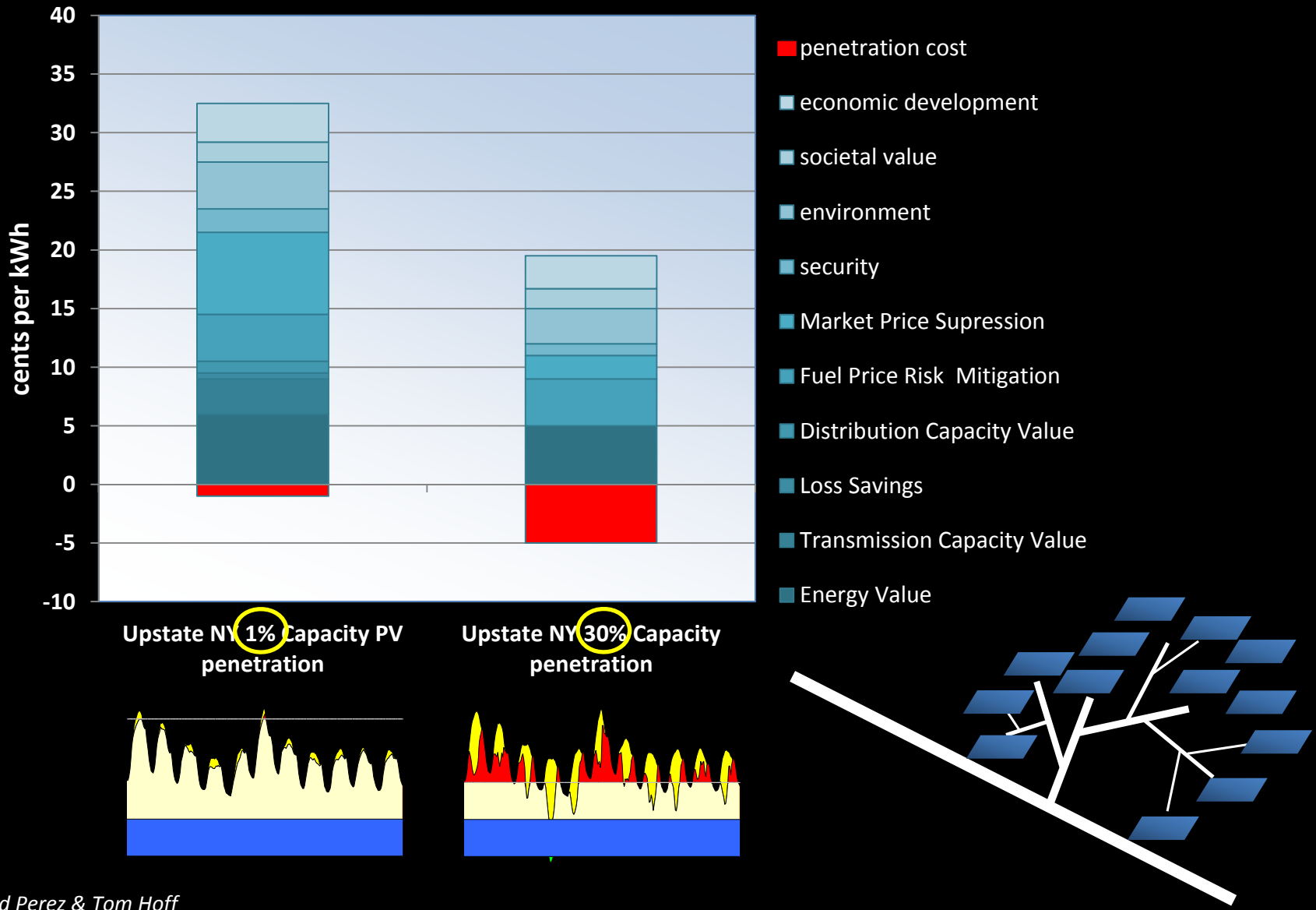


VALUE DEPENDS ON LOCATION

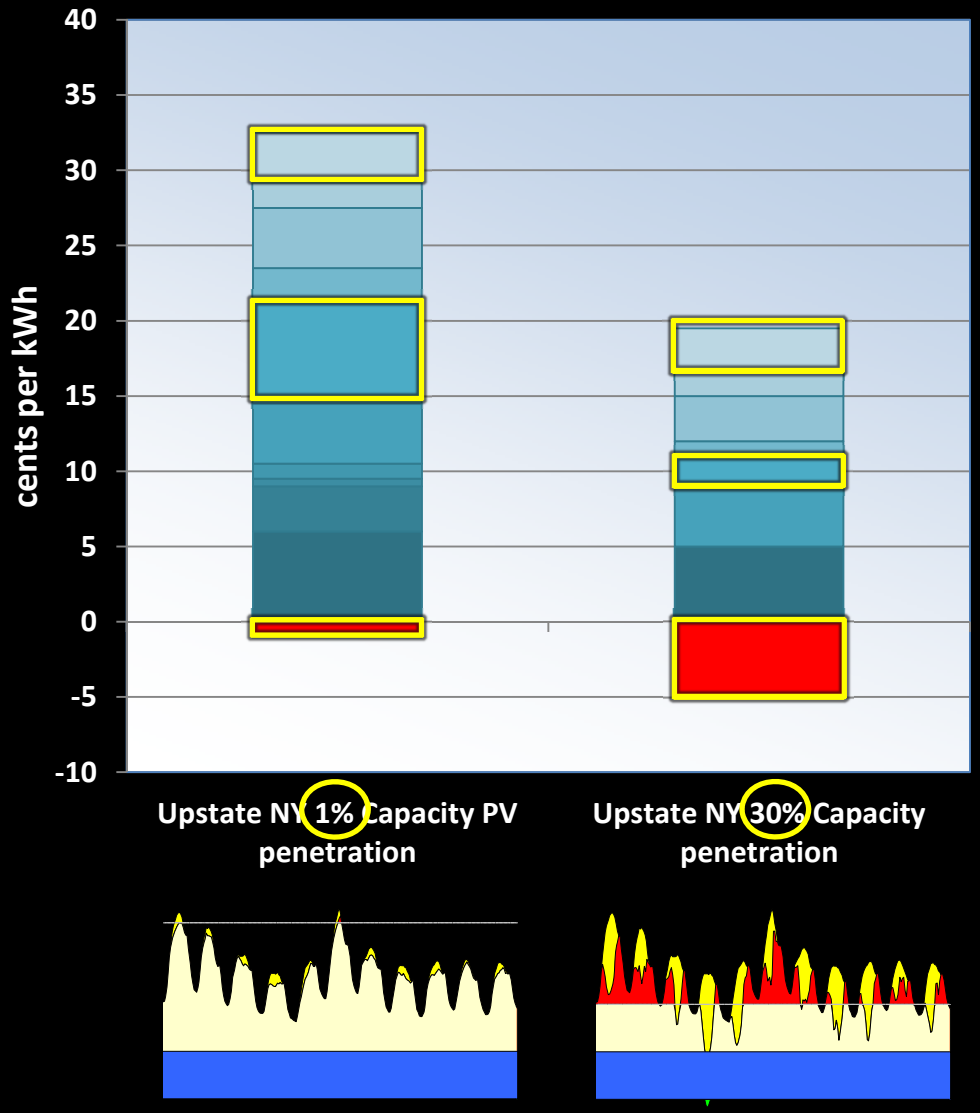




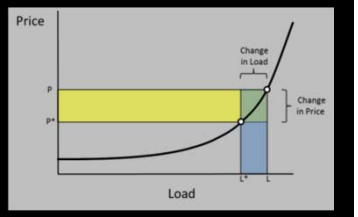
VALUE DEPENDS ON PENETRATION

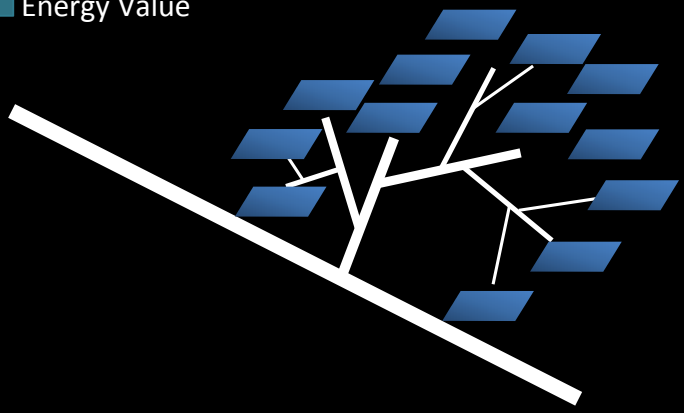


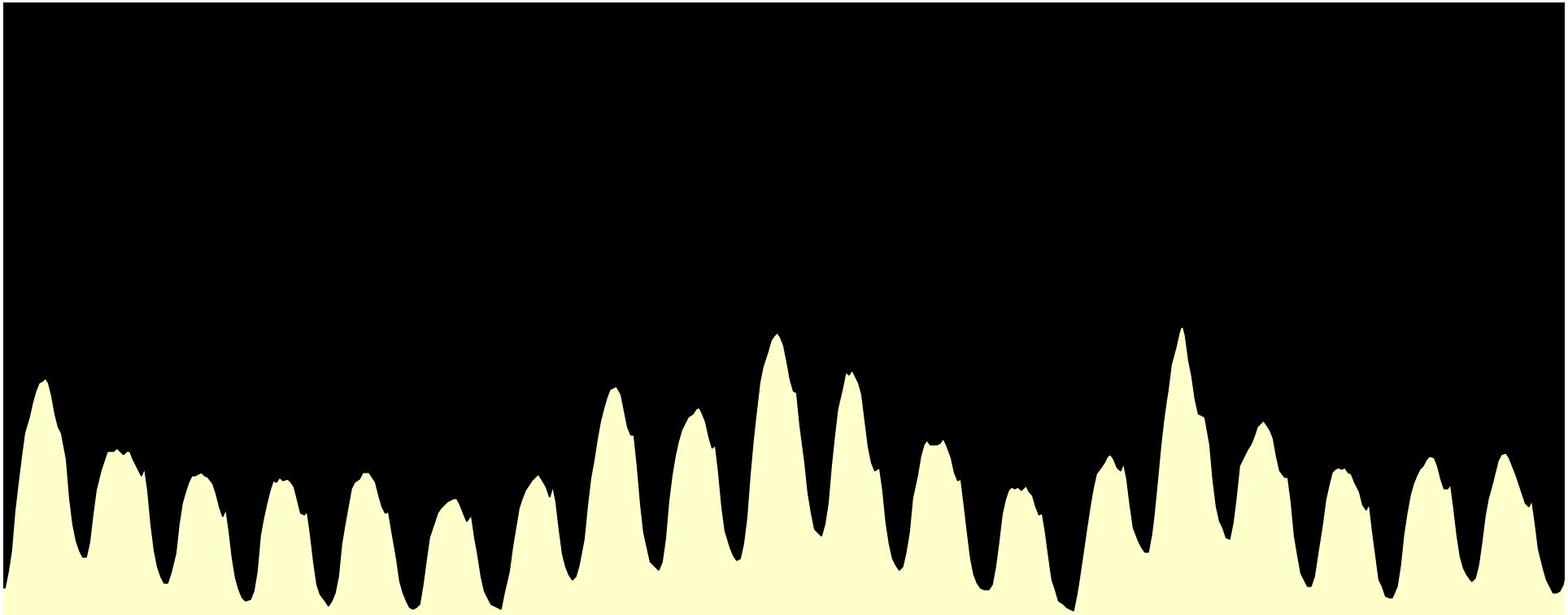
VALUE DEPENDS ON PENETRATION



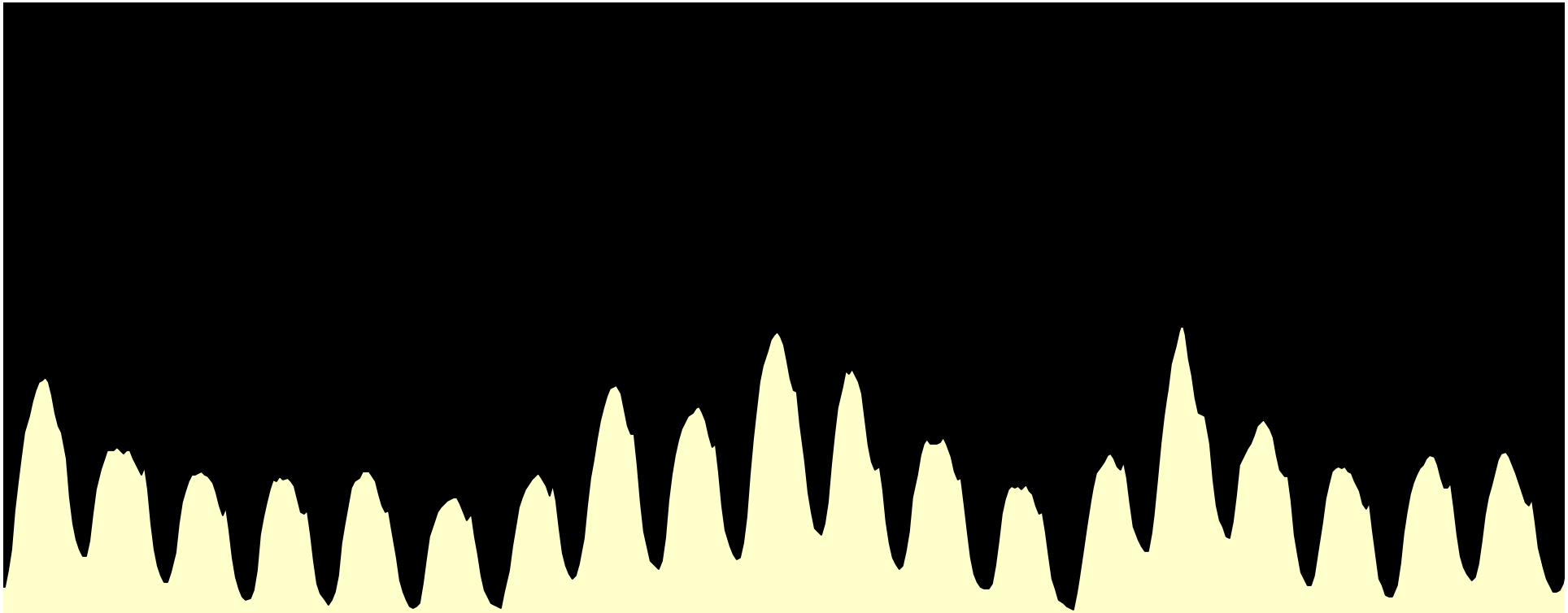
- penetration cost
- economic development
- societal value
- environment
- security
- Market Price Supression
- Fuel Price Risk Mitigation
- Distribution Capacity Value
- Loss Savings
- Transmission Capacity Value
- Energy Value







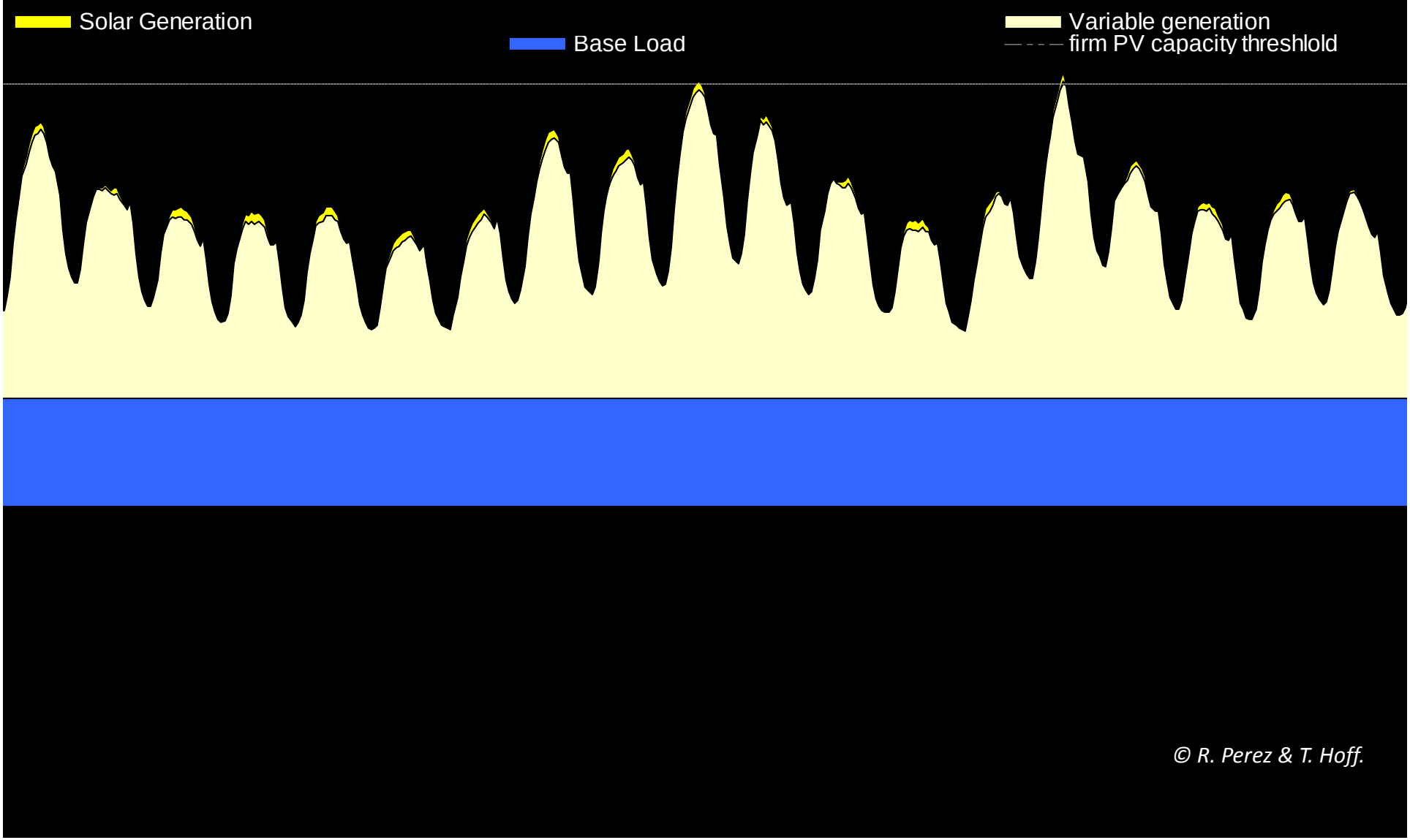
20 day sample of Summer New York City electrical load

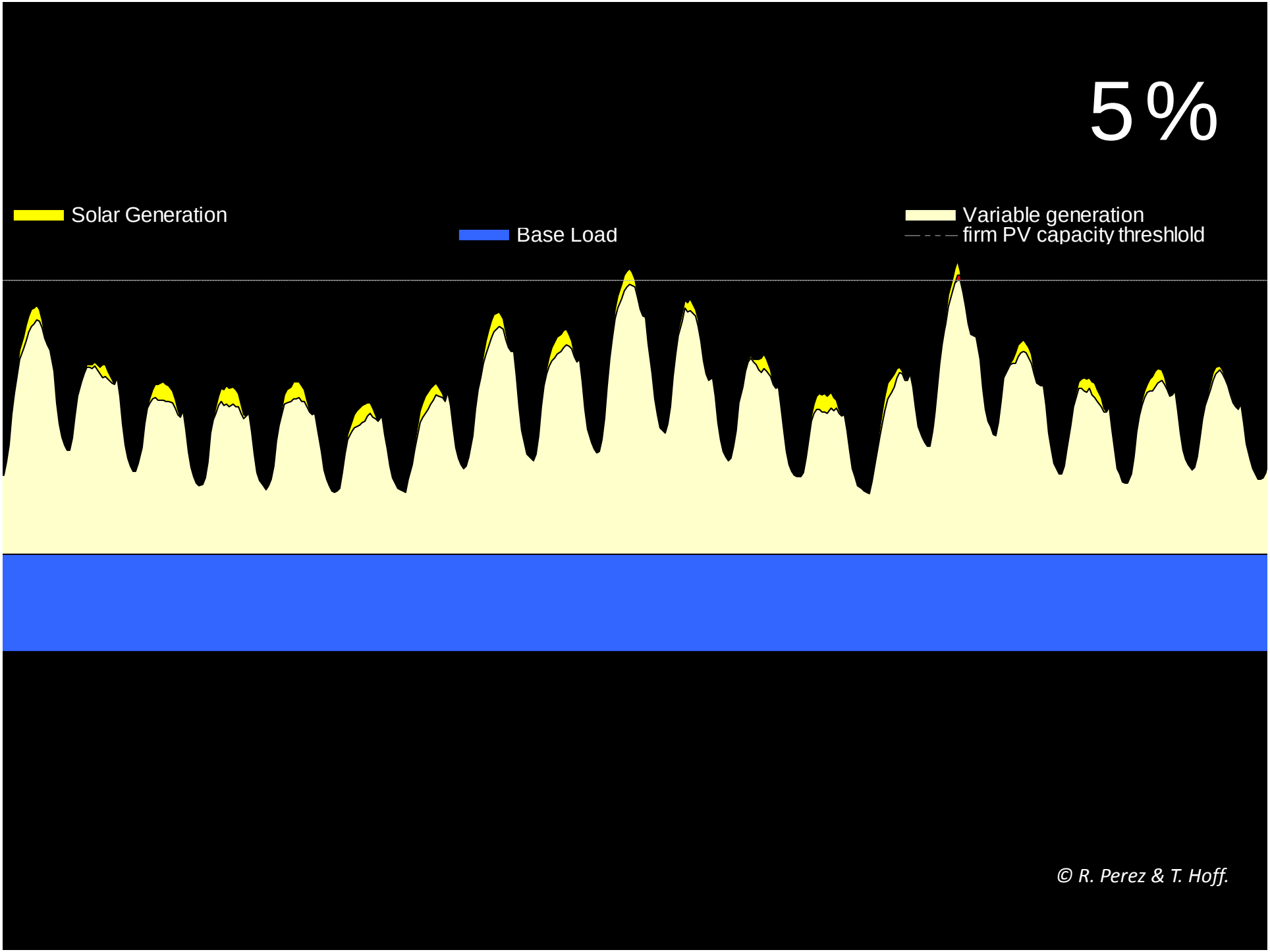


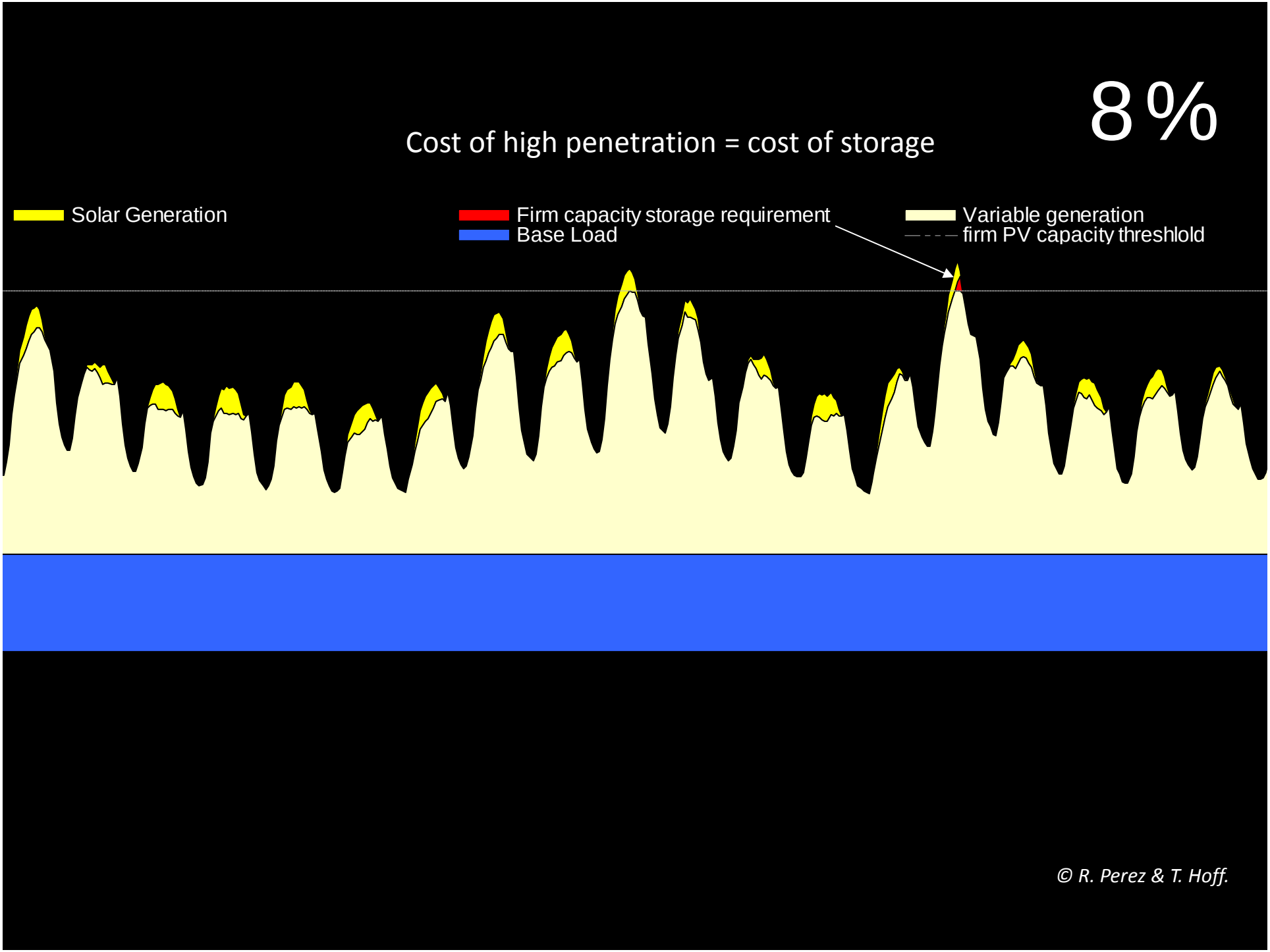
VARIABLE LOAD GENERATION

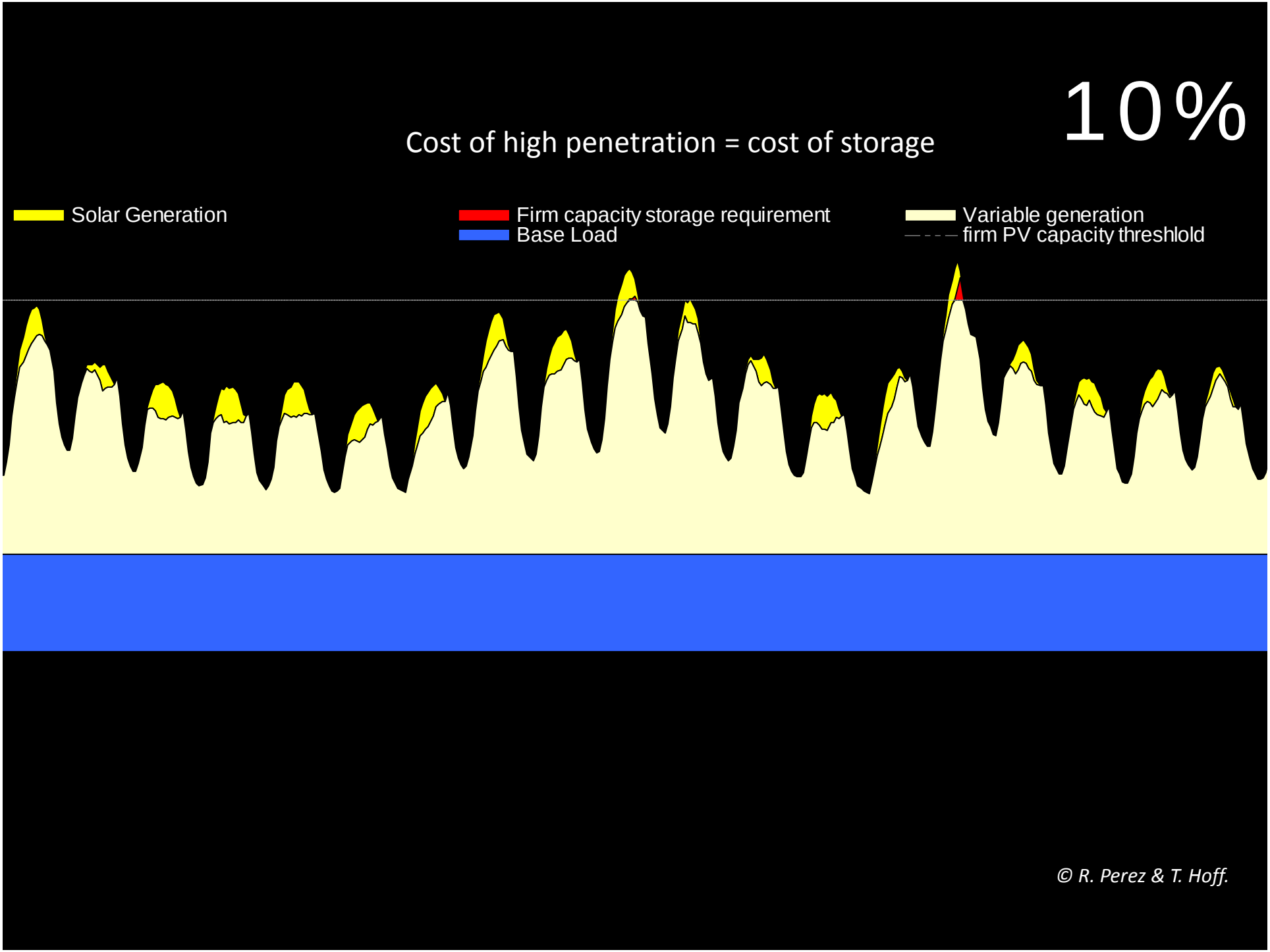
BASE LOAD GENERATION

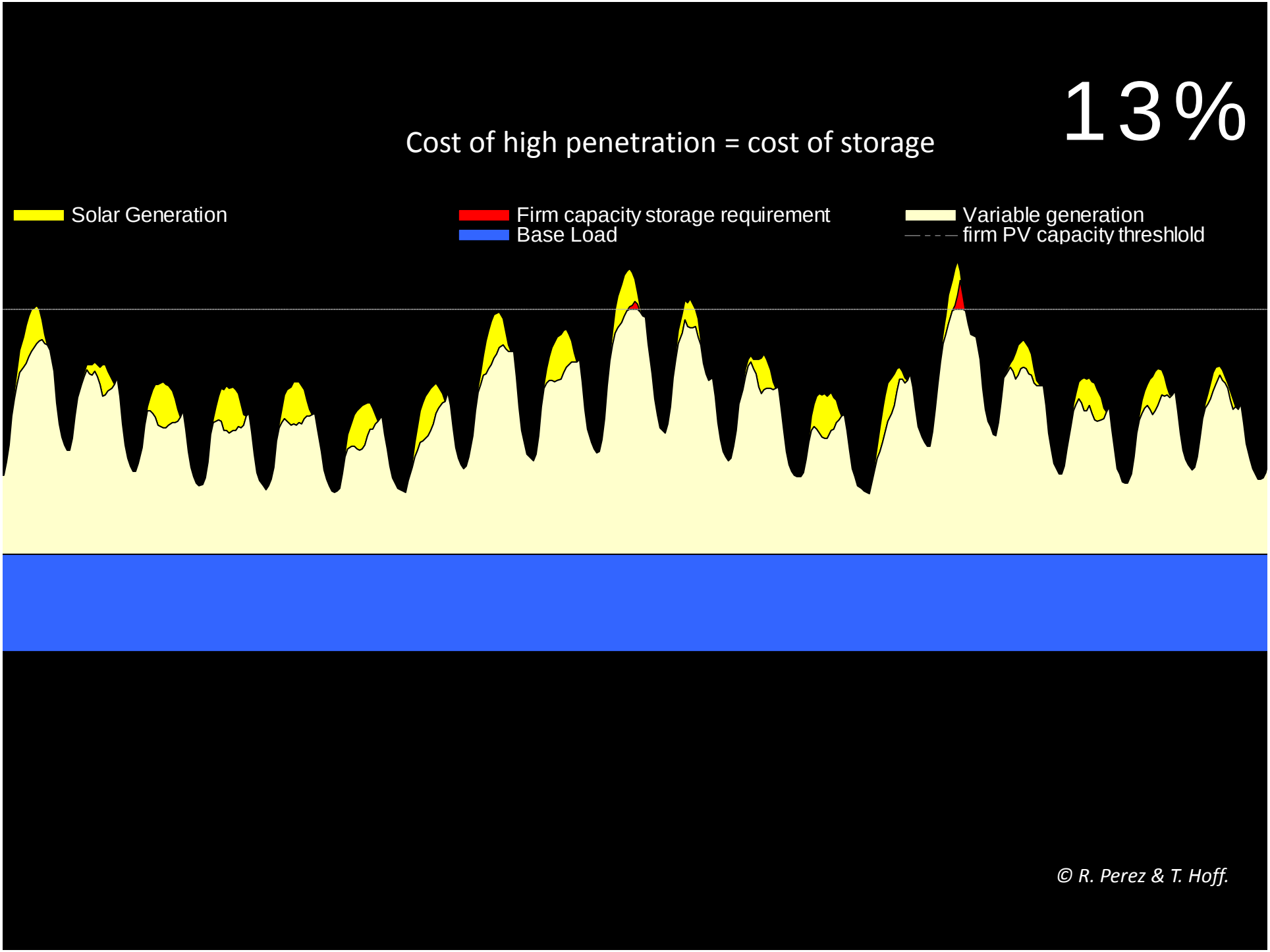
Solar Penetration: 3%

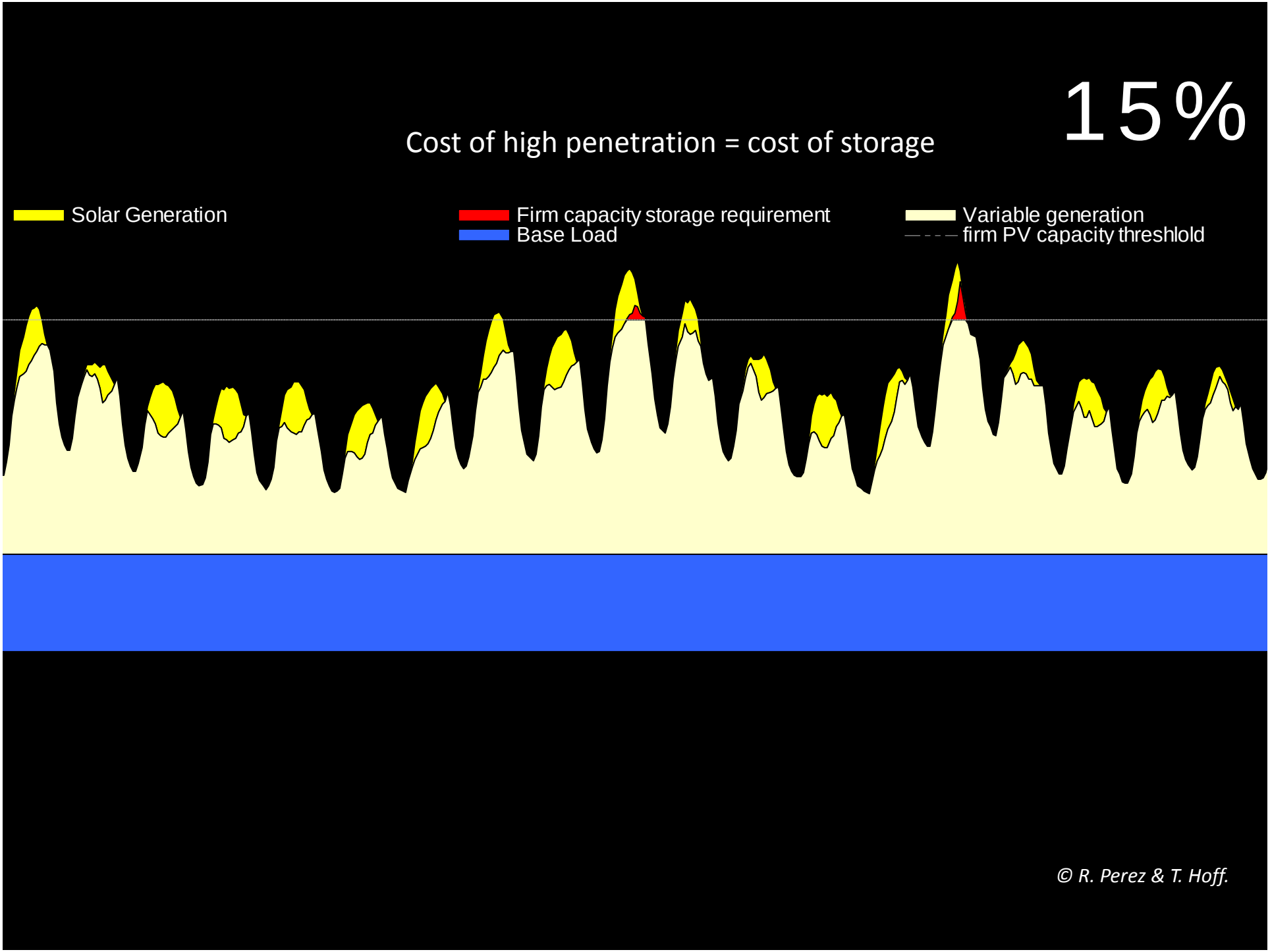


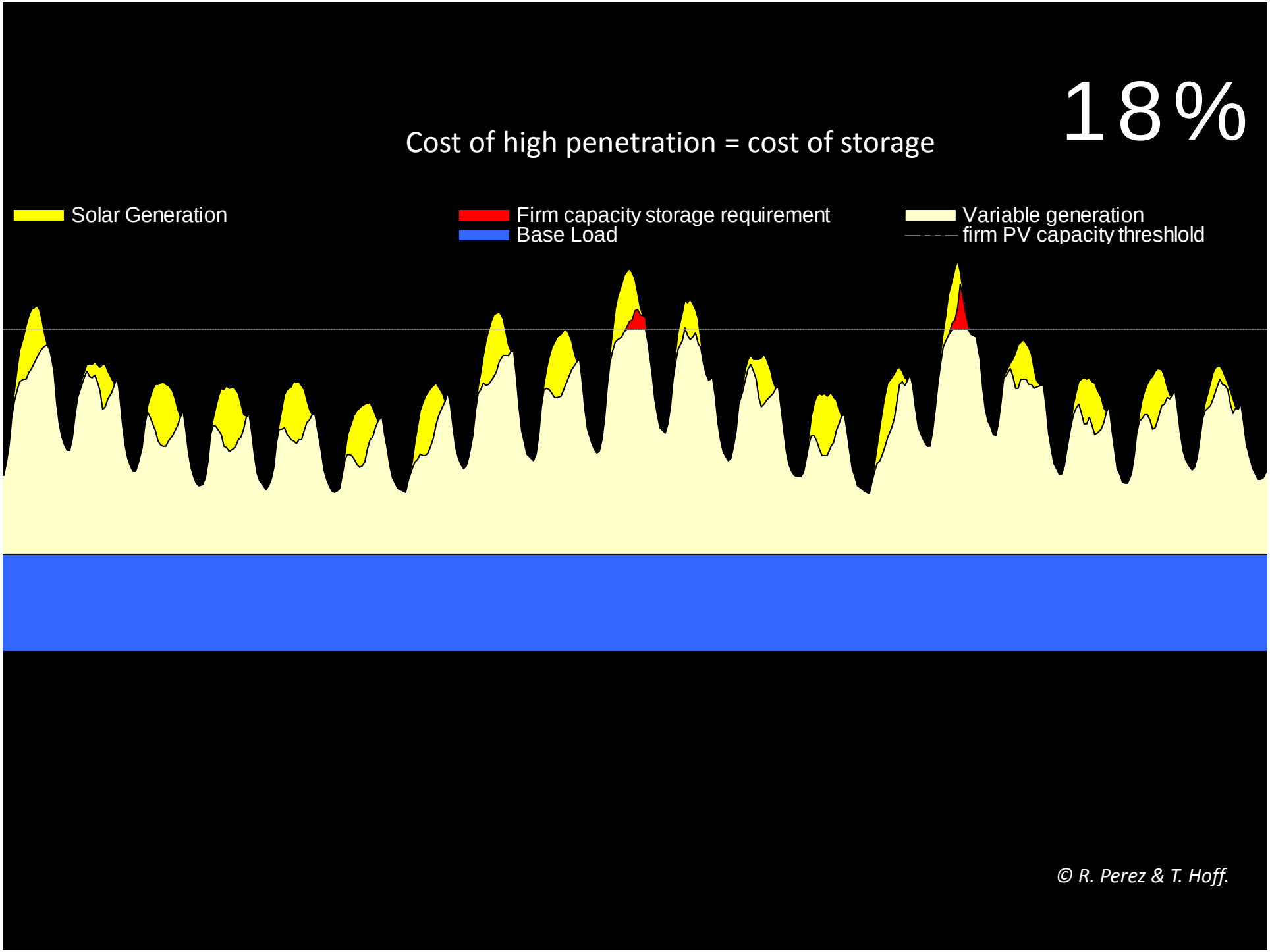

5%
Solar Generation
Base Load
Variable generation
firm PV capacity threshlold
© R. Perez & T. Hoff.

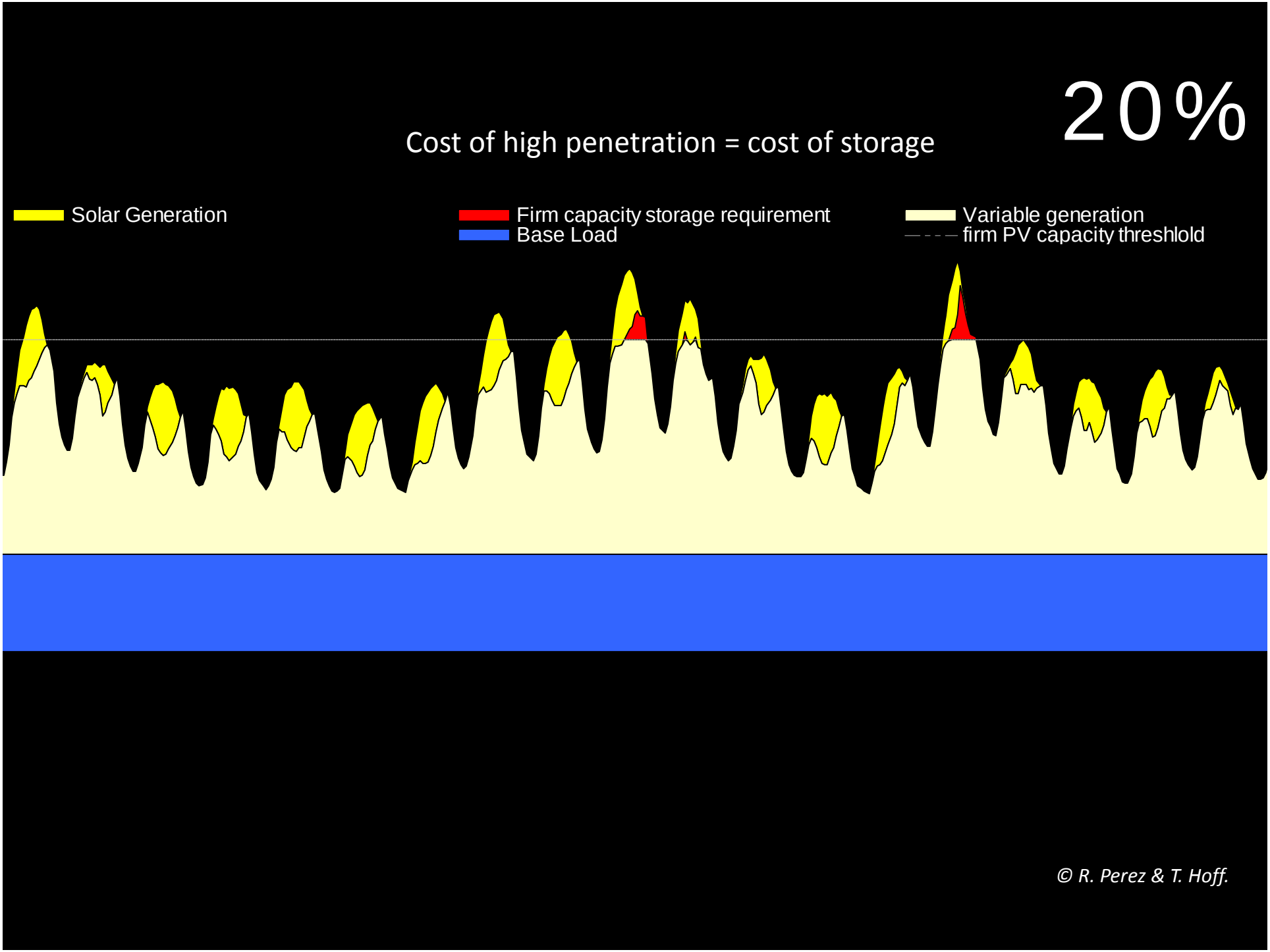

8%
Cost of high penetration = cost of storage
Solar Generation
Firm capacity storage requirement
Base Load
Variable generation
firm PV capacity threshlold
© R. Perez & T. Hoff.

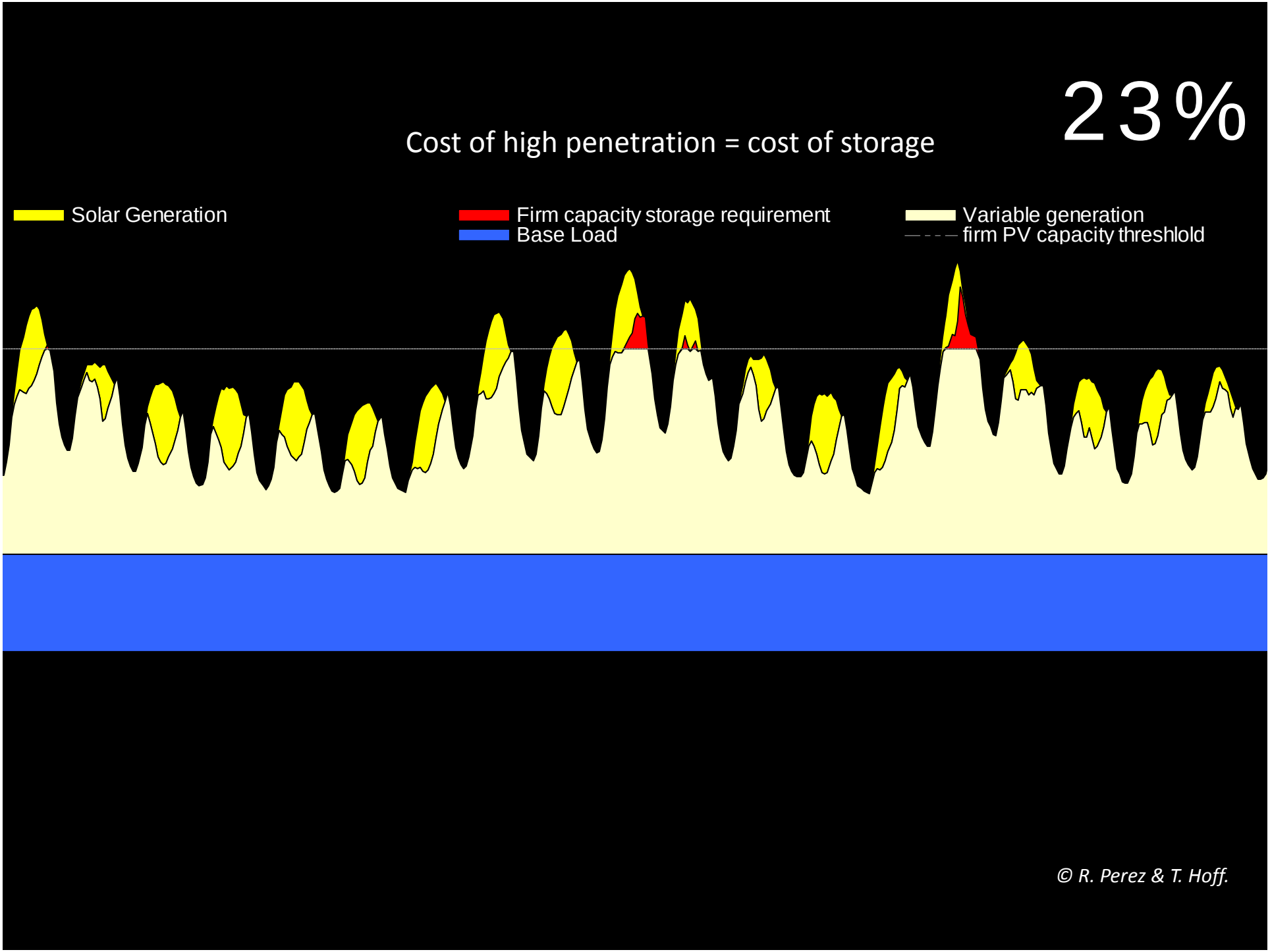

10%
Cost of high penetration = cost of storage
Solar Generation
Firm capacity storage requirement
Base Load
Variable generation
firm PV capacity threshlold
© R. Perez & T. Hoff.

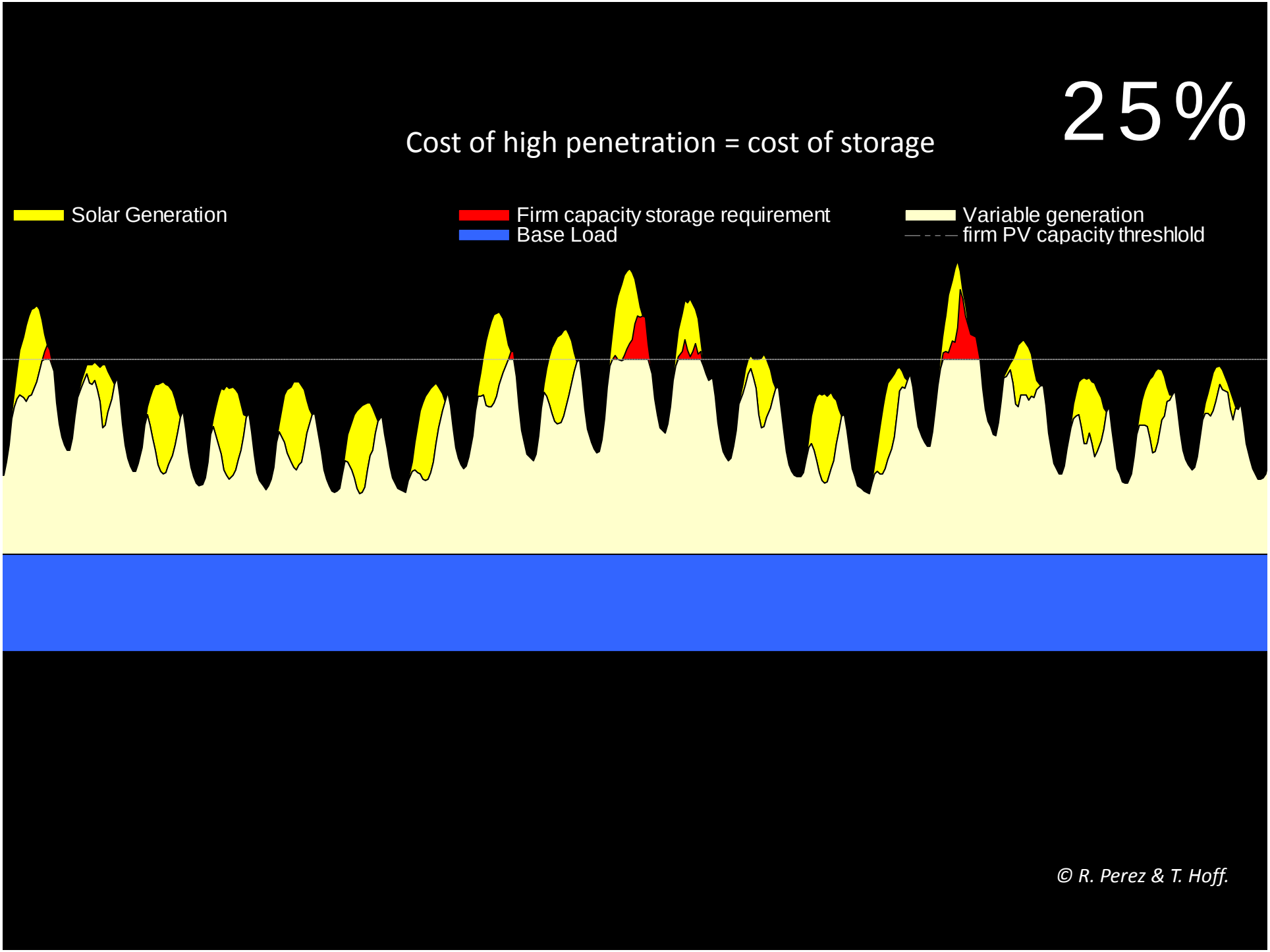

13%
Cost of high penetration = cost of storage
Solar Generation
Firm capacity storage requirement
Base Load
Variable generation
firm PV capacity threshlold
© R. Perez & T. Hoff.

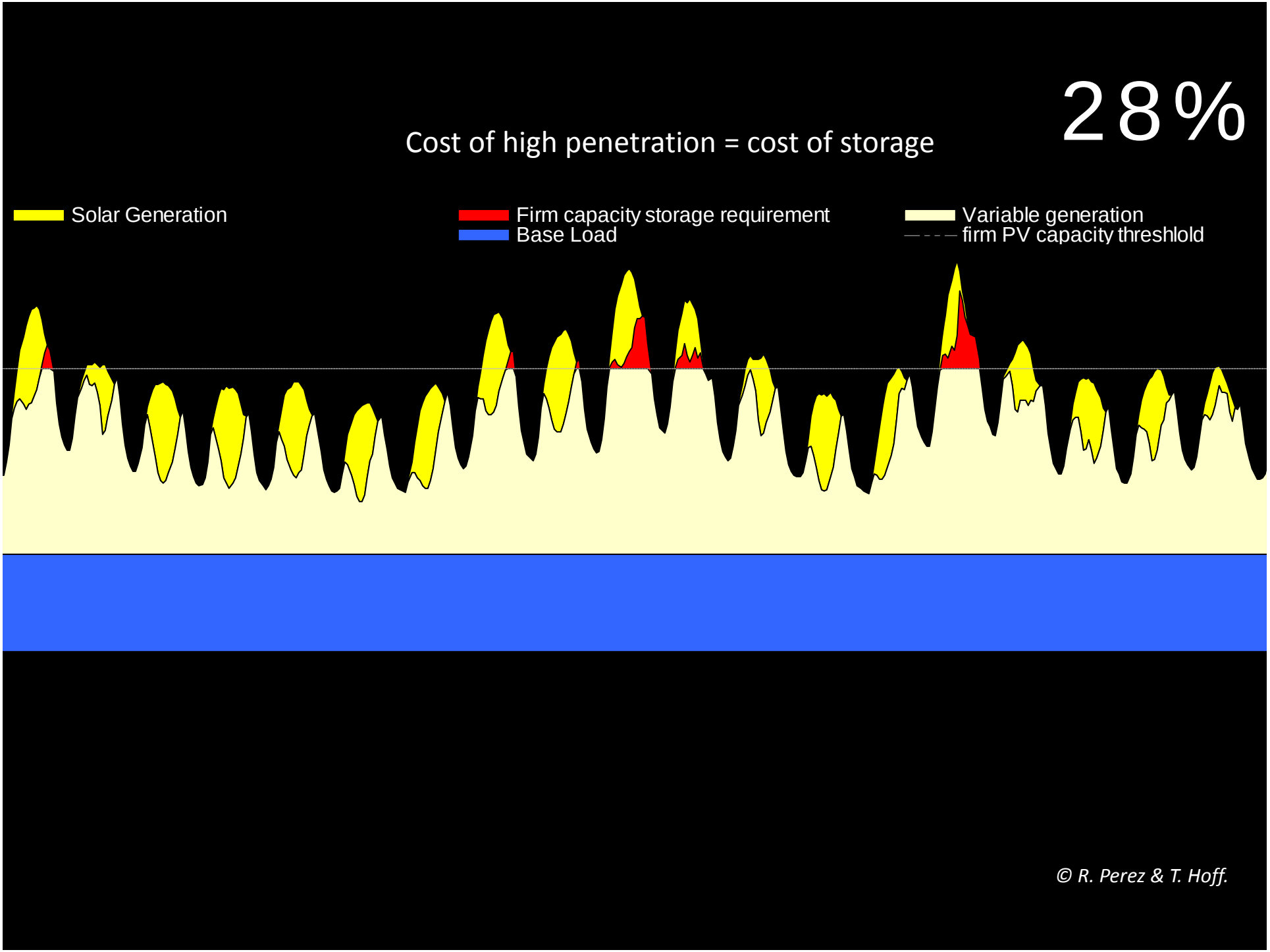

15%
Cost of high penetration = cost of storage
Solar Generation
Firm capacity storage requirement
Base Load
Variable generation
firm PV capacity threshlold
© R. Perez & T. Hoff.

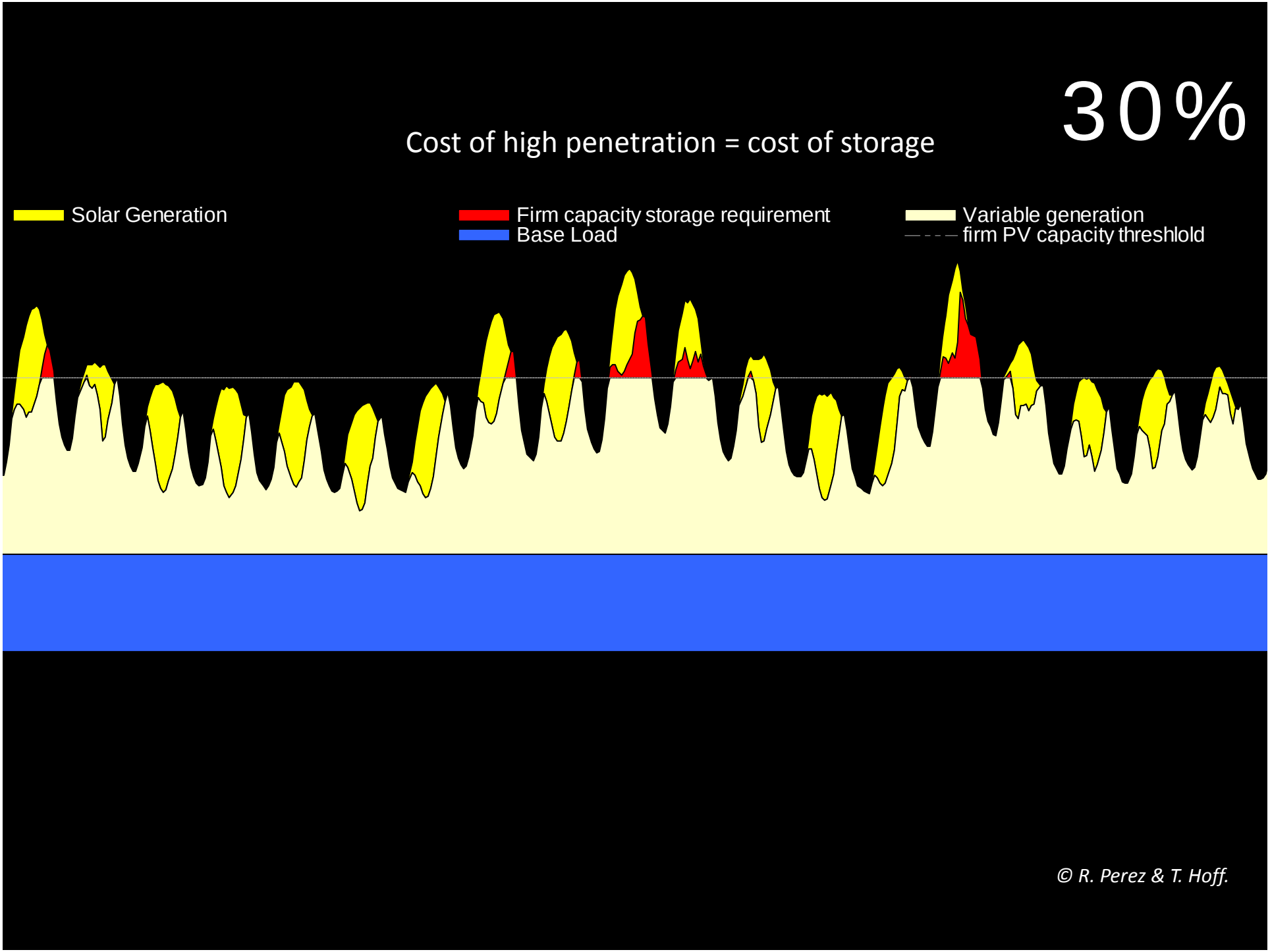

18%
Cost of high penetration = cost of storage
Solar Generation
Firm capacity storage requirement
Base Load
Variable generation
firm PV capacity threshlold
© R. Perez & T. Hoff.

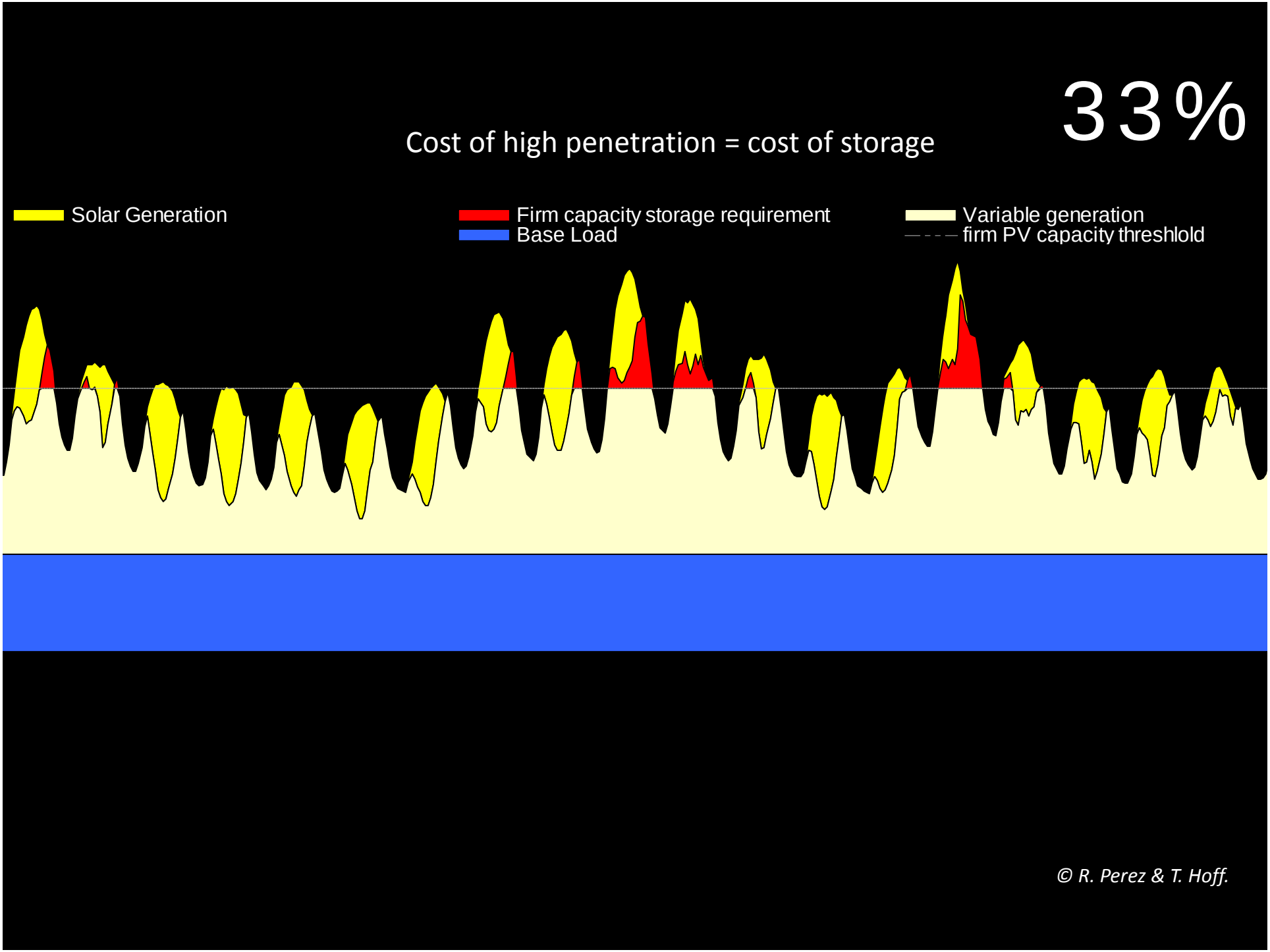

20%
Cost of high penetration = cost of storage
Solar Generation
Firm capacity storage requirement
Base Load
Variable generation
firm PV capacity threshlold
© R. Perez & T. Hoff.

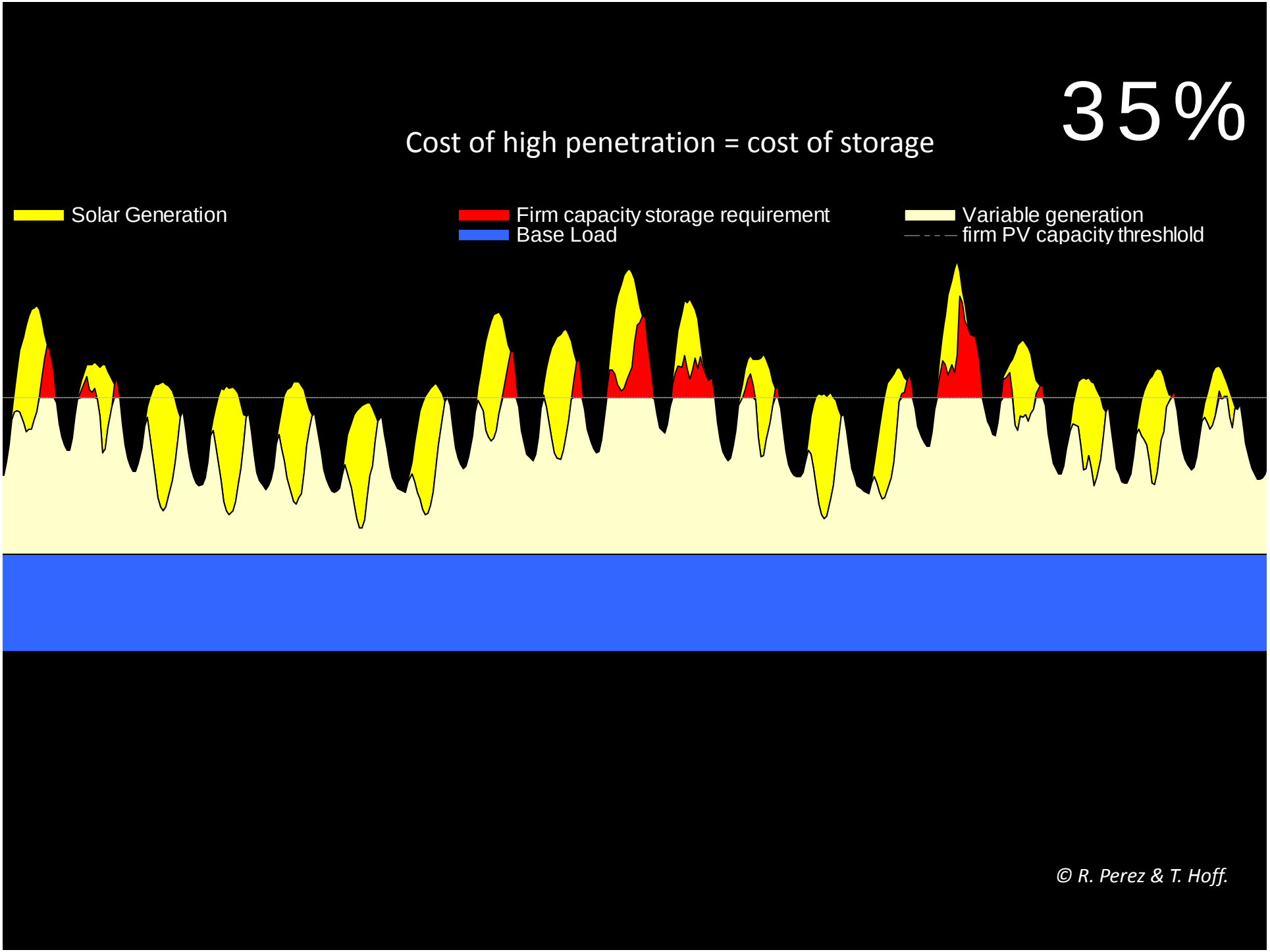

23%
Cost of high penetration = cost of storage
Solar Generation
Firm capacity storage requirement
Base Load
Variable generation
firm PV capacity threshlold
© R. Perez & T. Hoff.

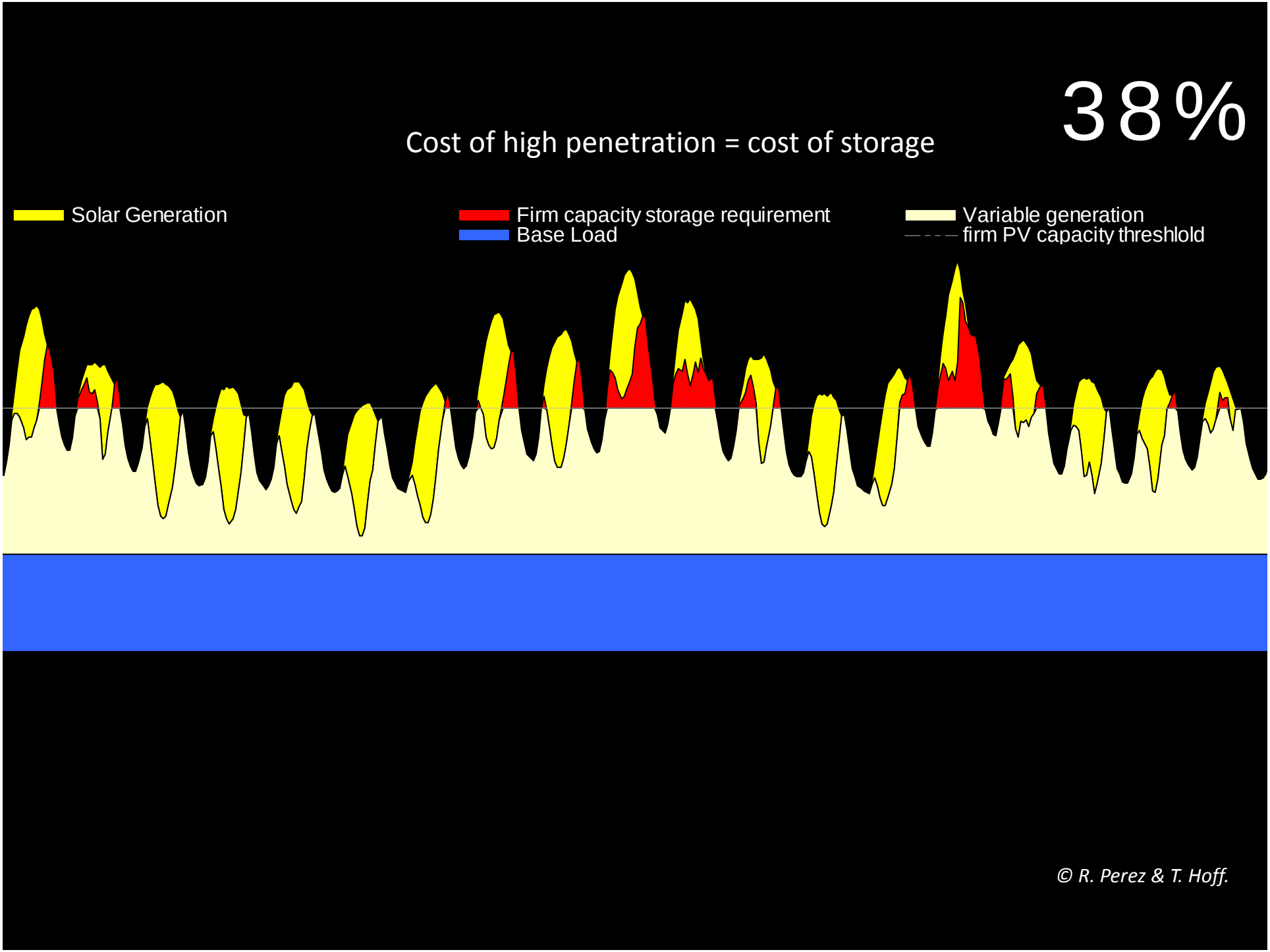

25%
Cost of high penetration = cost of storage
Solar Generation
Firm capacity storage requirement
Base Load
Variable generation
firm PV capacity threshlold
© R. Perez & T. Hoff.

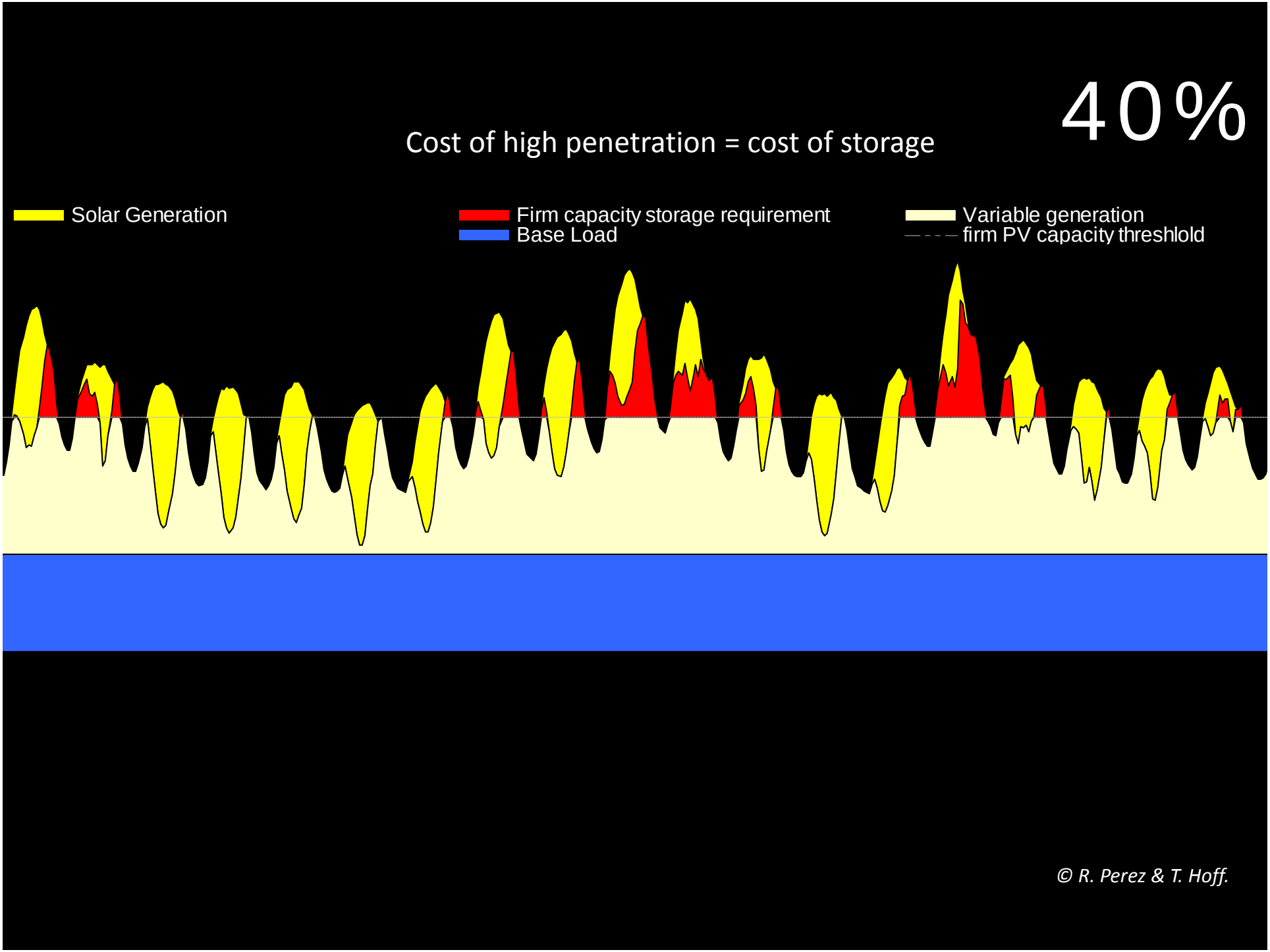

28%
Cost of high penetration = cost of storage
Solar Generation
Firm capacity storage requirement
Base Load
Variable generation
firm PV capacity threshlold
© R. Perez & T. Hoff.

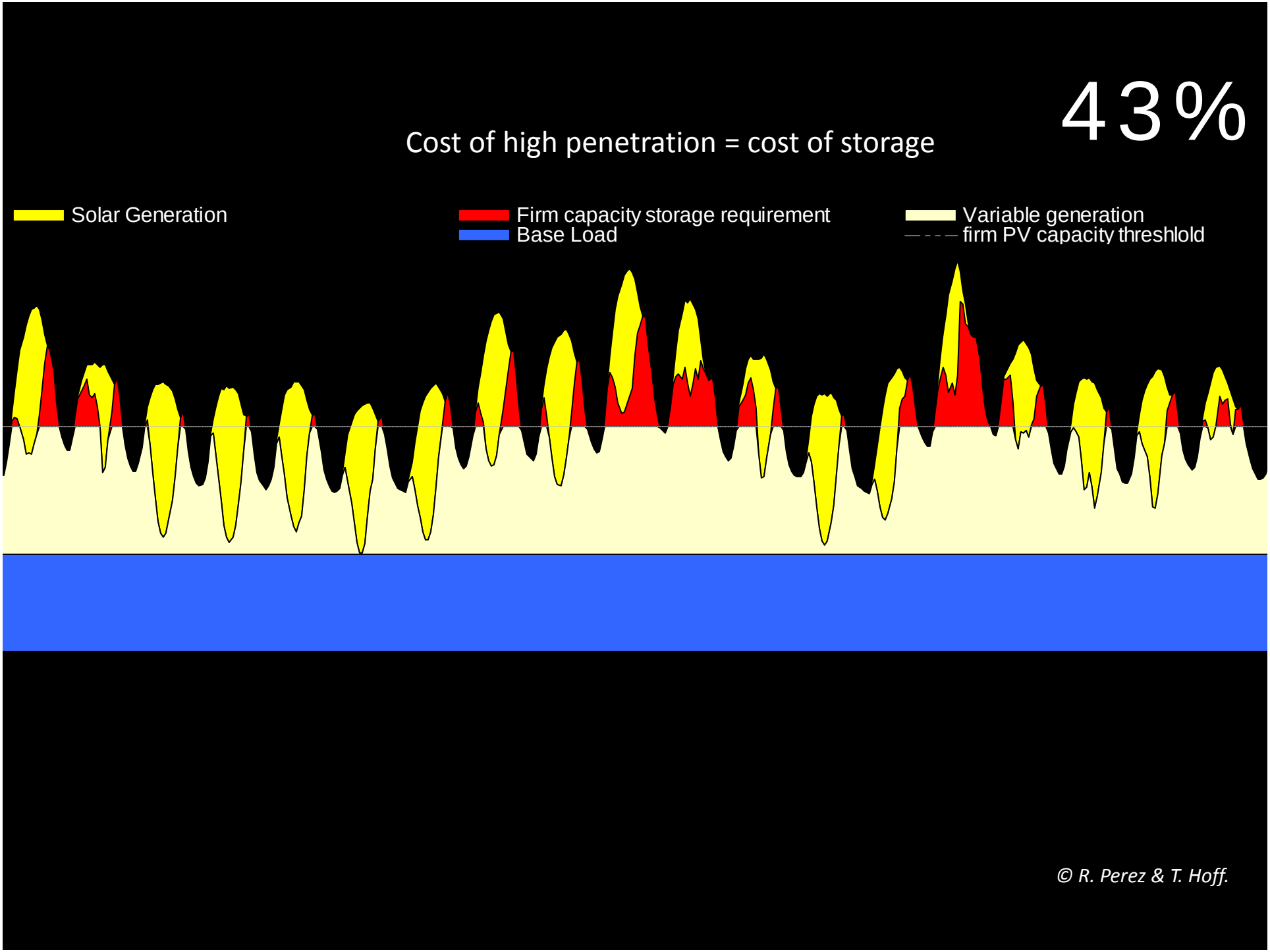

30%
Cost of high penetration = cost of storage
Solar Generation
Firm capacity storage requirement
Base Load
Variable generation
firm PV capacity threshlold
© R. Perez & T. Hoff.

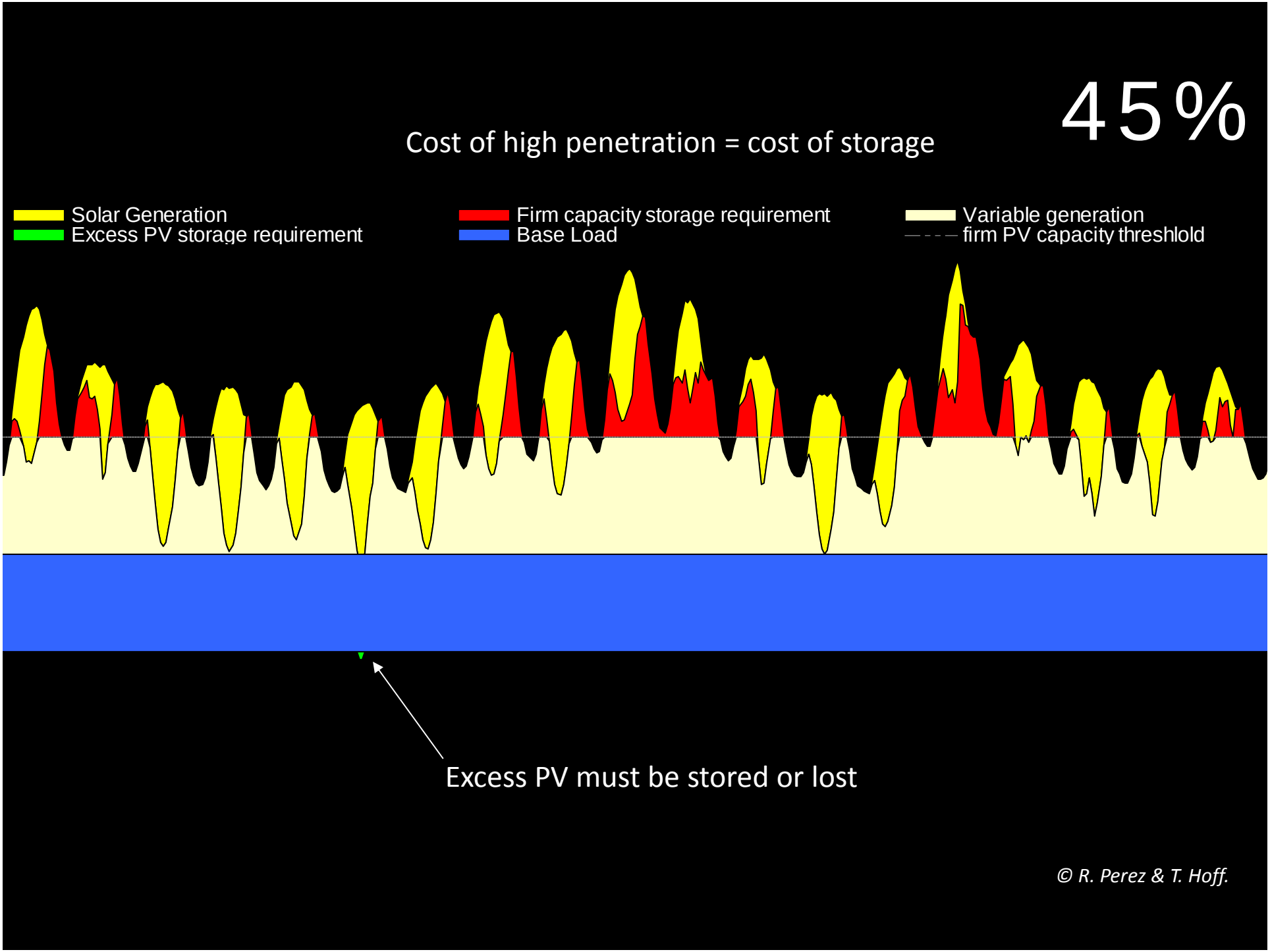

33%
Cost of high penetration = cost of storage
Solar Generation
Firm capacity storage requirement
Base Load
Variable generation
firm PV capacity threshlold
© R. Perez & T. Hoff.

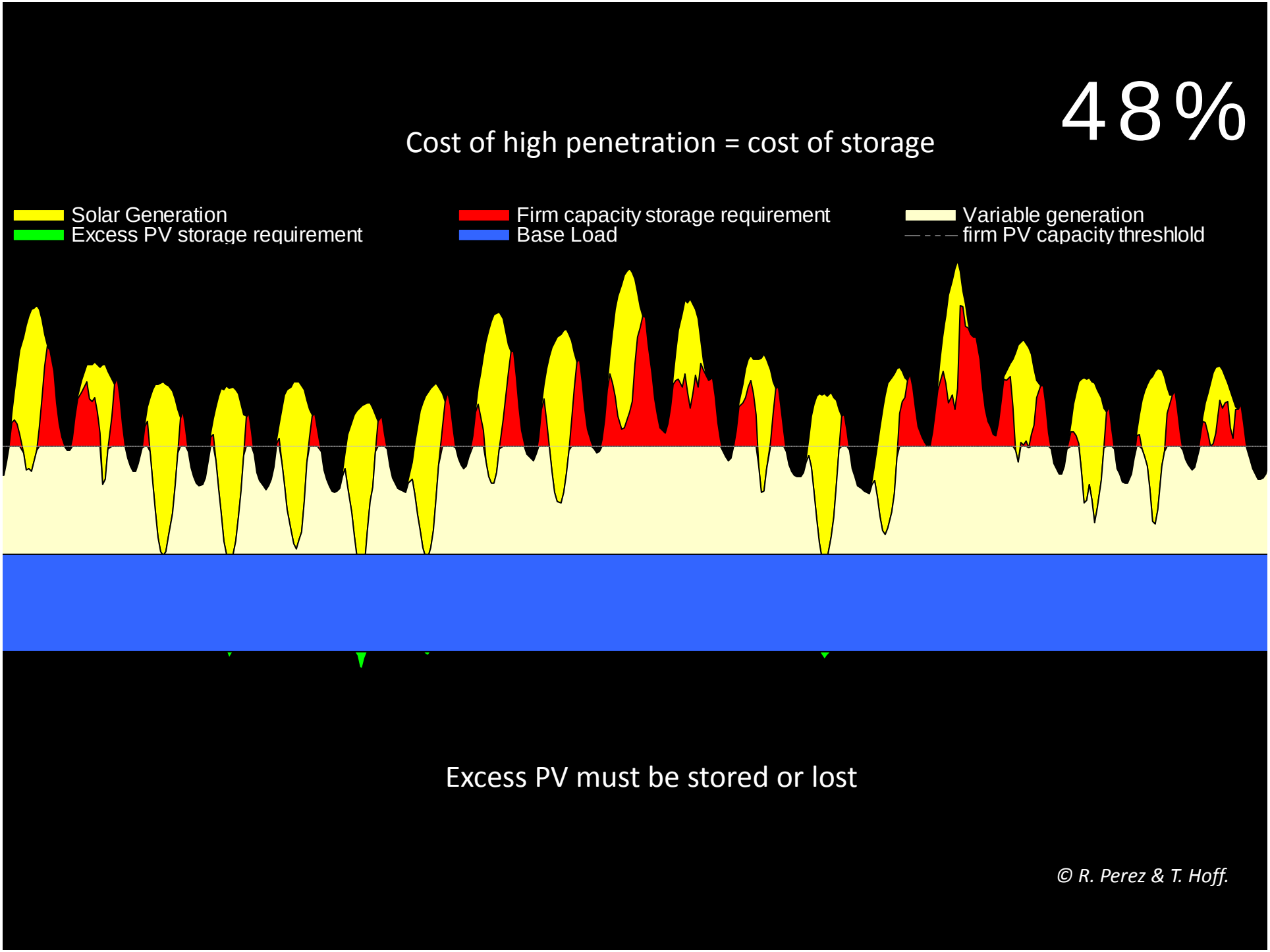

35%
Cost of high penetration = cost of storage
Solar Generation
Firm capacity storage requirement
Base Load
Variable generation
firm PV capacity threshlold
© R. Perez & T. Hoff.

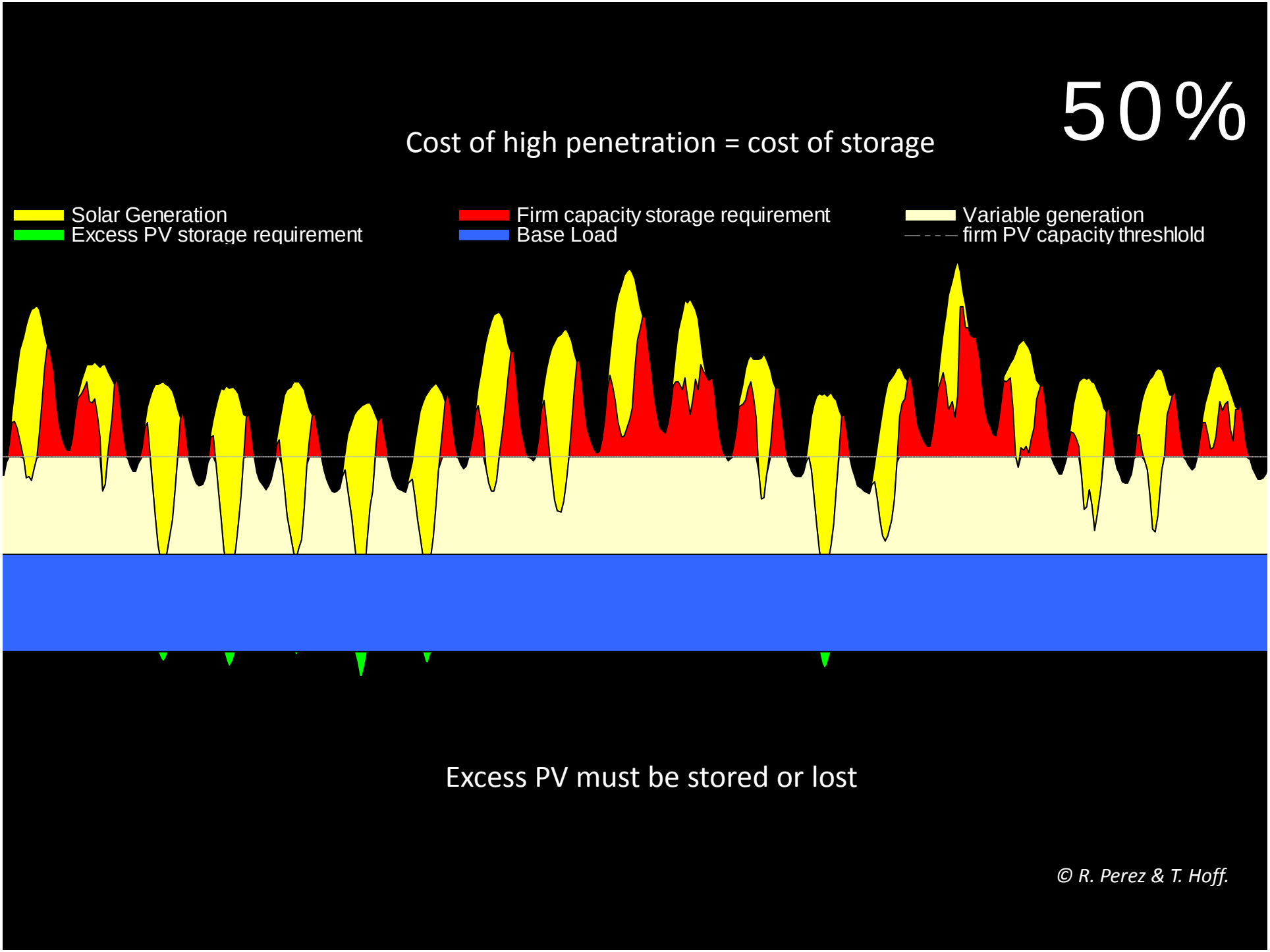

38%
Cost of high penetration = cost of storage
Solar Generation
Firm capacity storage requirement
Base Load
Variable generation
firm PV capacity threshlold
© R. Perez & T. Hoff.

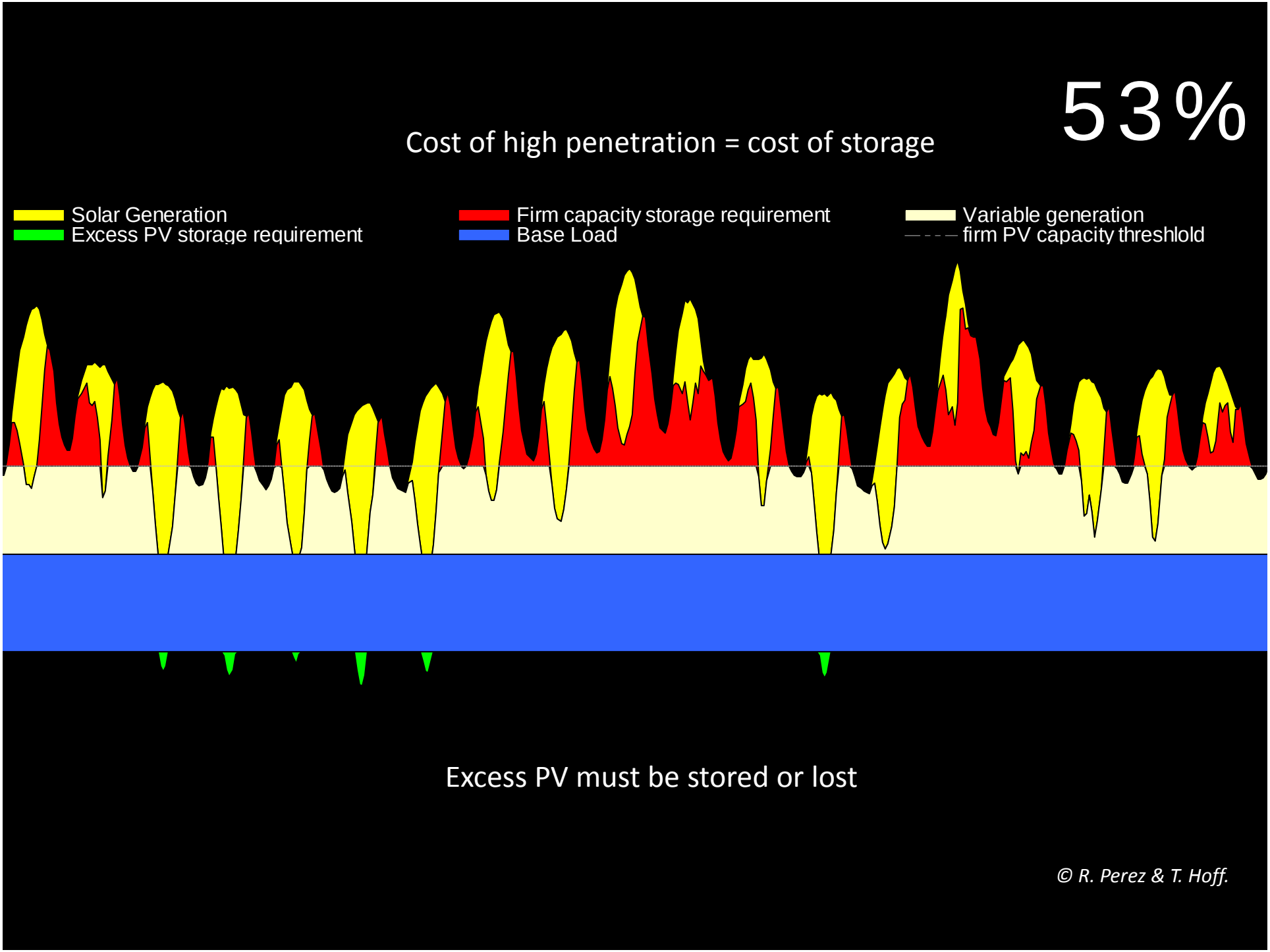

40%
Cost of high penetration = cost of storage
Solar Generation
Firm capacity storage requirement
Base Load
Variable generation
firm PV capacity threshlold
© R. Perez & T. Hoff.

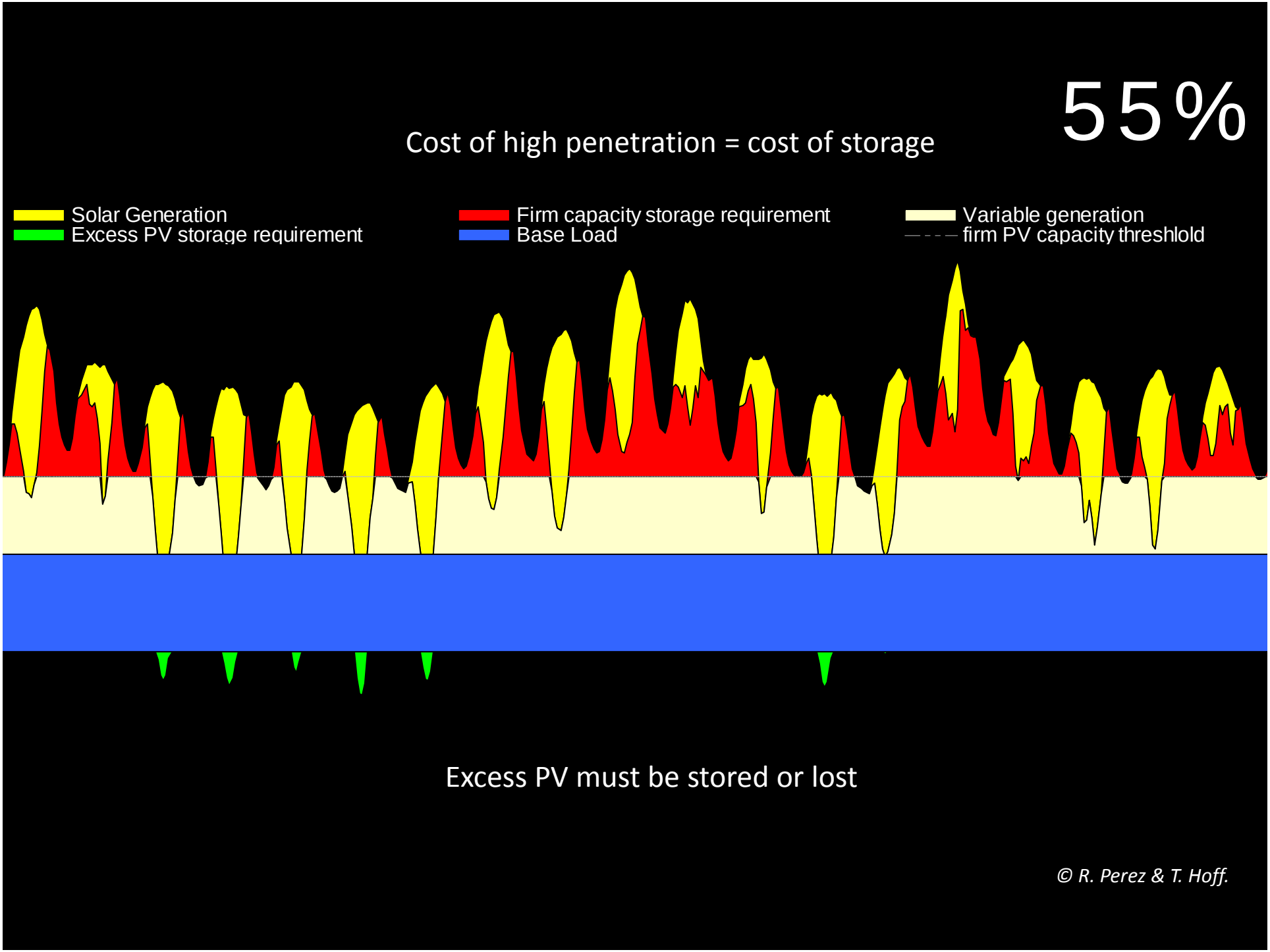

43%
Cost of high penetration = cost of storage
Solar Generation
Firm capacity storage requirement
Base Load
Variable generation
firm PV capacity threshlold
© R. Perez & T. Hoff.

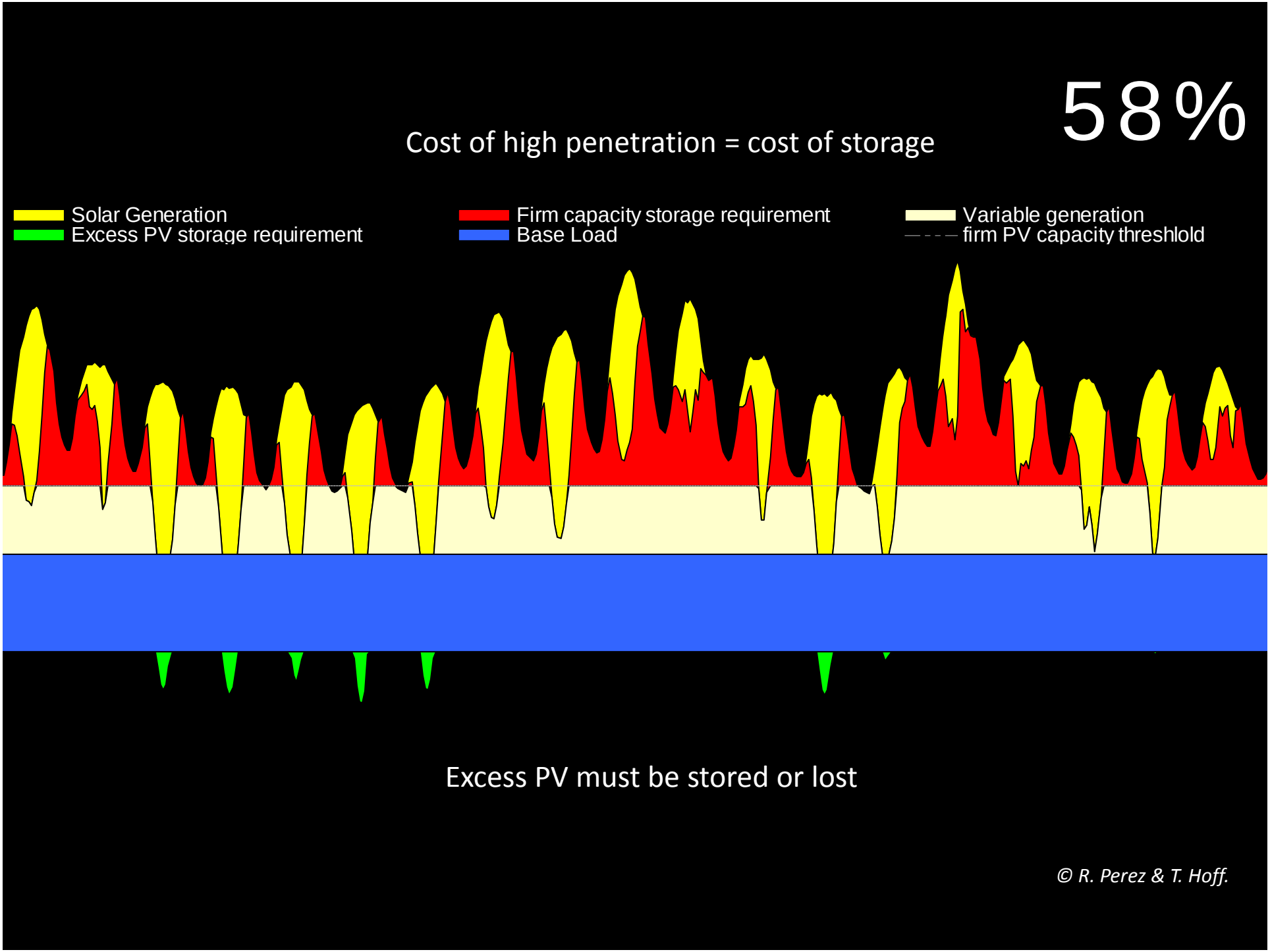

45%
Cost of high penetration = cost of storage
Solar Generation
Excess PV storage requirement
Firm capacity storage requirement
Base Load
Variable generation
firm PV capacity threshlold
Excess PV must be stored or lost
© R. Perez & T. Hoff.

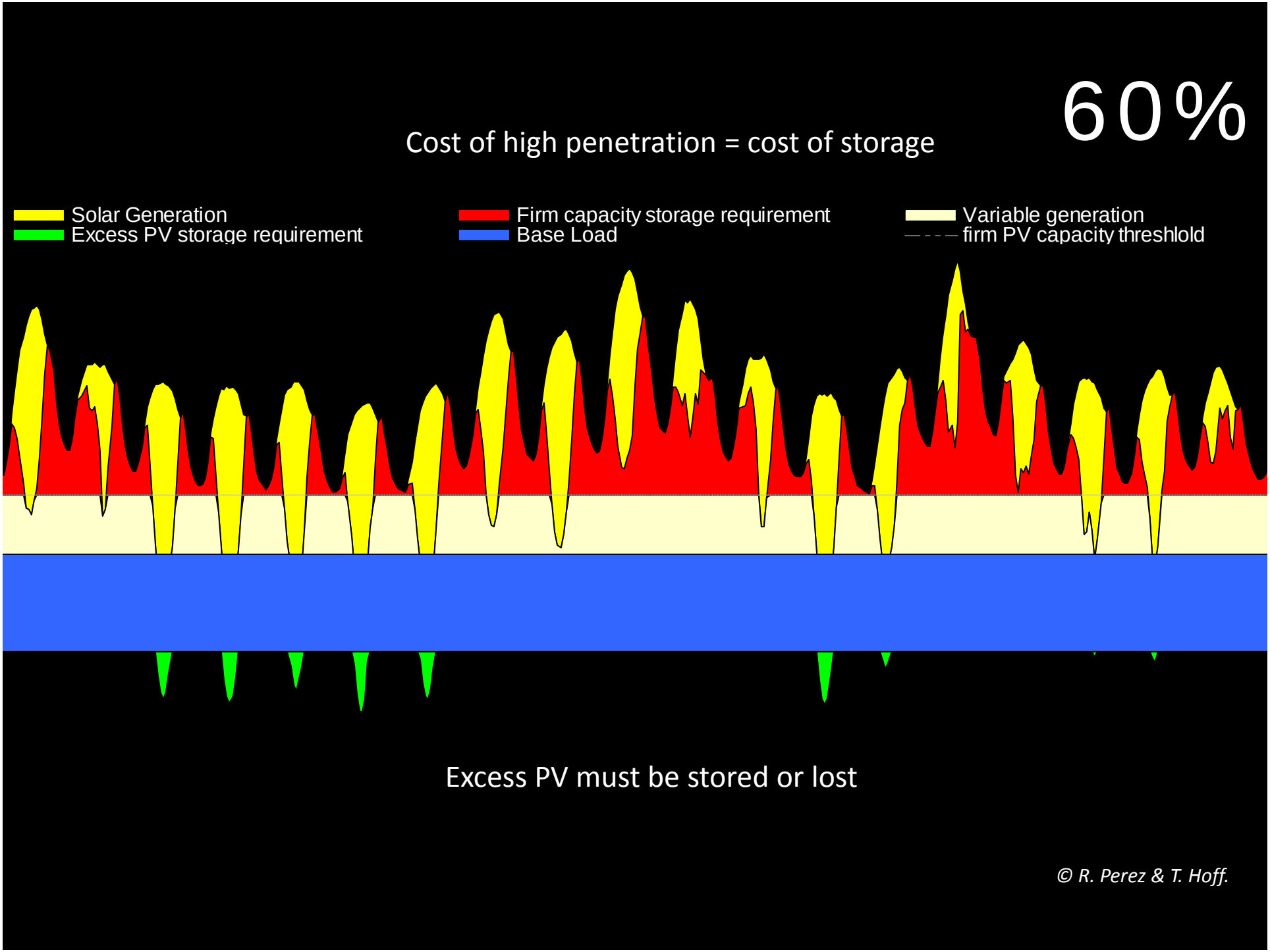

48%
Cost of high penetration = cost of storage
Solar Generation
Excess PV storage requirement
Firm capacity storage requirement
Base Load
Variable generation
firm PV capacity threshlold
Excess PV must be stored or lost
© R. Perez & T. Hoff.

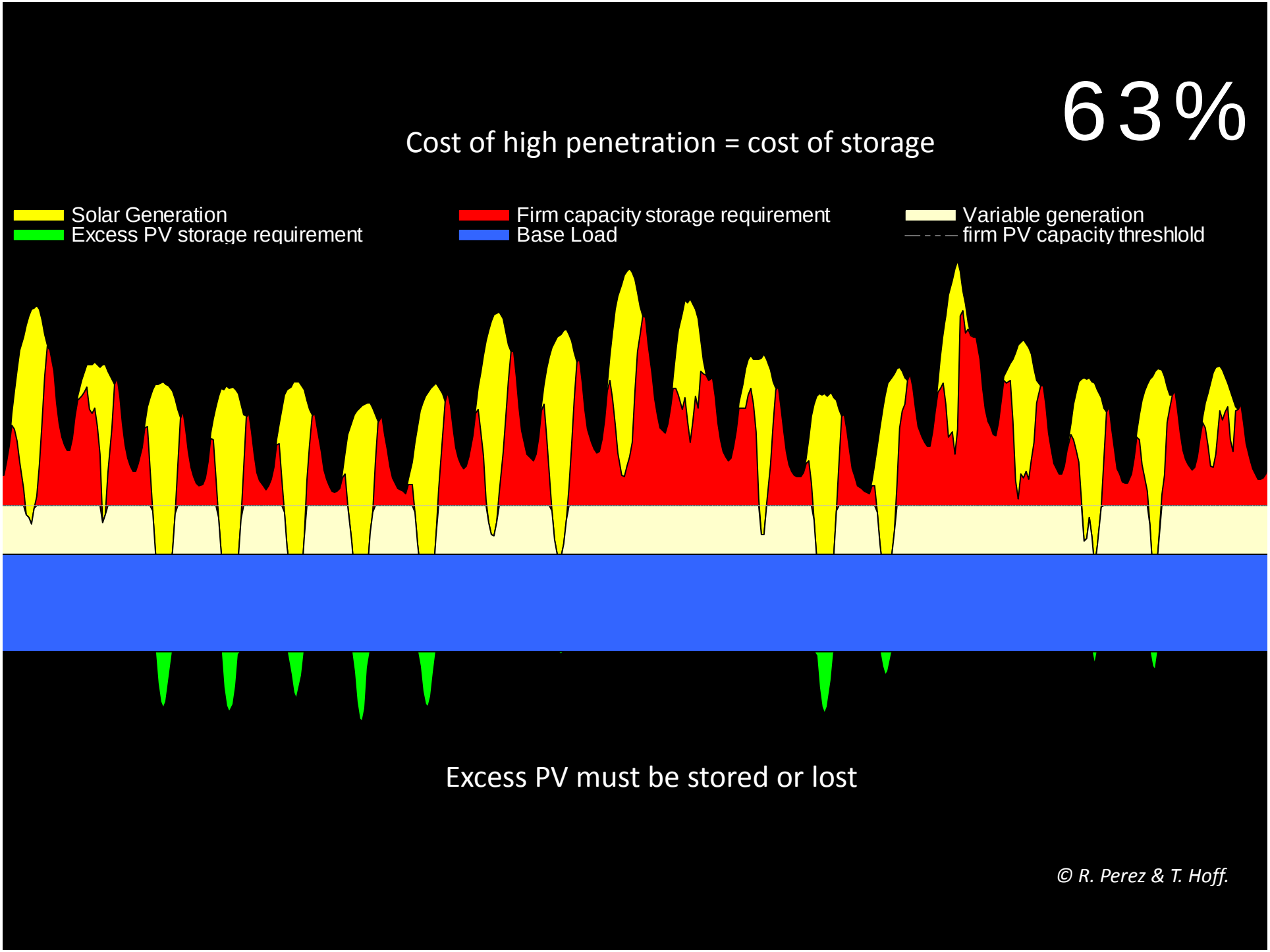

50%
Cost of high penetration = cost of storage
Solar Generation
Excess PV storage requirement
Firm capacity storage requirement
Base Load
Variable generation
firm PV capacity threshlold
Excess PV must be stored or lost
© R. Perez & T. Hoff.

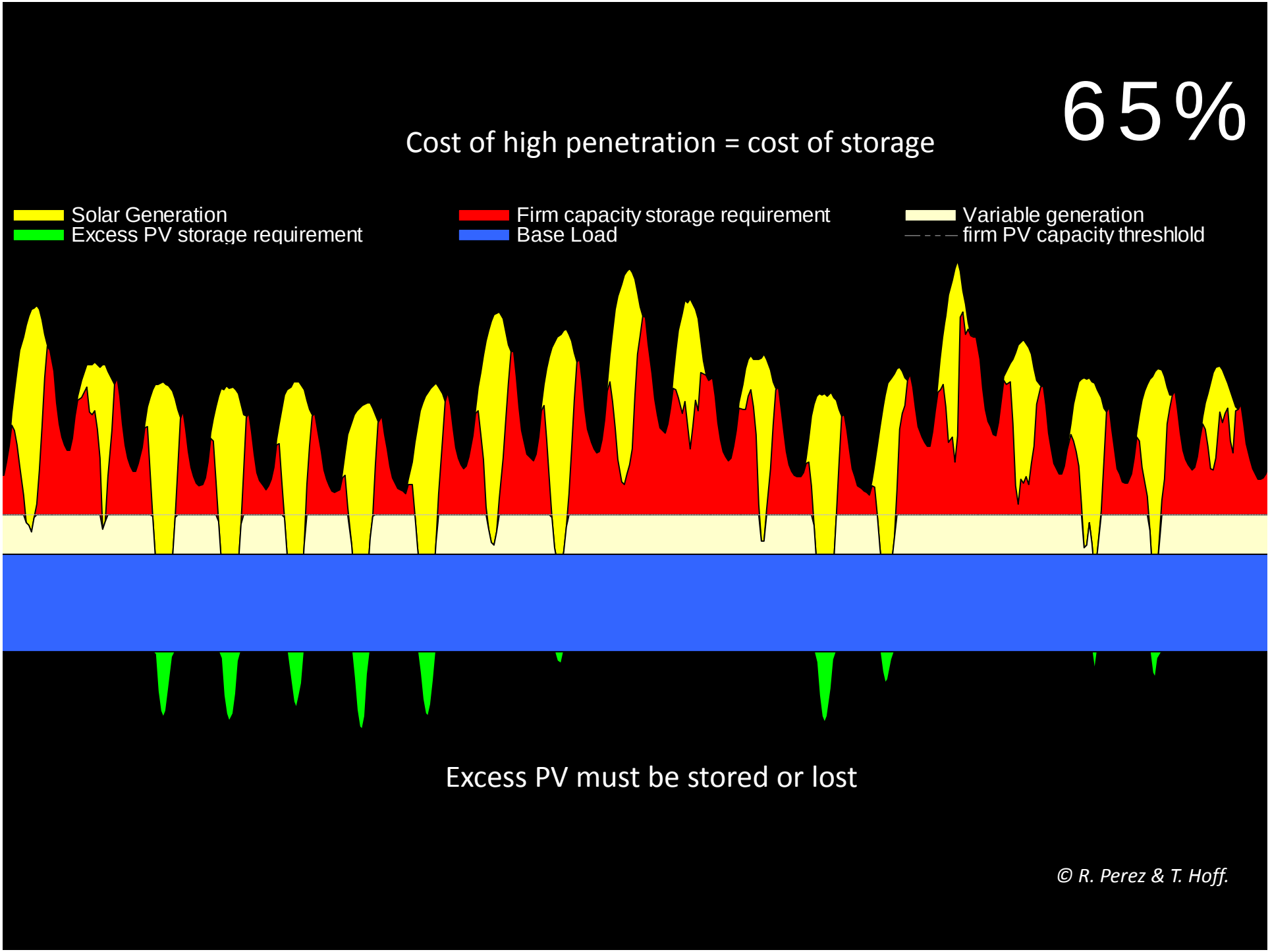

53%
Cost of high penetration = cost of storage
Solar Generation
Excess PV storage requirement
Firm capacity storage requirement
Base Load
Variable generation
firm PV capacity threshlold
Excess PV must be stored or lost
© R. Perez & T. Hoff.

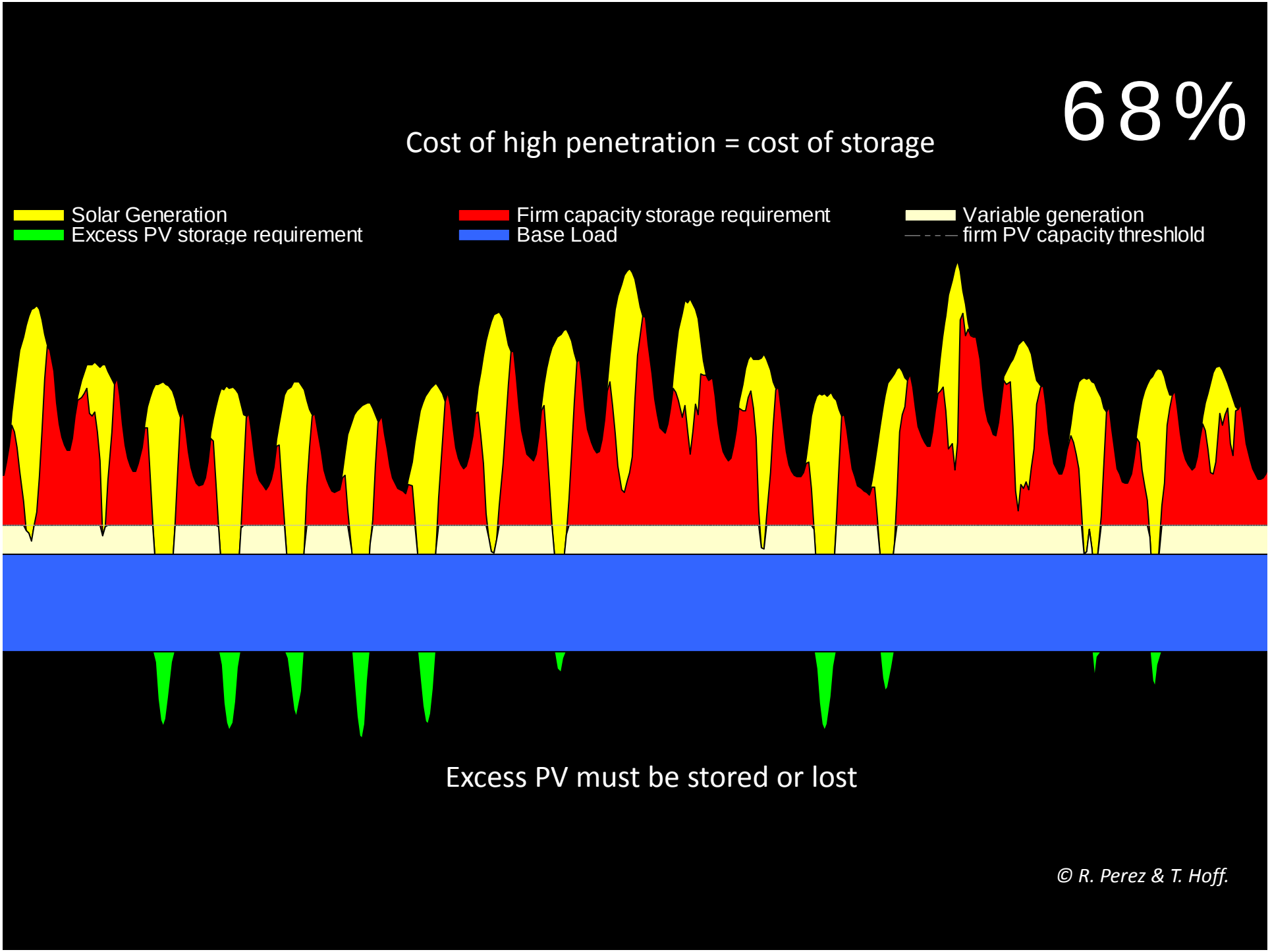

55%
Cost of high penetration = cost of storage
Solar Generation
Excess PV storage requirement
Firm capacity storage requirement
Base Load
Variable generation
firm PV capacity threshlold
Excess PV must be stored or lost
© R. Perez & T. Hoff.

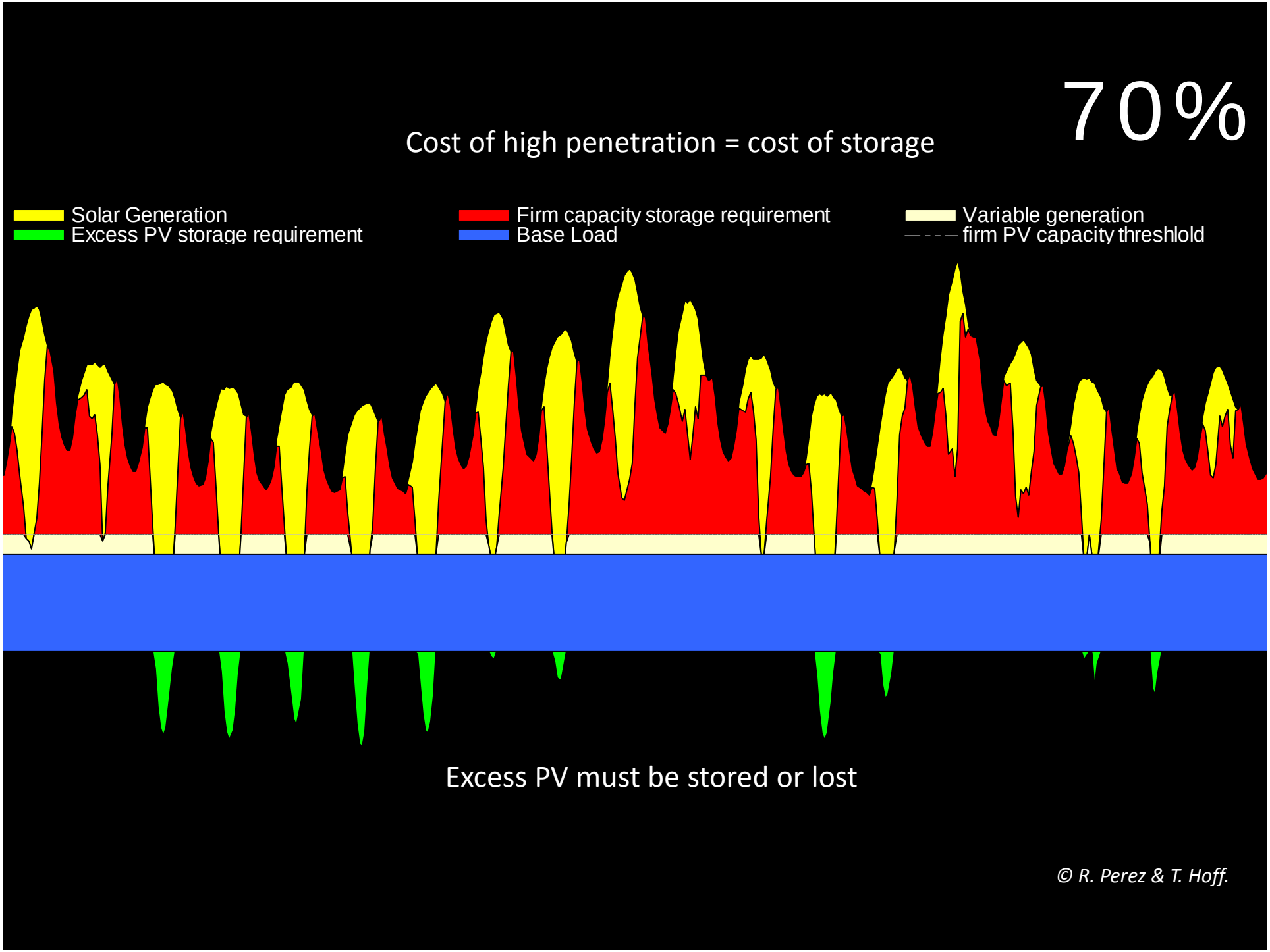

58%
Cost of high penetration = cost of storage
Solar Generation
Excess PV storage requirement
Firm capacity storage requirement
Base Load
Variable generation
firm PV capacity threshlold
Excess PV must be stored or lost
© R. Perez & T. Hoff.

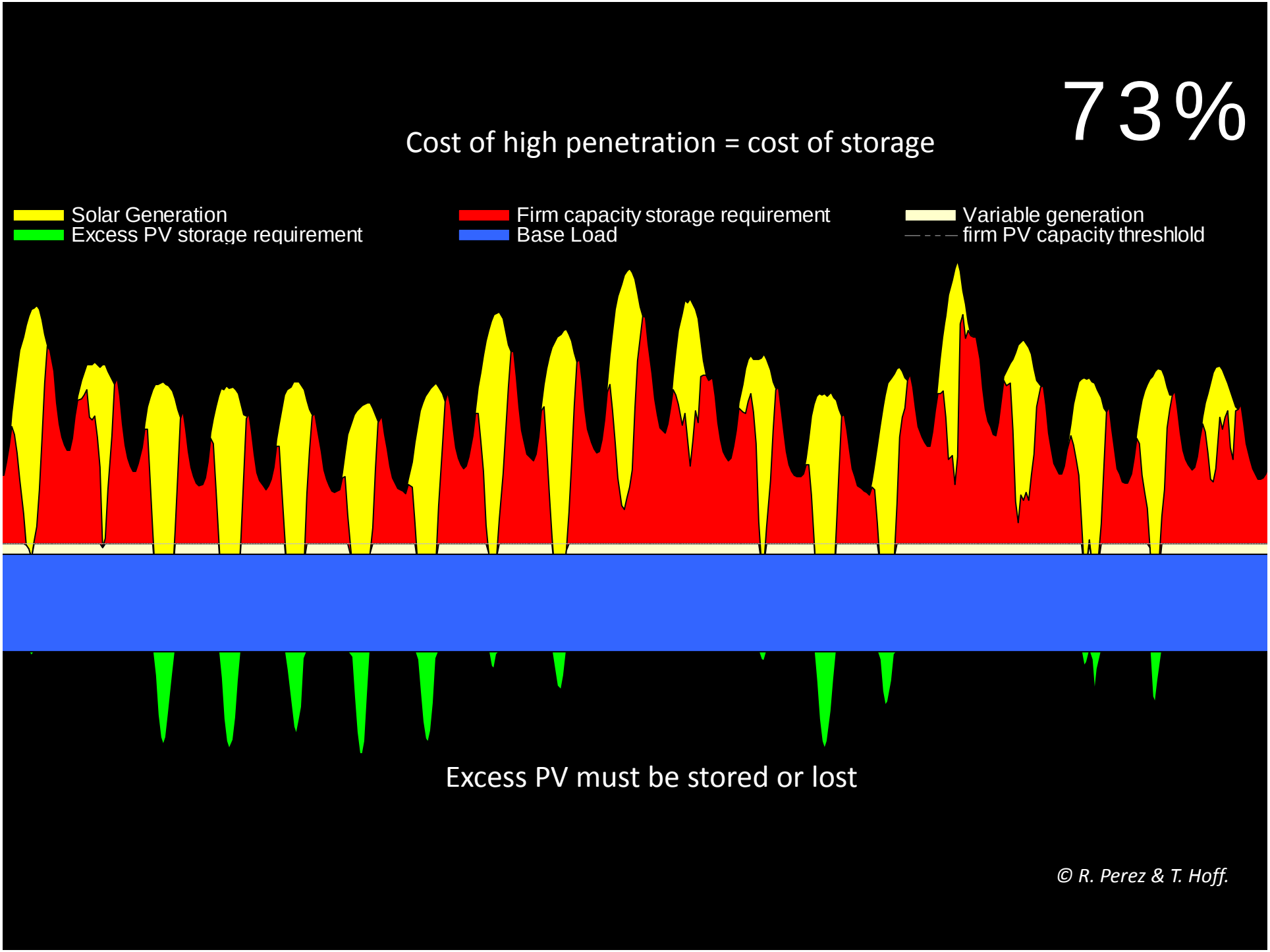

60%
Cost of high penetration = cost of storage
Solar Generation
Excess PV storage requirement
Firm capacity storage requirement
Base Load
Variable generation
firm PV capacity threshlold
Excess PV must be stored or lost
© R. Perez & T. Hoff.

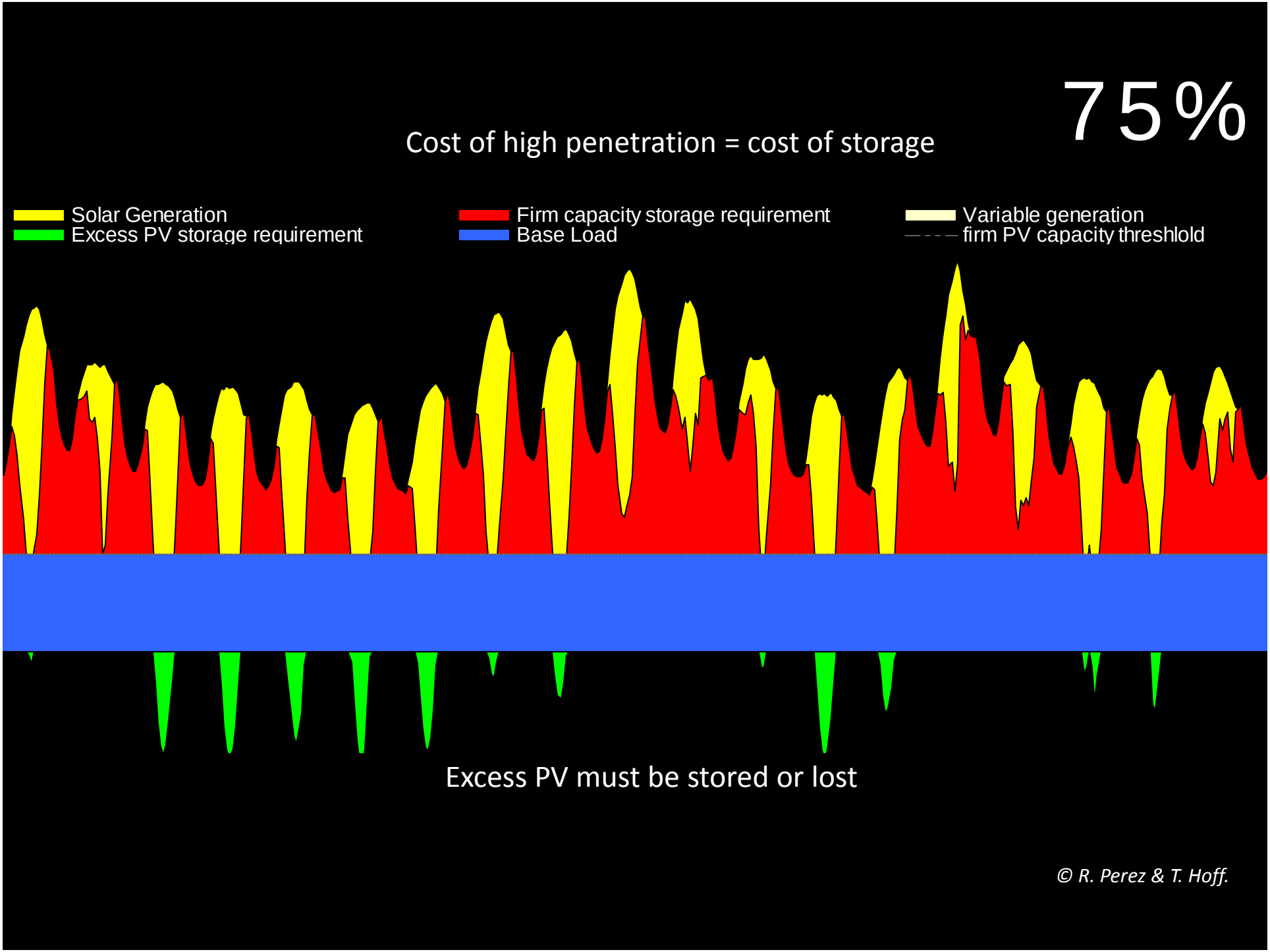

63%
Cost of high penetration = cost of storage
Solar Generation
Excess PV storage requirement
Firm capacity storage requirement
Base Load
Variable generation
firm PV capacity threshlold
Excess PV must be stored or lost
© R. Perez & T. Hoff.


65%
Cost of high penetration = cost of storage
Solar Generation
Excess PV storage requirement
Firm capacity storage requirement
Base Load
Variable generation
firm PV capacity threshlold
Excess PV must be stored or lost
© R. Perez & T. Hoff.


68%
Cost of high penetration = cost of storage
Solar Generation
Excess PV storage requirement
Firm capacity storage requirement
Base Load
Variable generation
firm PV capacity threshlold
Excess PV must be stored or lost
© R. Perez & T. Hoff.


70%
Cost of high penetration = cost of storage
Solar Generation
Excess PV storage requirement
Firm capacity storage requirement
Base Load
Variable generation
firm PV capacity threshlold
Excess PV must be stored or lost
© R. Perez & T. Hoff.


73%
Cost of high penetration = cost of storage
Solar Generation
Excess PV storage requirement
Firm capacity storage requirement
Base Load
Variable generation
firm PV capacity threshlold
Excess PV must be stored or lost
© R. Perez & T. Hoff.


75%
Cost of high penetration = cost of storage
Solar Generation
Excess PV storage requirement
Firm capacity storage requirement
Base Load
Variable generation
firm PV capacity threshlold
Excess PV must be stored or lost
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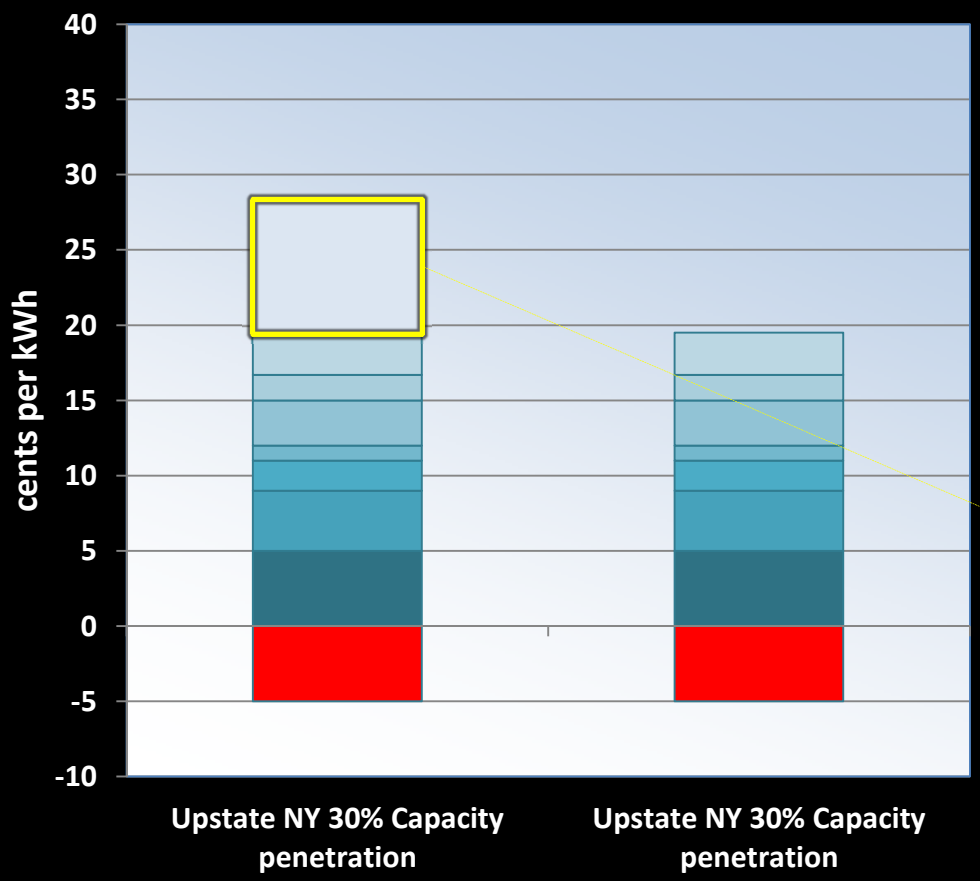
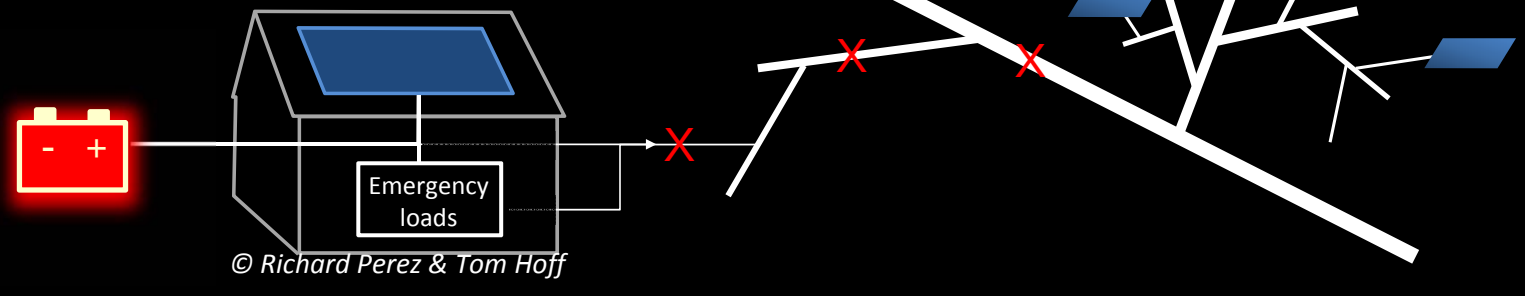
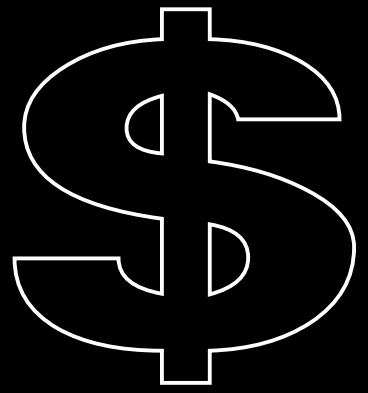
VALUE DEPENDS ON SYSTEM SPECS



- Outage recovery capability
- penetration cost
- economic development
- societal value
- environment
- security
- Market Price Supression
- Fuel Price Risk Mitigation
- Distribution Capacity Value
- Loss Savings
- Transmission Capacity Value
- Energy Value



VALUE DEPENDS ON LOCATION
VALUE DEPENDS ON PENETRATION
VALUE DEPENDS ON SYSTEM SPECS



PV REMUNERATION

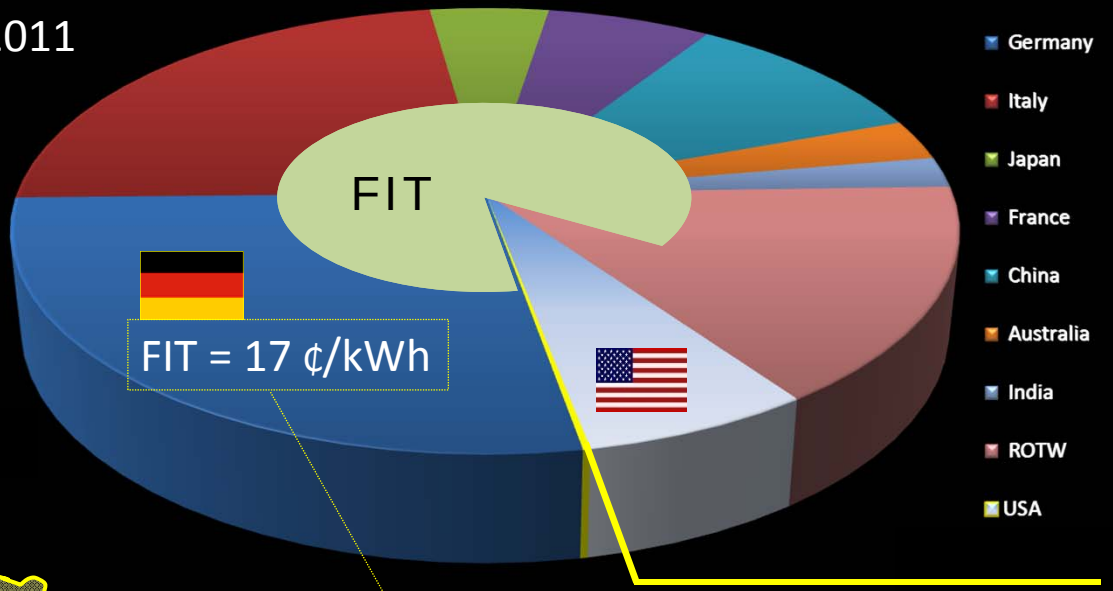
IT SHOULD DEPEND ON: LOCATION, PENETRATION & SPECS

10% City real estate tax abatement
25% State tax Credit (residential)
30% Federal tax Credit
$ 1.00 / Watt from NYSERDA
~ 5 yr. Accel. Depreciation (business)
Net metering (15+ cents per kWh)

Installations in 2011
27 GW

Q4'12 Installed price:
(10-100 kW systems)

FIT world: $2.25/W

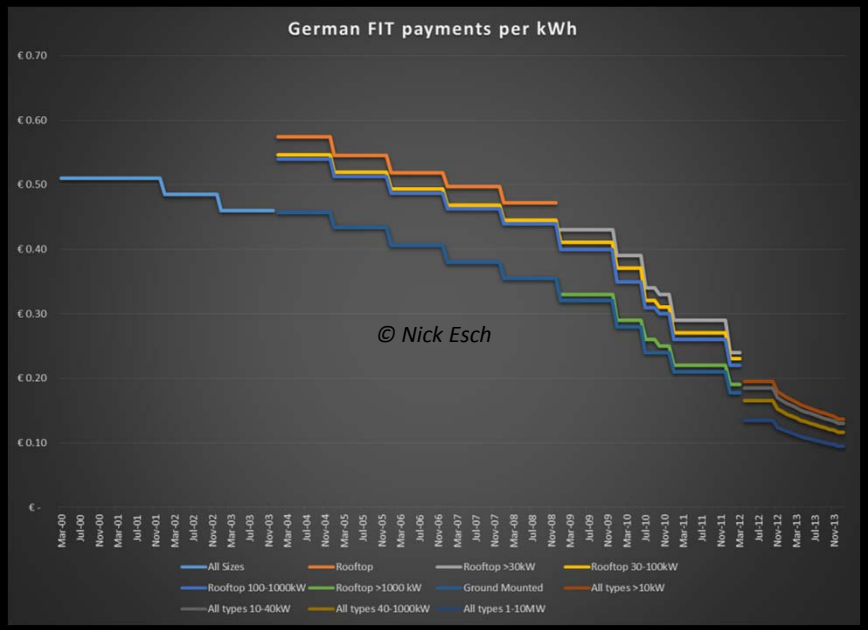


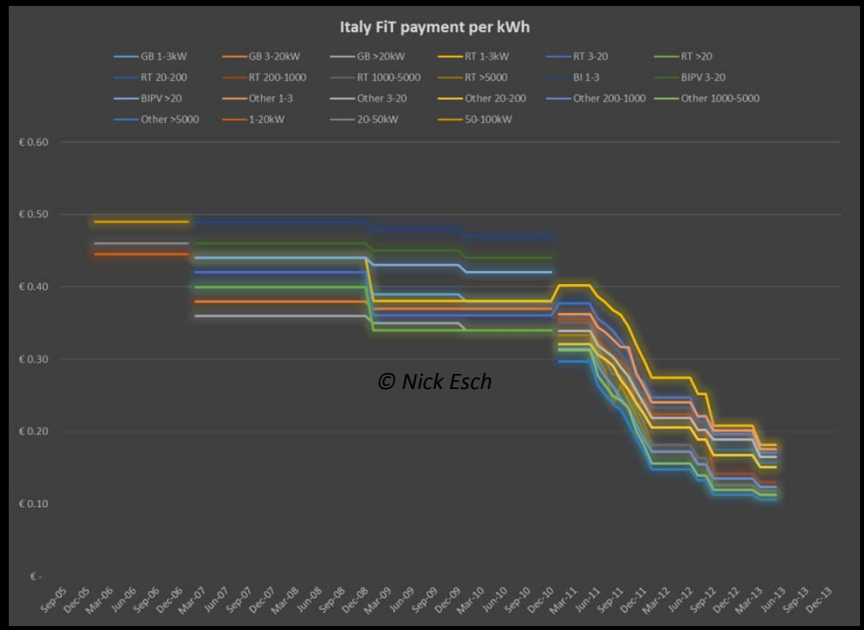
FIT = 17 ¢/kWh

10% City real estate tax abatement
25% State tax Credit (residential)
30% Federal tax Credit
$ 1.00 / Watt from NYSERDA
~ 5 yr. Accel. Depreciation (business)
Net metering (15+ cents per kWh)

ISSUES with FiT

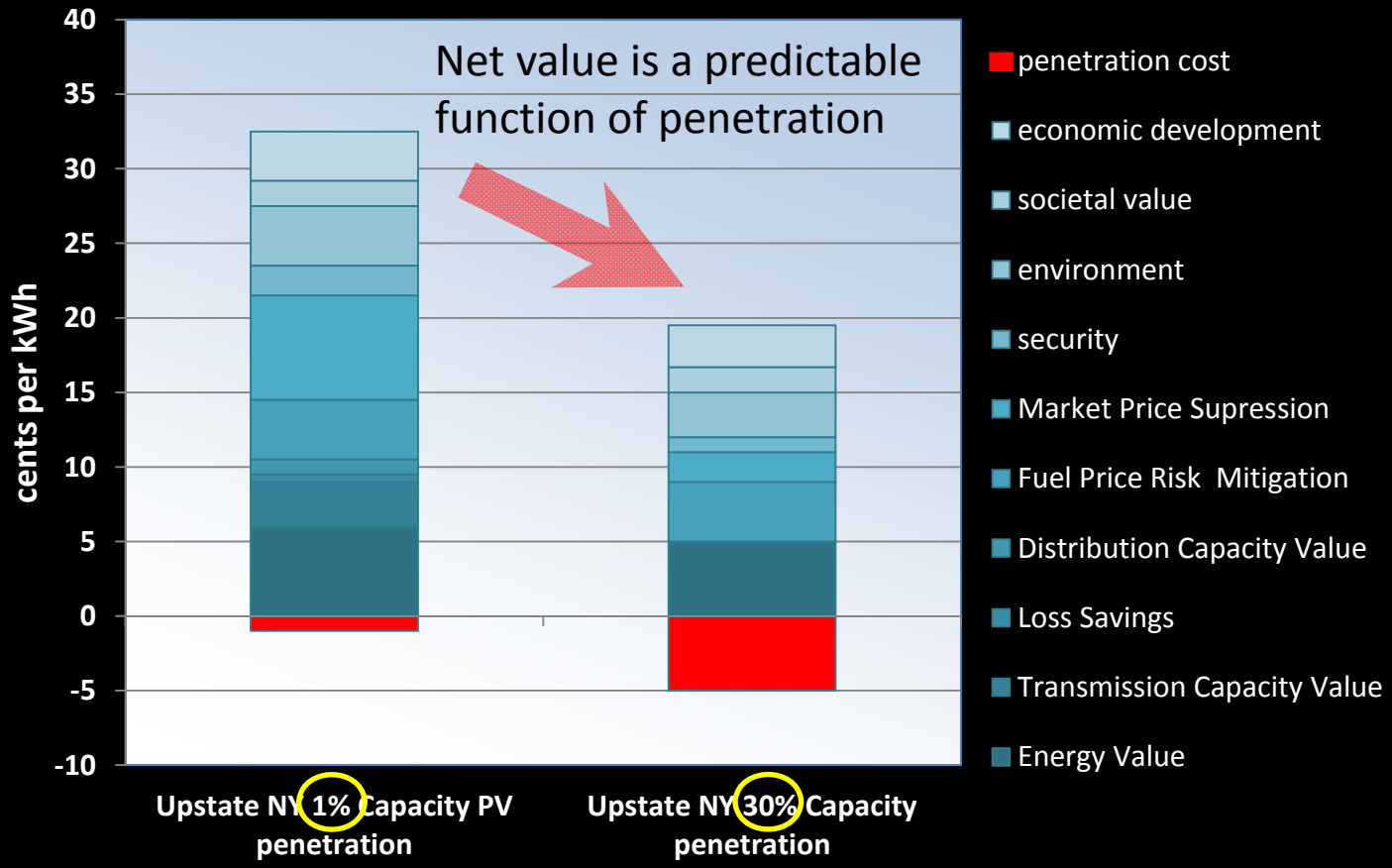
- Cost based – designed to make a technology cost-effective
  - i.e., the more expensive the technology the higher the FiT
    - Many take issue with this
  - Adjustment following cost changes are often abrupt
- Limited or no market controls
  - Risk of overbuilding, non-optimal deployment, boom/bust cycles which can be extreme, e.g., Spain





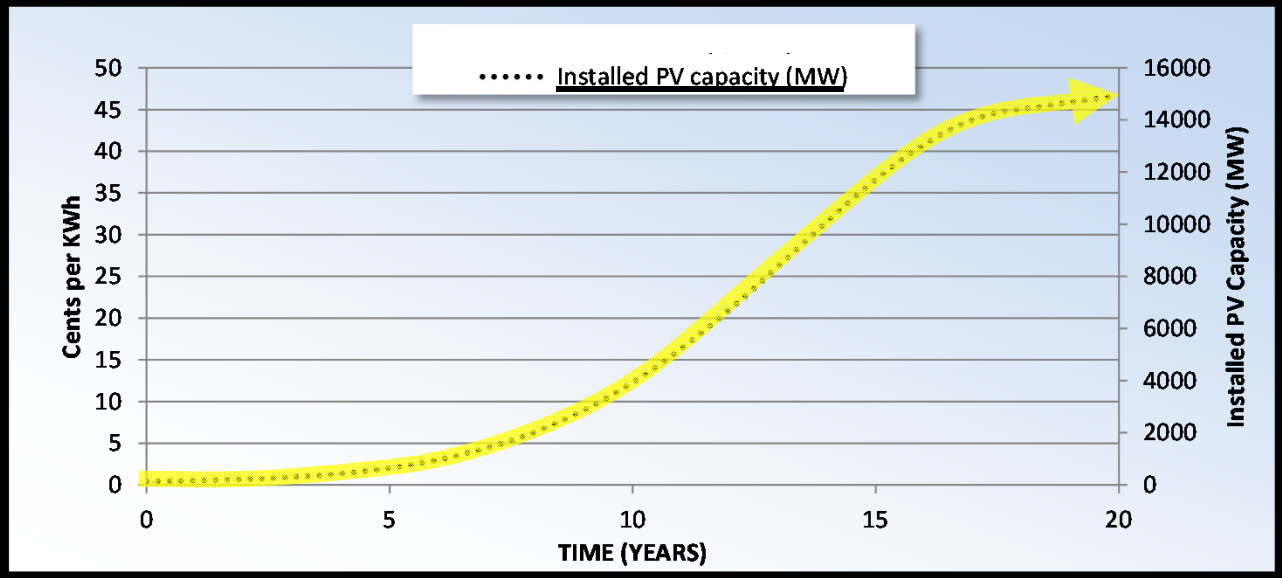
Introducing the SmartFiT
Long term Perspective

LOCATION, PENETRATION & SPECS



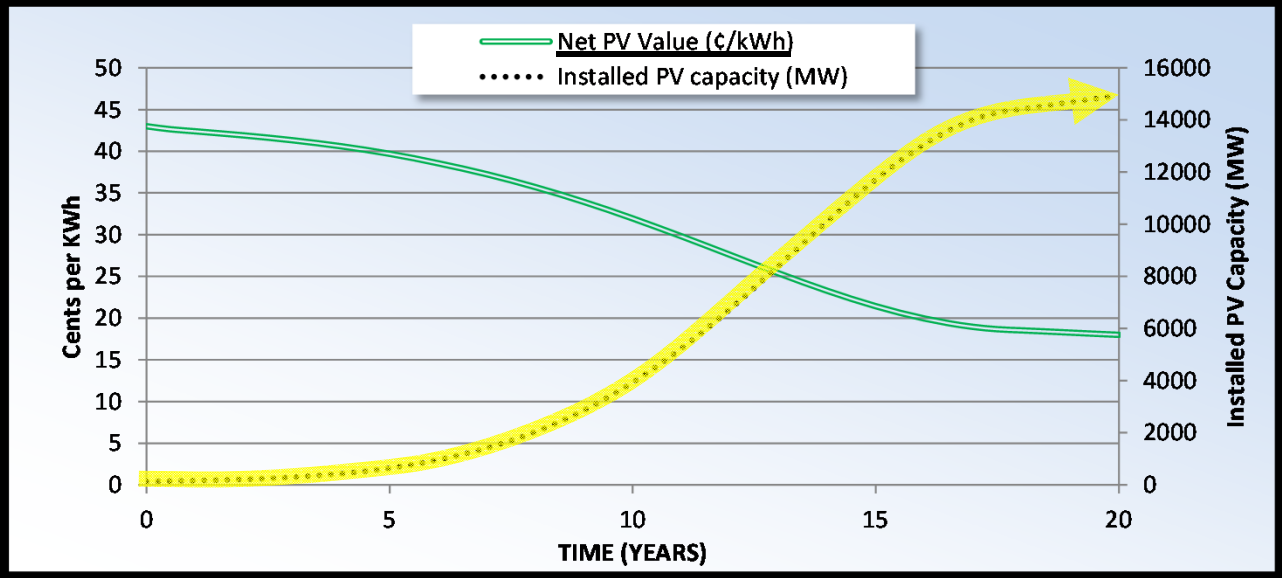
Introducing the SmartFiT
Long term Perspective

LOCATION, PENETRATION & SPECS



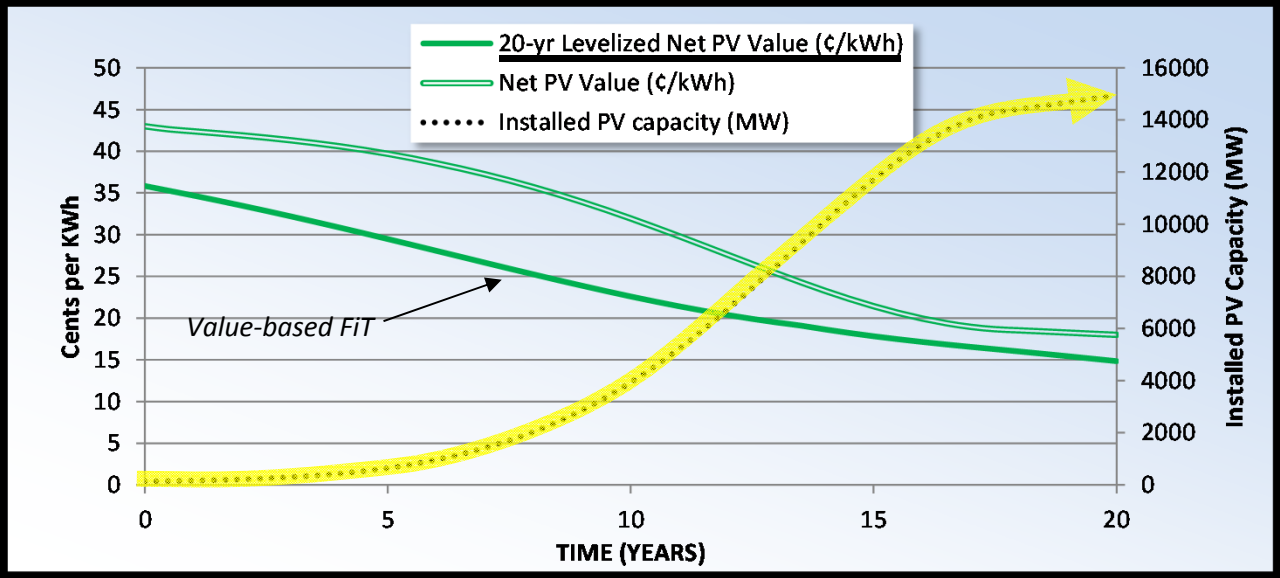
Introducing the SmartFiT
Long term Perspective

LOCATION, PENETRATION & SPECS



Introducing the SmartFiT
Long term Perspective

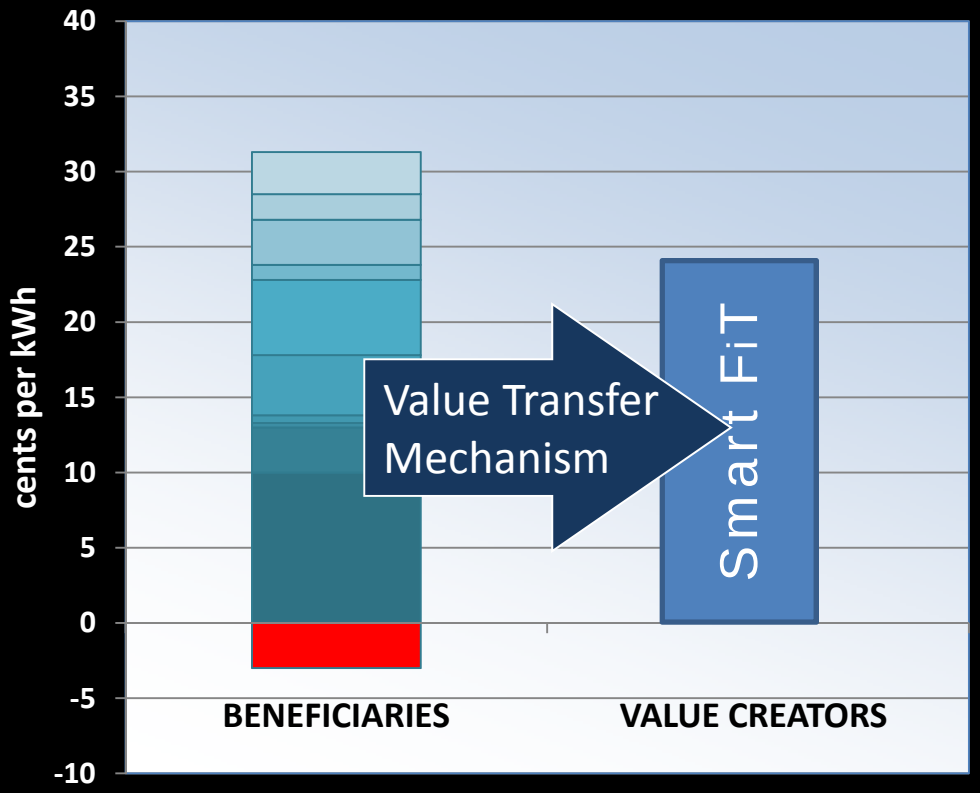
LOCATION, PENETRATION & SPECS



SmartFiT

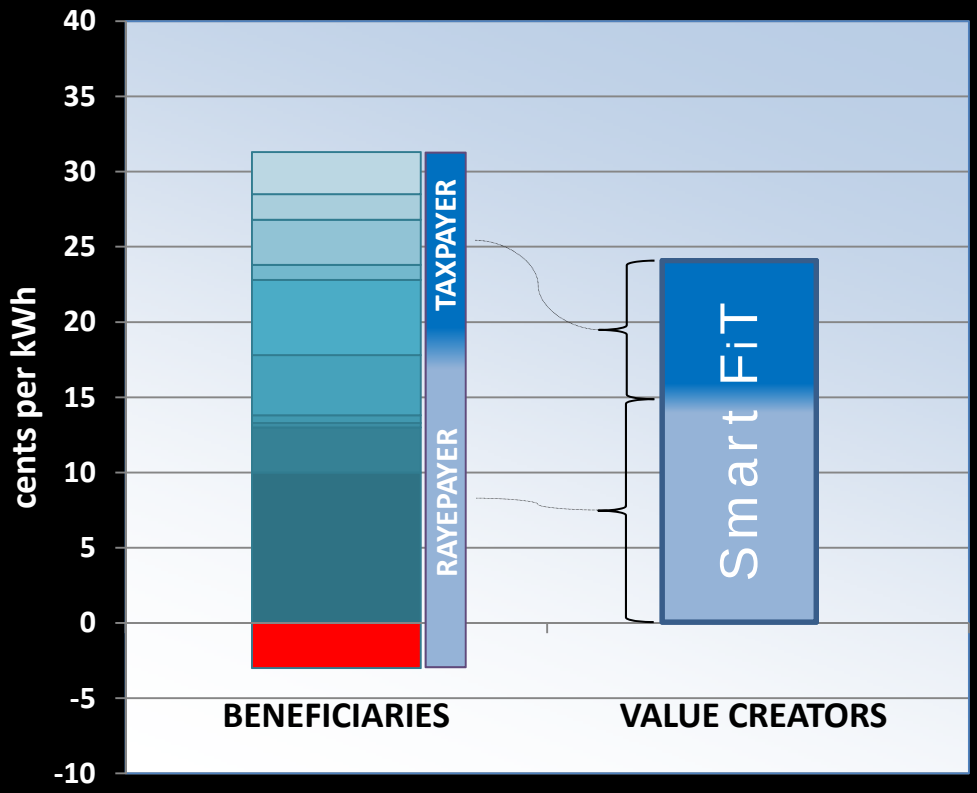
Introducing the SmartFiT
Long term Perspective

- Not a subsidy



Introducing the SmartFiT
Long term Perspective

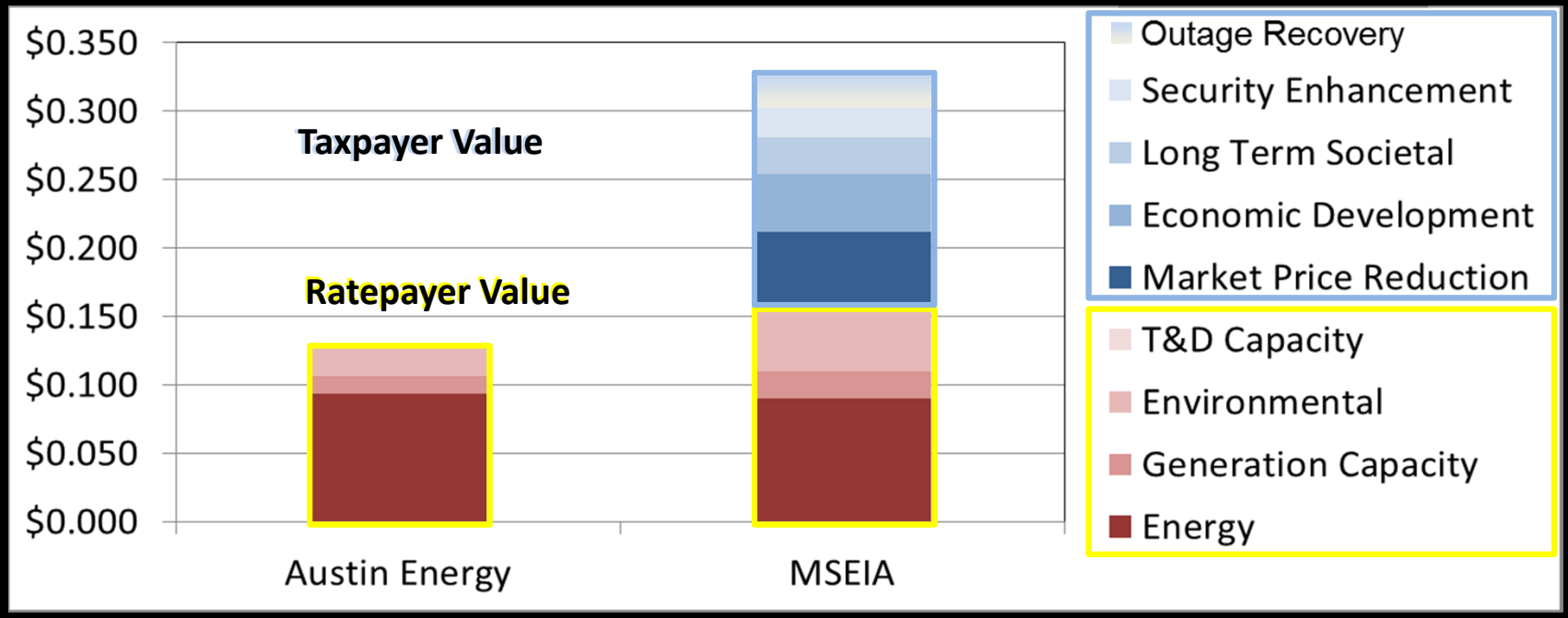
- Not a subsidy
- Who should pay for the Smart FiT



Introducing the SmartFiT

LOCATION, PENETRATION & SPECS

Precursor programs: Austin, NJ/MSEIA (proposed), Minnesota



Introducing the SmartFiT

LOCATION, PENETRATION & SPECS

REMUNERATION = NET VALUE