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EmPowering the Power Grid through ICT

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University of Groningen (NL)

Energy

✦ Electricity is a utility…


BENETEAU


PLUS
state
€ 7.67
0000000
e power
MENNEKES
16A 6h 200-250V ~
2P+E
Typ 905
MENNEKES


NISSAN
64-RBP-9
NL
VOLVO
00-TFF-1
NL
38-HJK-2

Top 10 countries by market share of new car sales in 2013 by electric-drive segment(1)[316]					
Ranking	Country	PEV market share(%)	Ranking	Country	BEV market share(%)
1	Norway	6.10%	1	Norway	5.75%
2	Netherlands	5.55%	2	Netherlands	0.83%
3	Iceland	0.94%	3	France	0.79%
4	Japan	0.91%	4	Estonia	0.73%
5	France	0.83%	5	Iceland	0.69%
6	Estonia	0.73%	6	Japan	0.51%
7	Sweden	0.71%	7	Switzerland	0.39%
8	United States	0.60%	8	Sweden	0.30%
9	Switzerland	0.44%	9	Denmark	0.28%
10	Denmark	0.29%	10	United States	0.28%

Note: (1) Market share of highway-capable electric-drive vehicles in the corresponding segment as percentage of total new car sales in the country in 2013.

...or is it a commodity?


FREE
CHARGING
powered by
Innergie
brought to you by
CHANGI
G1
Apple
G6
G11
G2
G7
G4
G5

Claim

the commodification of energy passes through ICT

How did we get here?

The beginning

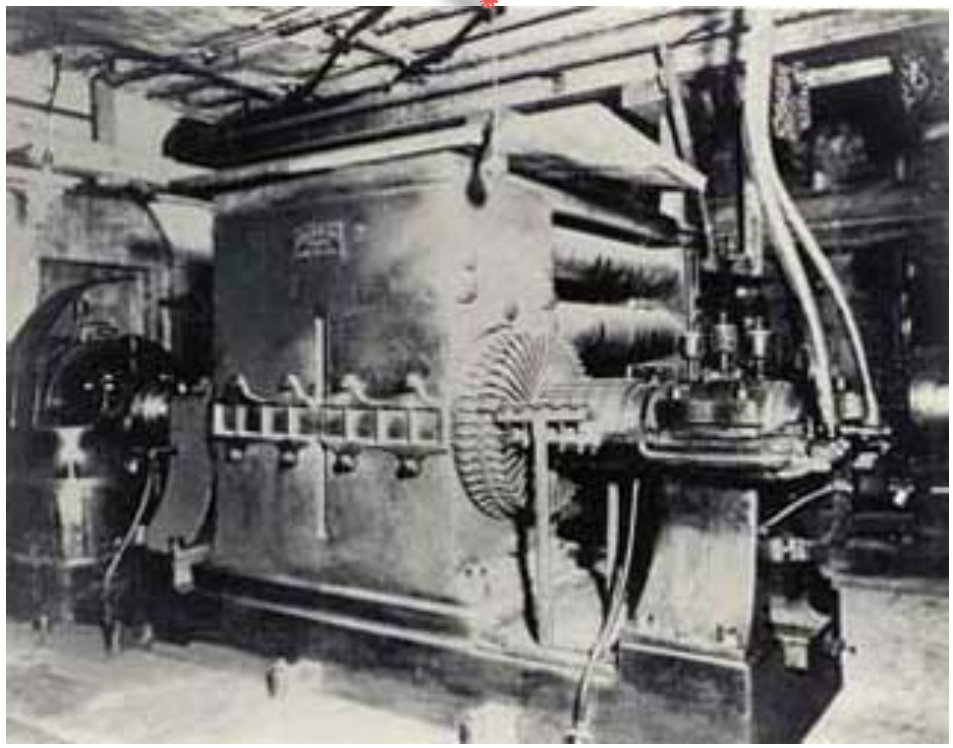
Morgan Mansion at Madison Ave. & 36th St., NYC.

1881

The beginning

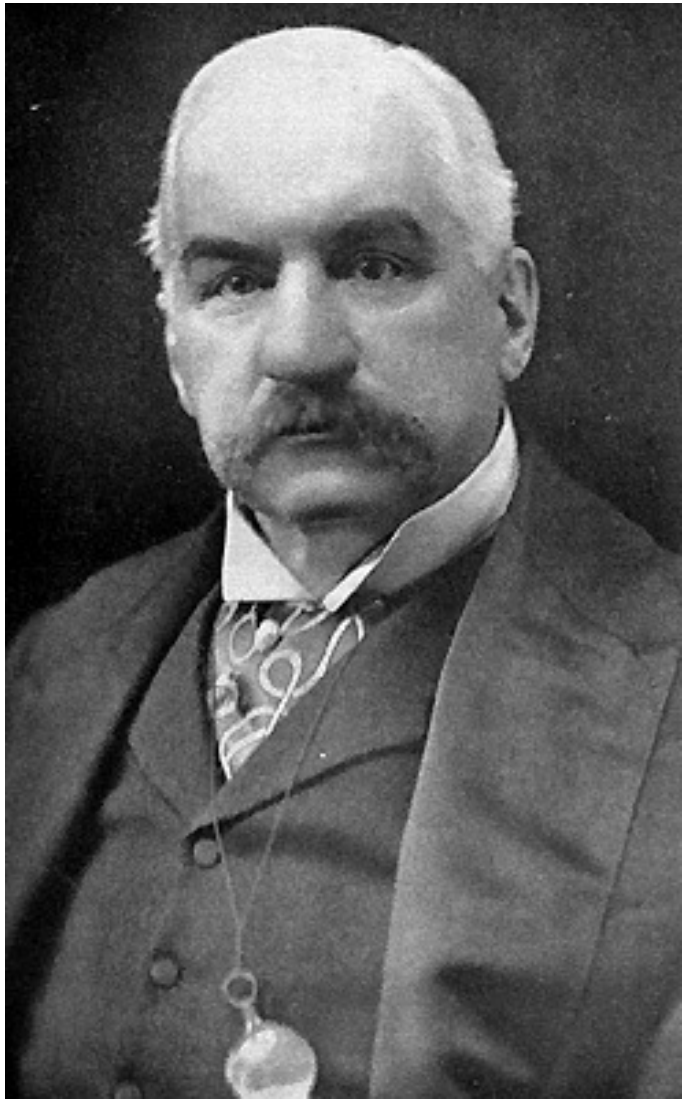
1881

Morgan Mansion at Madison Ave. & 36th St., NYC.



J. P. Morgan

- In 1881, Morgan's house became the world's first electrified residence, when Thomas Edison wired the structure with incandescent lights and installed a steam engine and dynamo in the back yard to provide power. The following year, Edison wired Morgan's office building, and for years Morgan was the primary investor in Edison's projects.



Then Global

"every home, every factory and every transportation line will obtain its energy from one common source, for the simple reason that that will be the cheapest way to produce and distribute it"

-Samuel Insull (1859–1938)

and back?

Generation

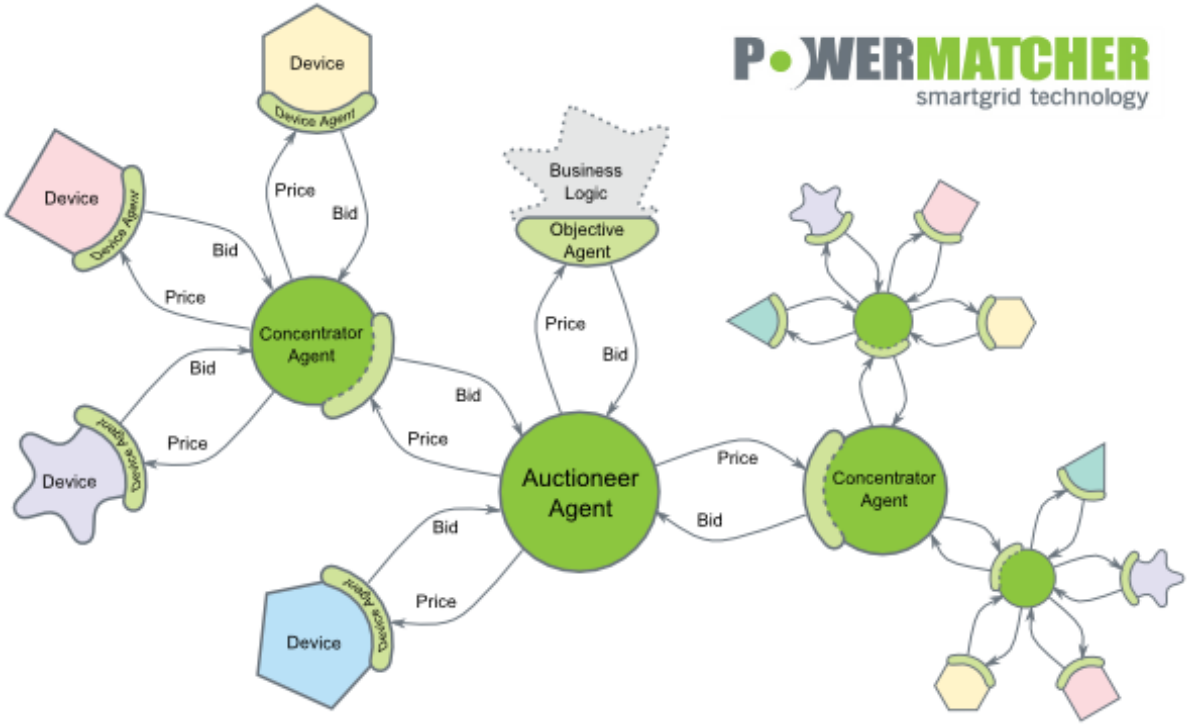
Roof solar panel 125 W per module

Wind installation 1.4KW

Vaillant EcoPOWER 1.0 (Honda mCHP) 1KWe

Energy distribution

PowerMatcher



http://youtu.be/Zz4OpVwYWYE

http://youtu.be/Zz4OpVwYWYE

data generation potential

About a meter

0 bit/y

Smart?

In The Netherlands 1 reading every two months

Assume 200 bytes per reading

9.600 bit/y

More data

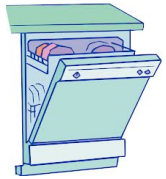
Messages could be bigger than 200 bytes, but let's disregard it for now

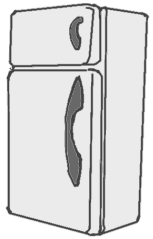
1 reading every 15 minutes is likely

42.075.888 bit/y

Smart everything

Appliances in the home are also getting smart...

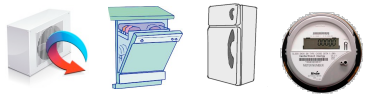




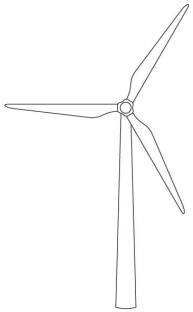
Let's assume 20 smart appliances per home with 15 minutes readings

883.593.648 bit/y

You promised Green!



Renewable installations generate also data



Let's assume 2 installations per home with 15 minutes reading

967.745424 bit/y

What about storage?

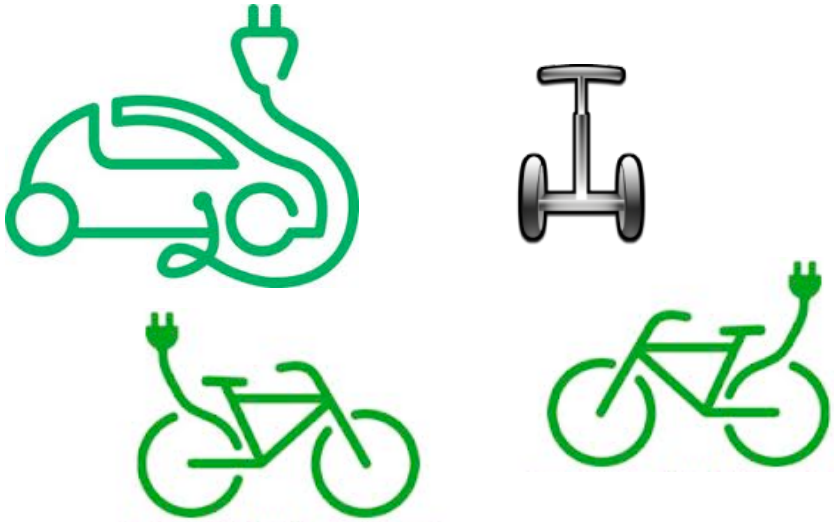
Renewables are inconstant in generating, thus we will need storage

Let's assume 1 battery set per home with 15 minutes reading

1.009.821.312 bit/y

And mobility?

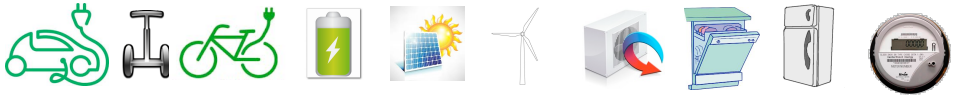
Let's assume a car per household, 0.75 eBikes/personal mobility per household.



Let's safely assume 1.000 bytes per day

1.014.931.312 bit/y

More data?



Weather information with km² precision and more

Social information

Social networks

Let's ignore this for now in our computation!

1.014.931.312 bit/y

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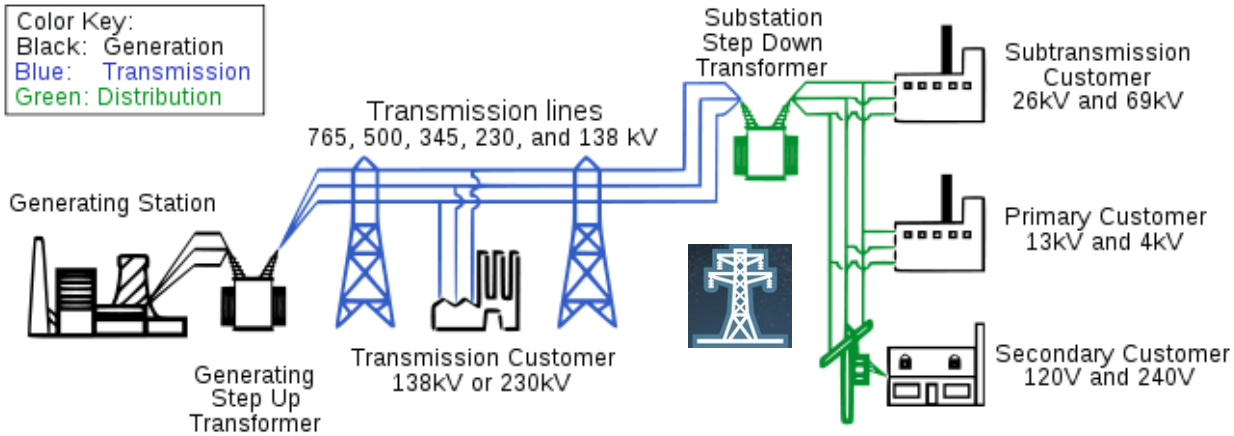
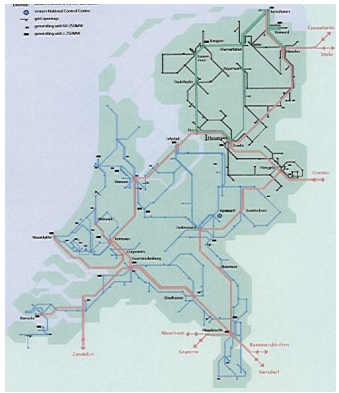
8 million households

7.944.222.604.983.200 bit/y

No home is an island!



Nodes HV (380/220kV)	36	1Mb/node/h
Nodes MV/LV	155.000	1Kb/node/h
Lines HV (380/220kV)	2.685 km	100 byte/km/h
Lines HV (50/110/150kV)	9.836 km	100 byte/km/h
Lines MV (3-25kV)	101.275 km	10 byte/km/h
Lines LV (0.4kV)	195.706 km	1 byte/km/h



7.957.780.320.747.680 bit/y

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It's a small world

X.XXX.XX7.957.780.320.747.68 bit/y

related research in Groningen

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Bernoulli building

The Bernoulliborg, located on the Zernike Complex (Nijenborgh 9), is a new (2008) building of the University of Groningen.

Floor area: 12.000 / 8295 Nett

Number of staff: 307

Students capacity: 500

Number of offices: 180

Number of meeting rooms: 8

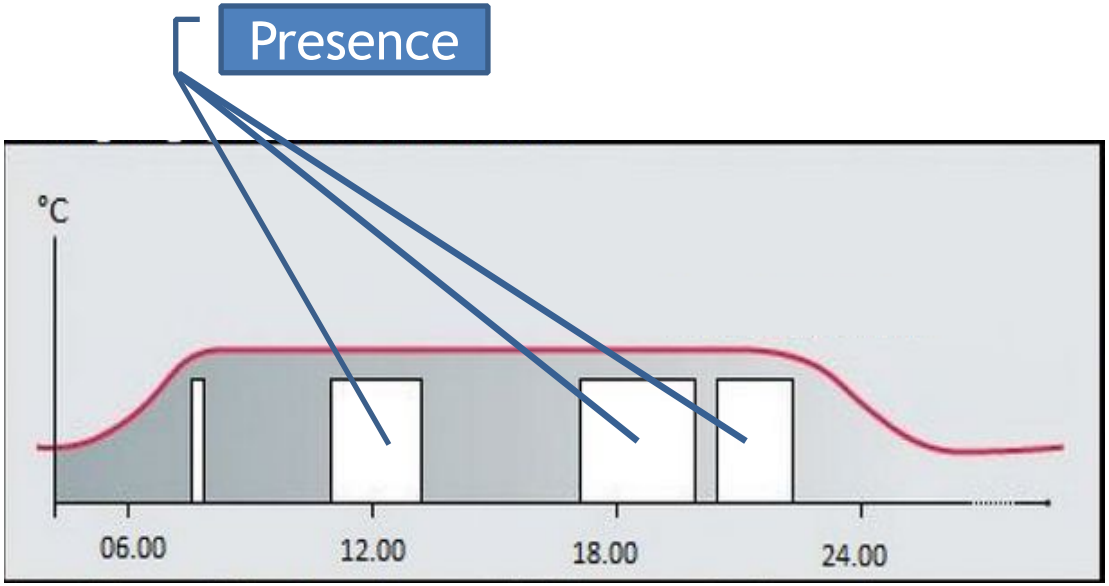
Number of lecture rooms: 16

Number of social corners: 6

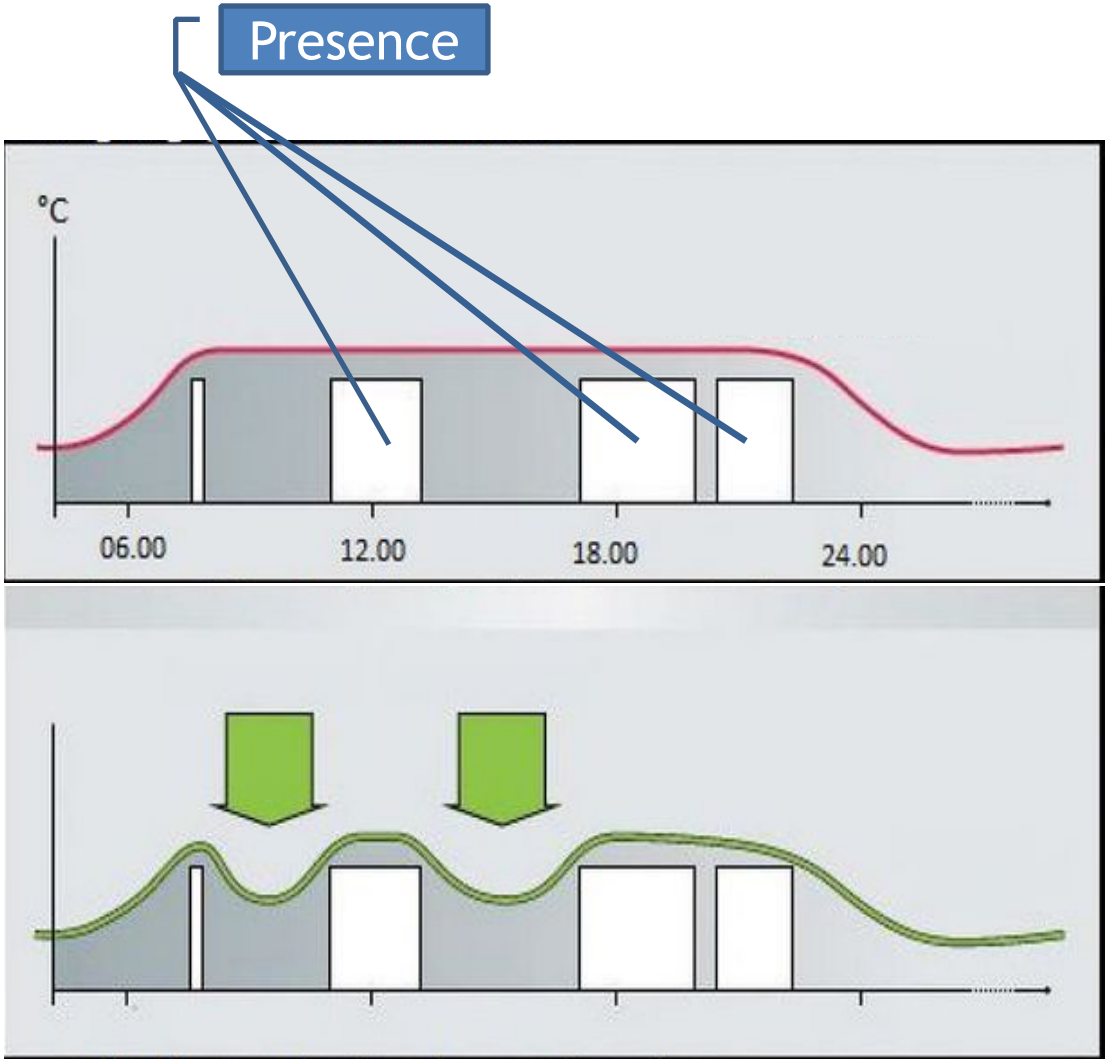
Annual electricity consumption:
1,396,276 kwh (2011)
1,359,821 kwh (2012)

User’s presence

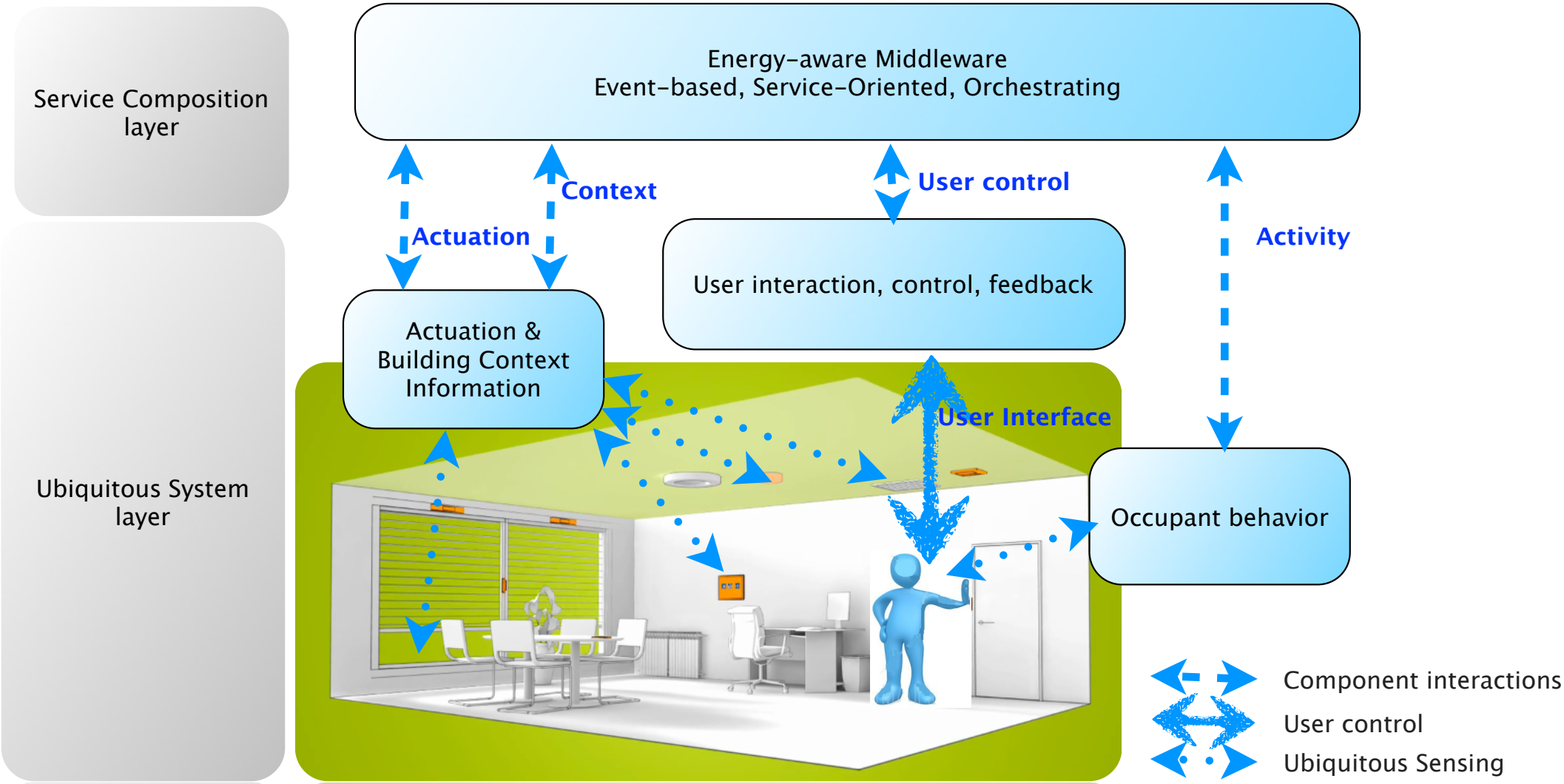
User's presence



User's presence



Human in the loop



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Activity Recognition

1) Consumption measurement

Purpose:

Monitoring (and controlling) personal consumption

Location:

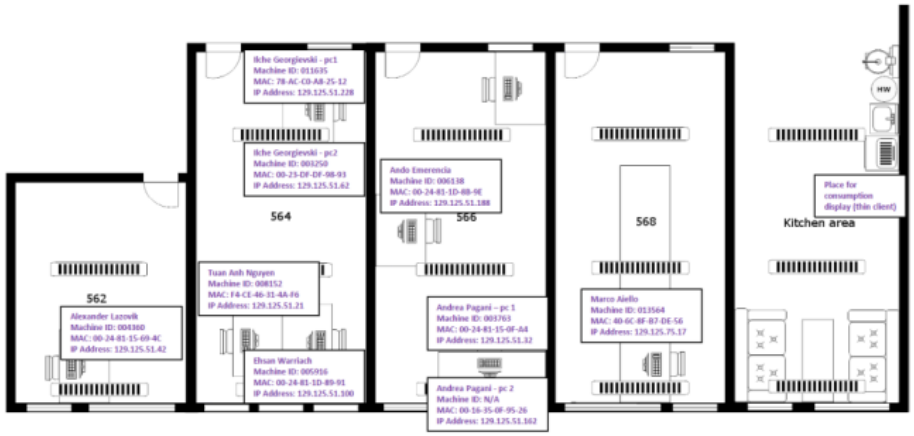
Bernoulli building, 5th floor

Scale:

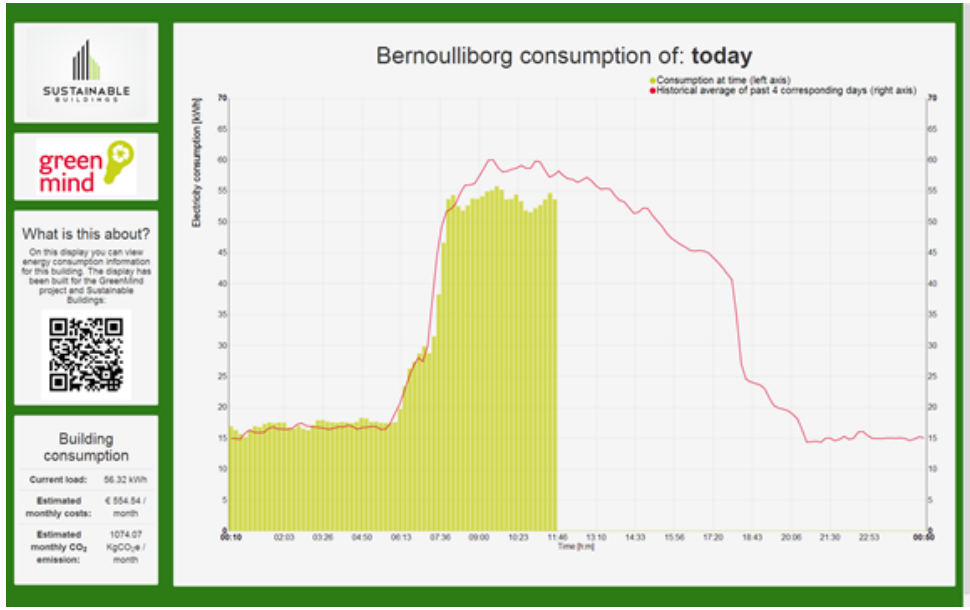
12 areas (rooms)

Devices:

45 sensors



2) Consumption Display



Purpose:

Showing common electricity consumption

Location:

BB 5th floor, CS social corner

Scale:

1 location

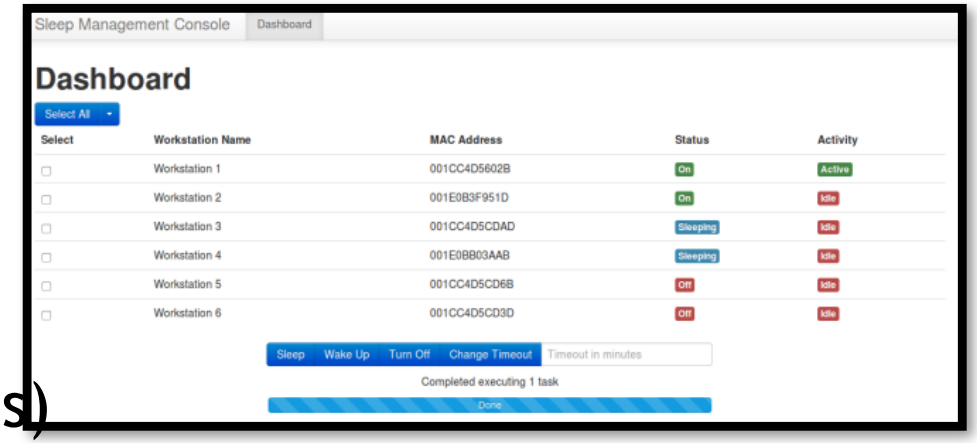
Devices:

1 live-display (also available on web interface)

3) Computer Sleep solution

Purpose:
Monitoring and controlling PC consumption in a controlled environment

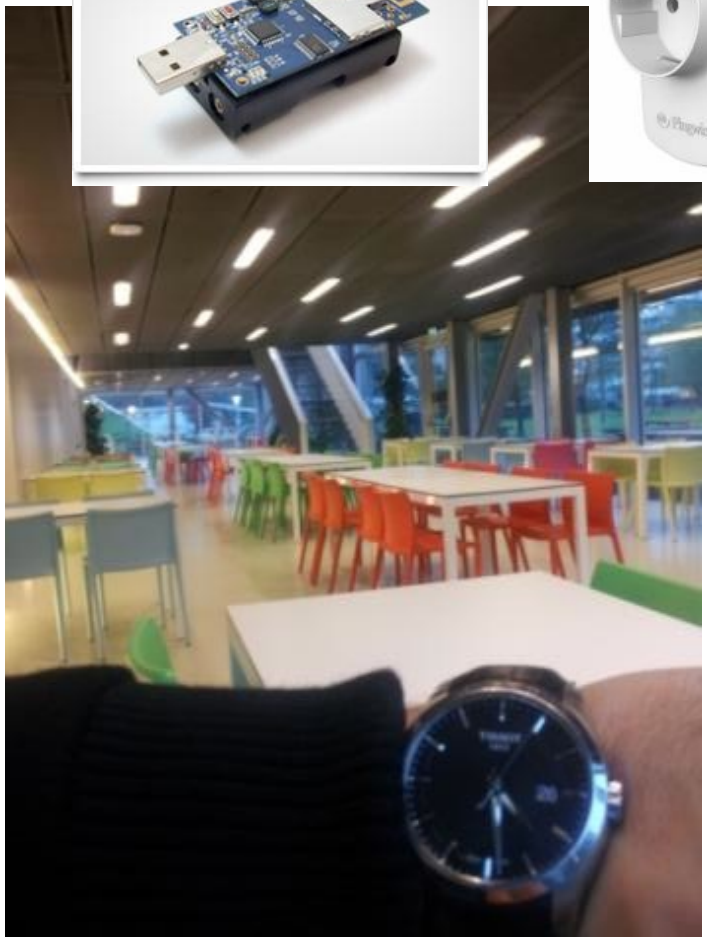
Location:
BB 5th floor



Scale:
1 lab
(next step, scaling-out to 200 rooms)

Devices:
10 PCs
(next step, scaling-out to 300 PCs)

4) Lighting control

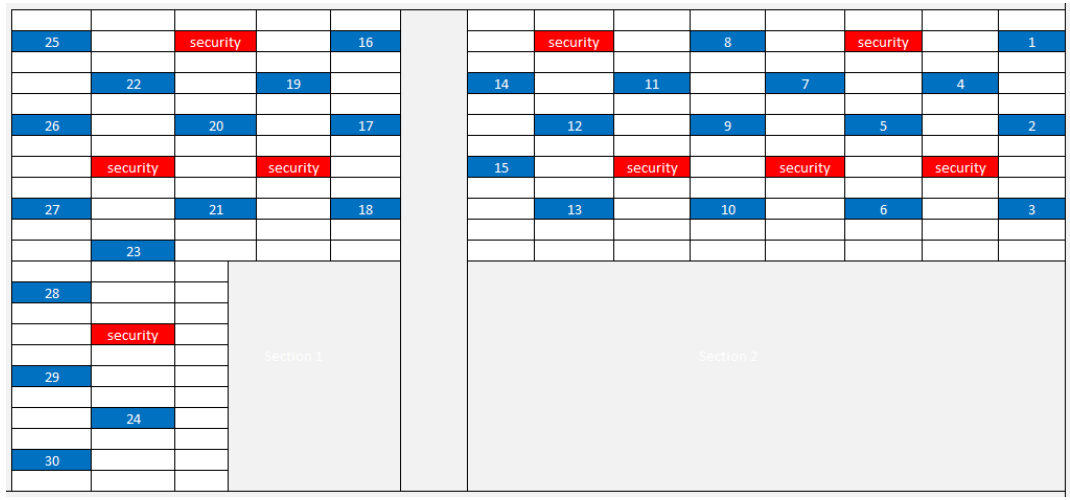


Purpose:
Monitoring and controlling common consumption

Location:
BB restaurant at the ground floor

Scale:
1 large room

Devices:
30+ sensors/actuators



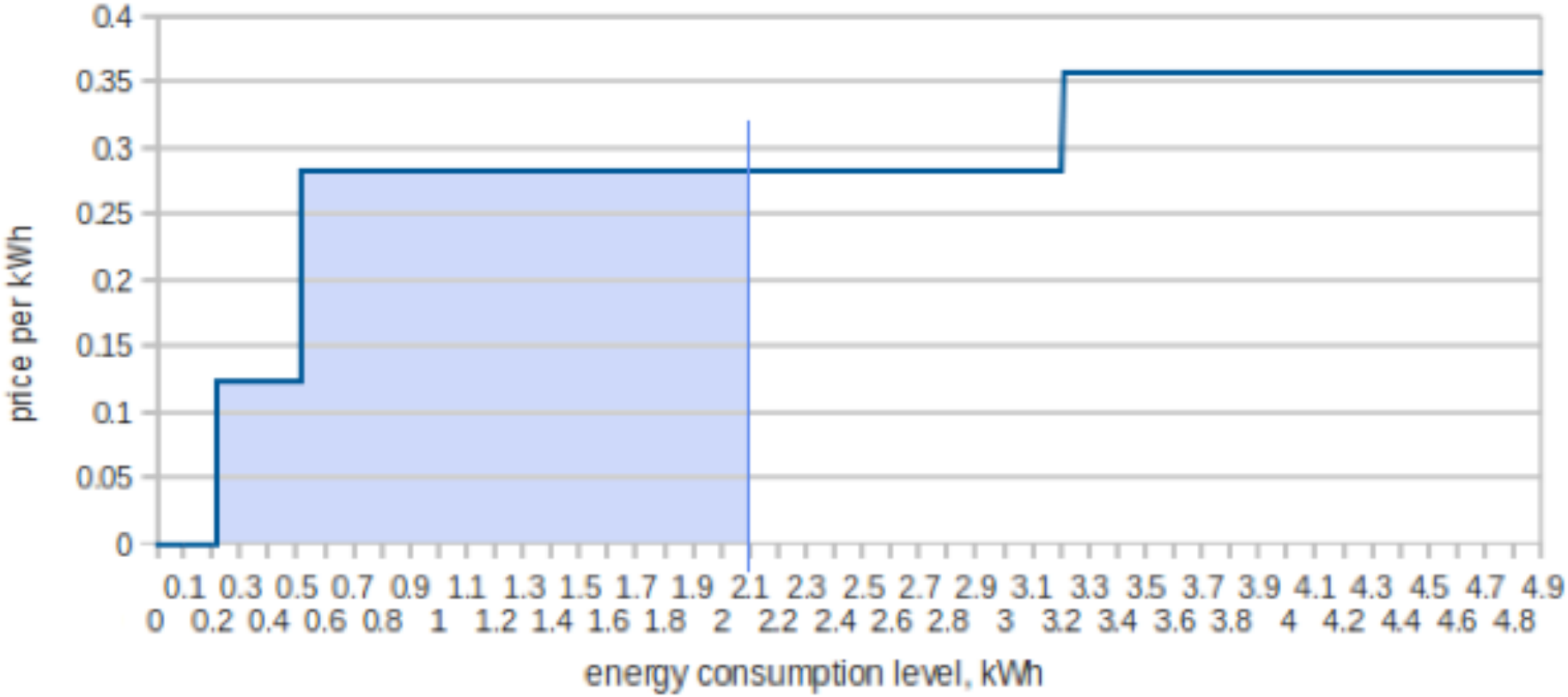
in turn affecting the distribution grid

Driving decisions:

1) Pricing Signals
2) Control from the infrastructure
3) Social pressure, sustainability

Provider	Energy supply	Price per kWh
Internal Wind Turbine	0.214292	0.0
Internal Solar Panel	0.302314	0.122916
COMED	2.755946	0.282973
ATSI	3.154828	0.357123
AEP	2.411659	0.360658
more providers ...		

Table 2: Example of energy providers and prices.




Profinox
POWER LEVEL
X2
PROG
STOP/ RESET
START


NEC


Deponeer


DELL

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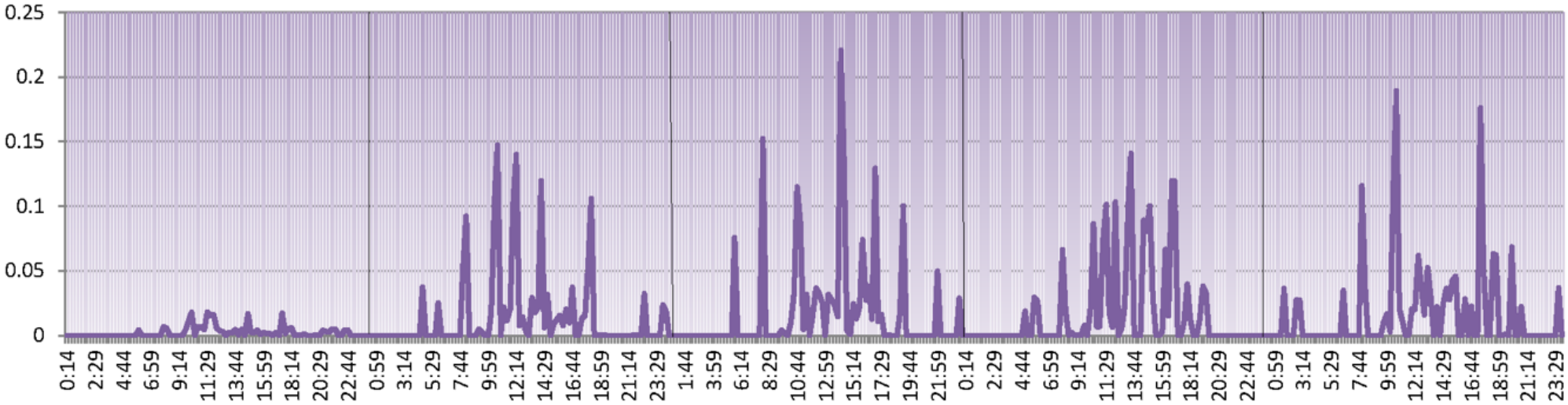
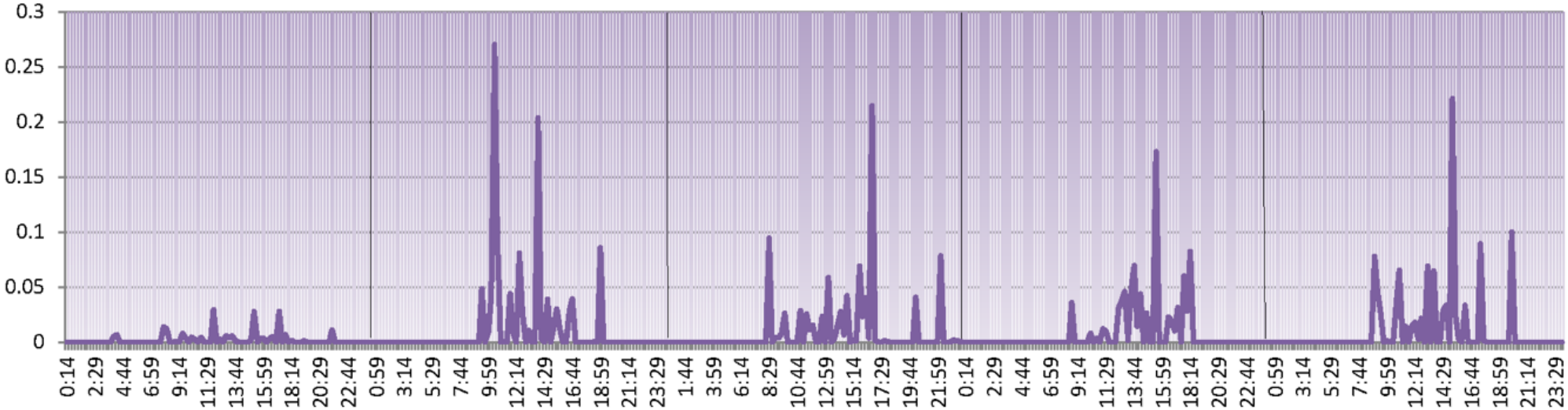
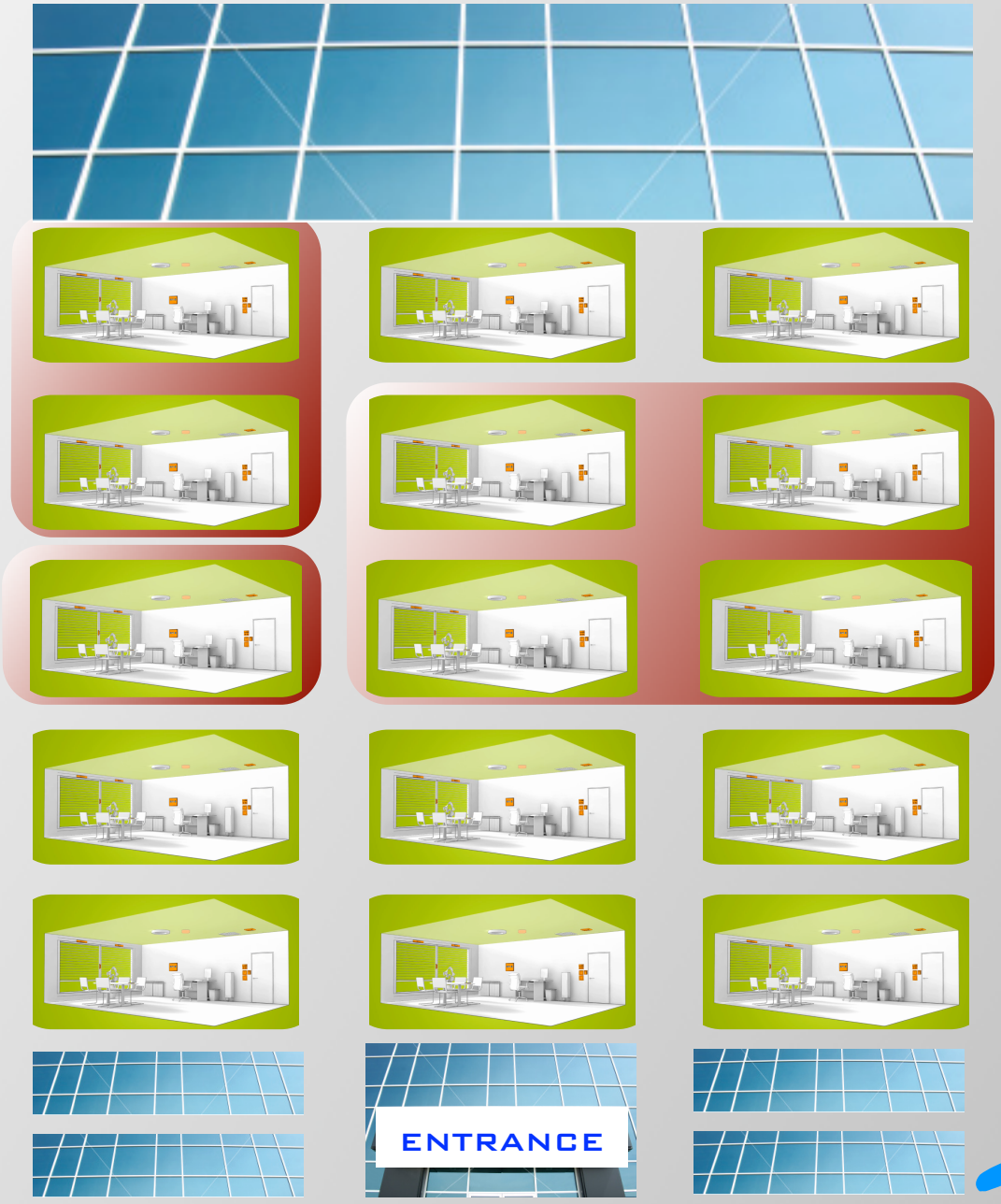
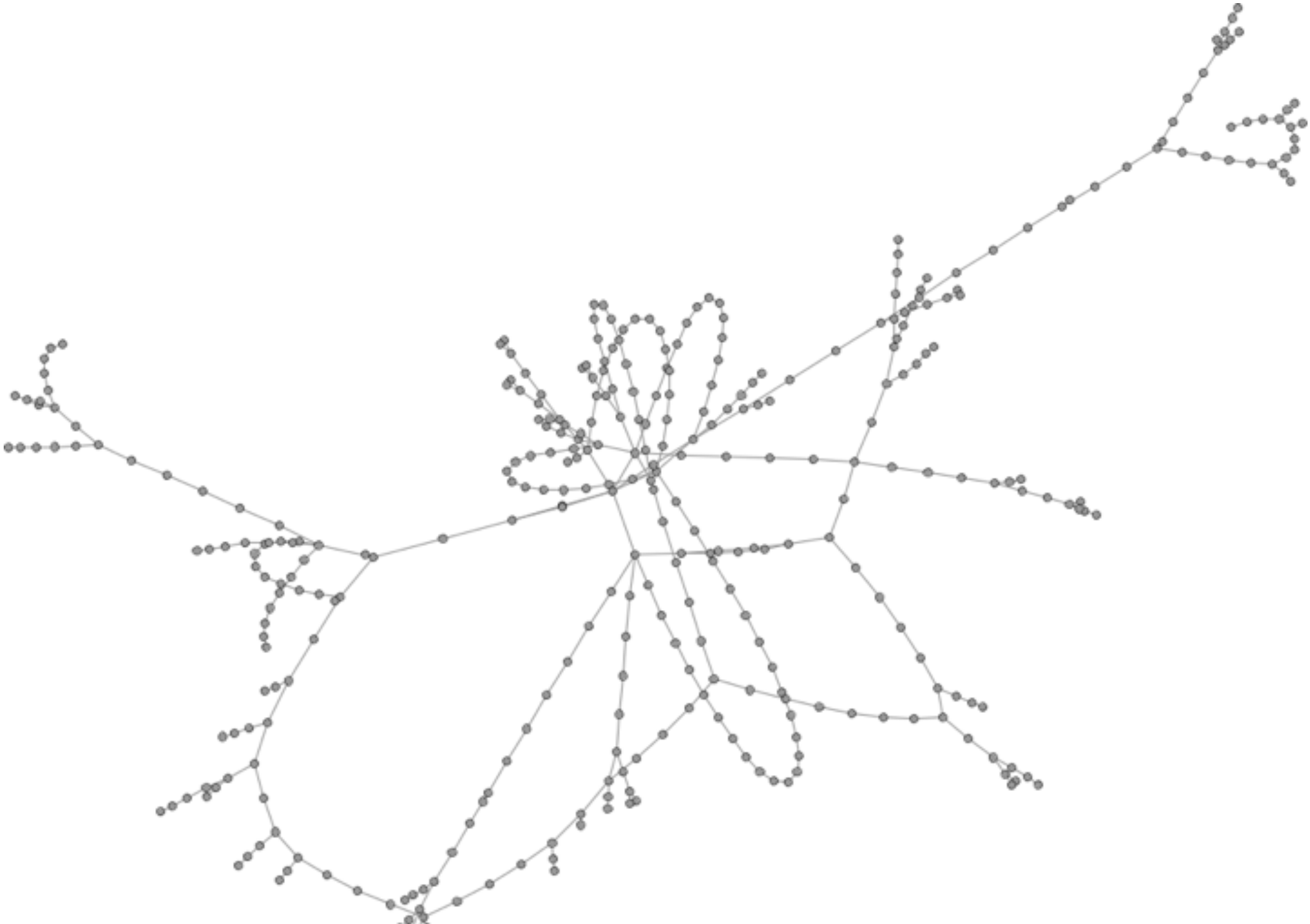
Real-time pricing related savings (~35%)





From the Grid's point of view:
a physical update is necessary?


ENTRANCE



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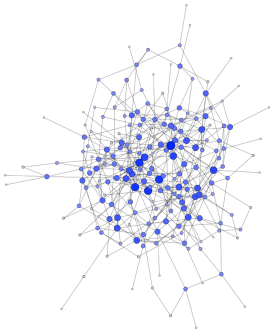
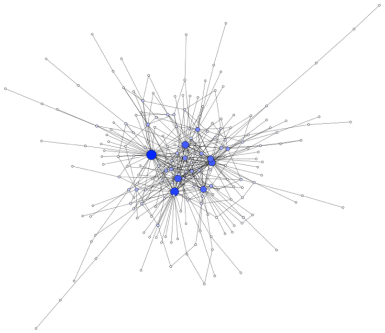
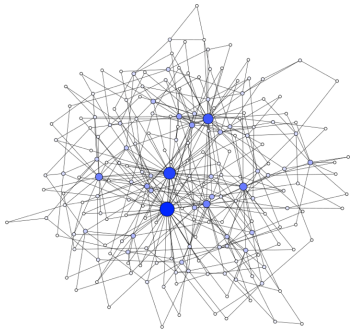
Network Evolutions



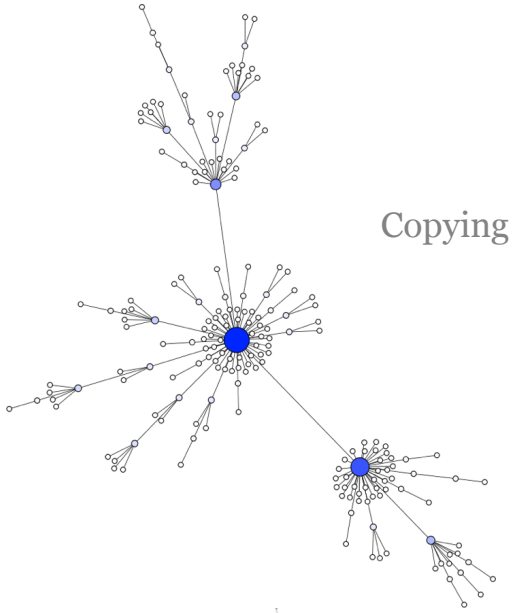
Random Graph



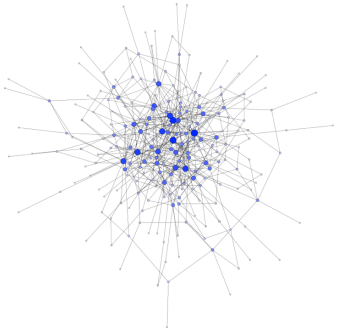
Random Graph Power Law



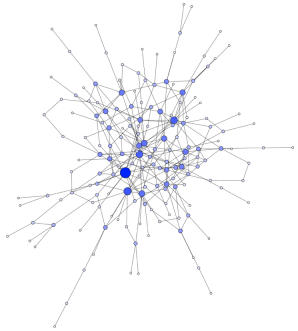
Preferential Attachment



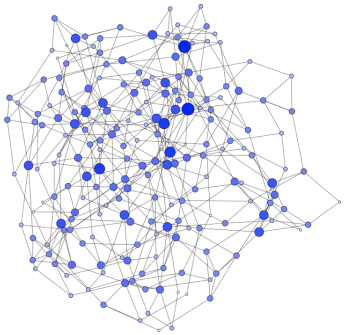
Copying model



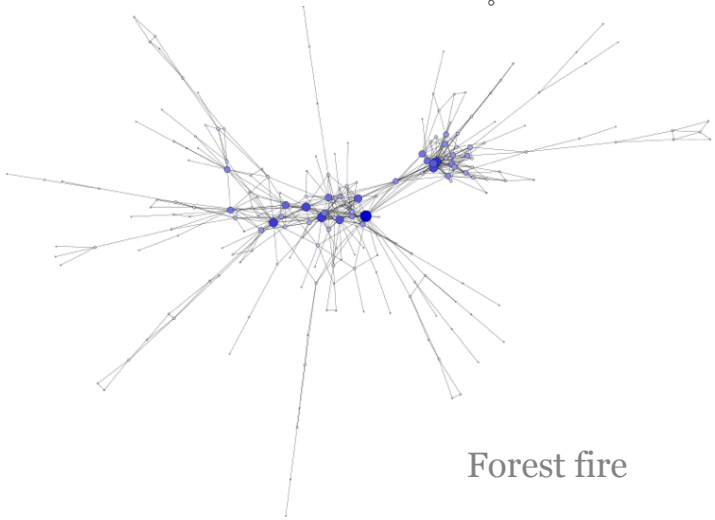
RMat



Kronecker model



Small World



Forest fire

Which synthetic network model is best?

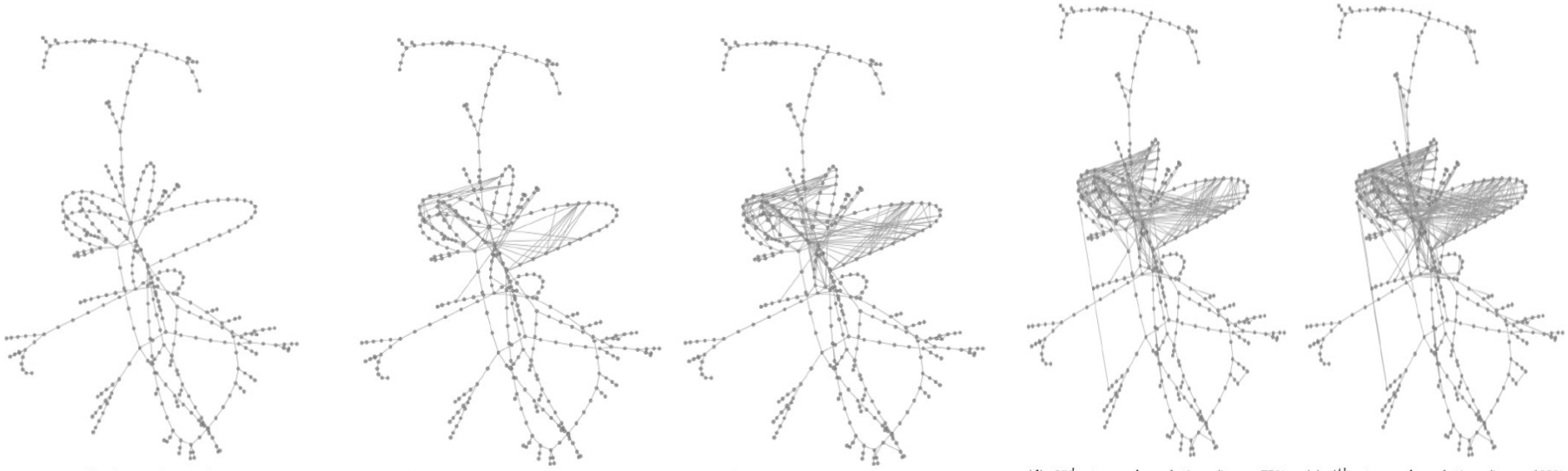
1-modularity

2-quantitative metrics

3-thrift

Network Model	Avg. node degree $< k > \approx 2$	Avg. node degree $< k > \approx 4$	Avg. node degree $< k > \approx 6$
Small-world	✓✓	✓✓✓	✓✓
Preferential Attachment	✓	✓✓	✓
Random Graph	✓	✓✓	✓
R-MAT	✓✓	✓✓	✓✓

Example of evolution: least distance strategy



(a) Physical sample.

(b) 1st stage of evolution (i.e., +25% edges).

(c) 2nd stage of evolution (i.e., +50% edges).

(d) 3rd stage of evolution (i.e., +75% edges).

(e) 4th stage of evolution (i.e., +100% edges).

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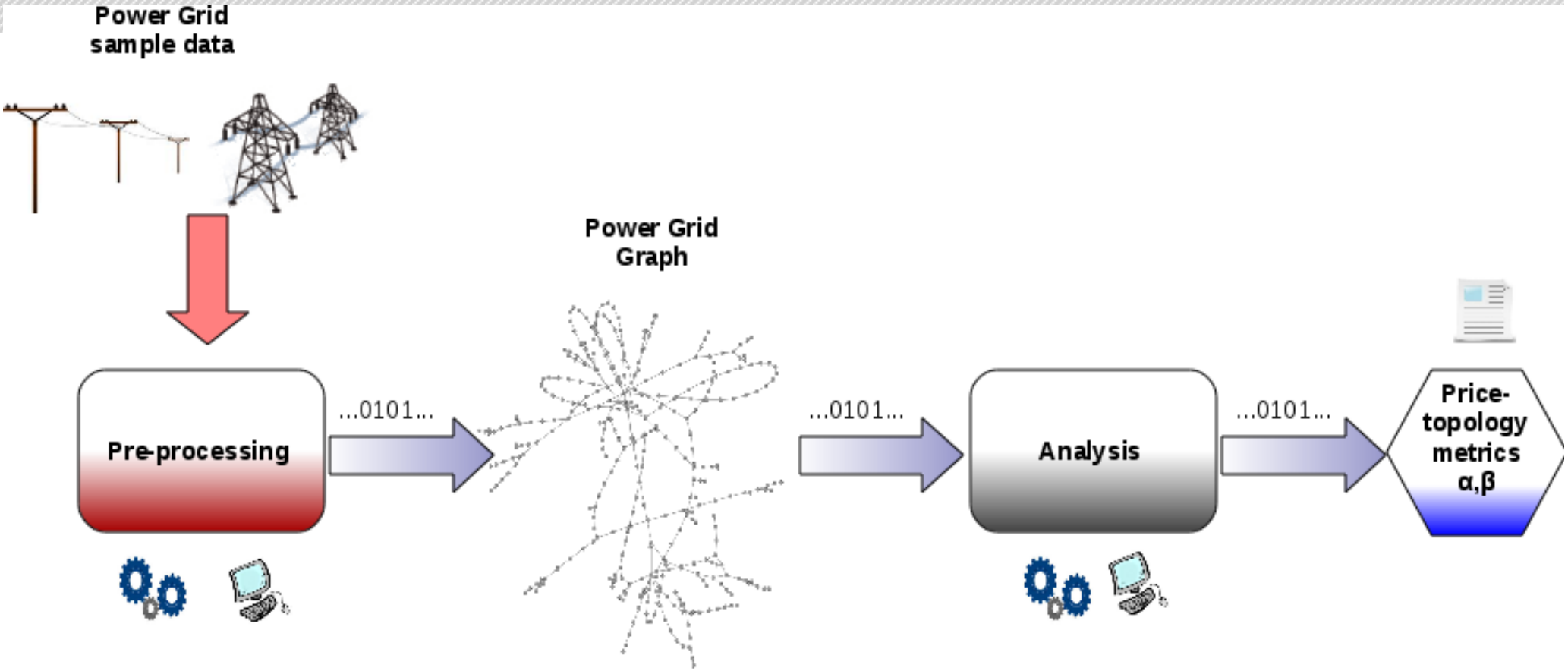

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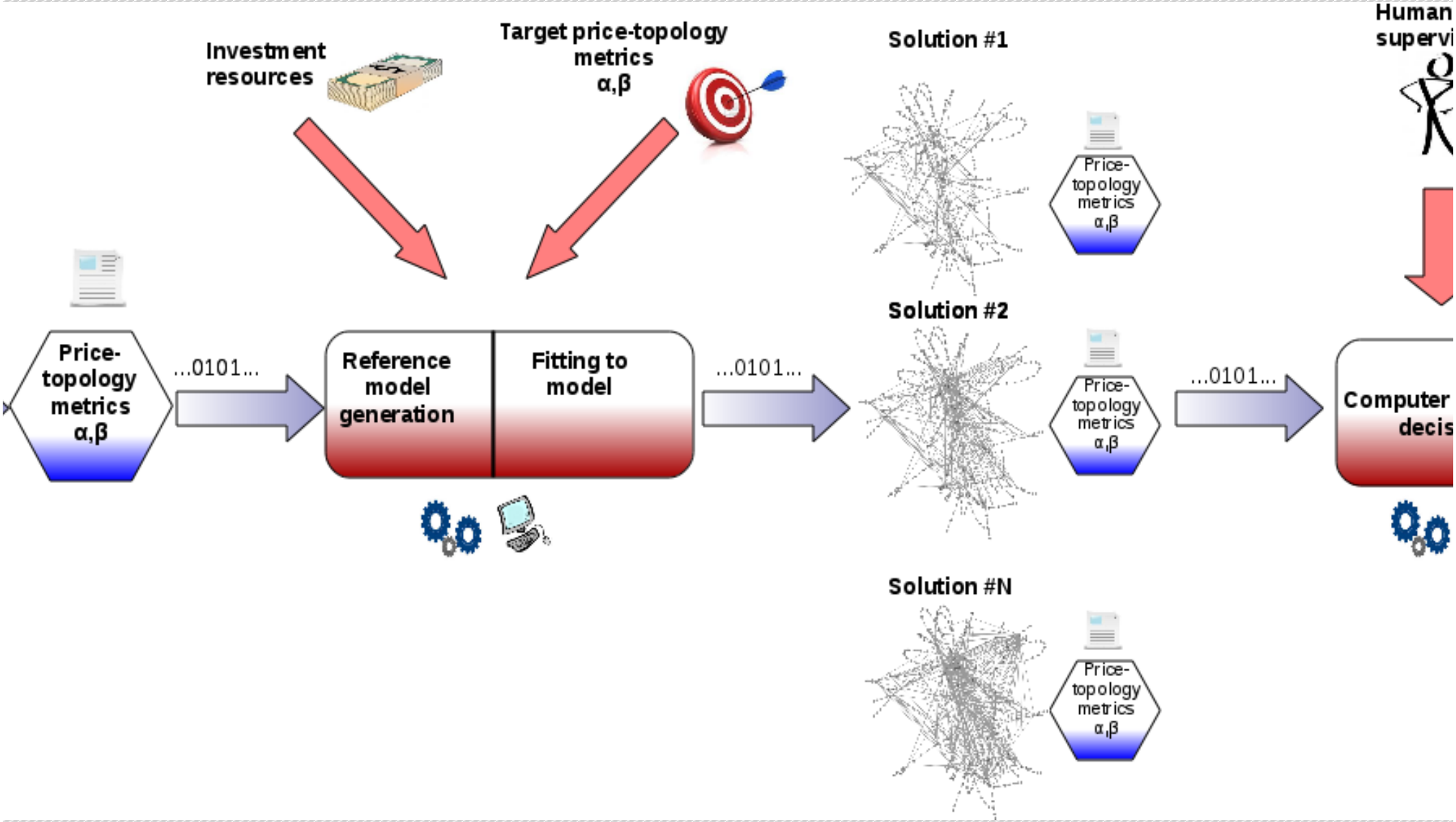

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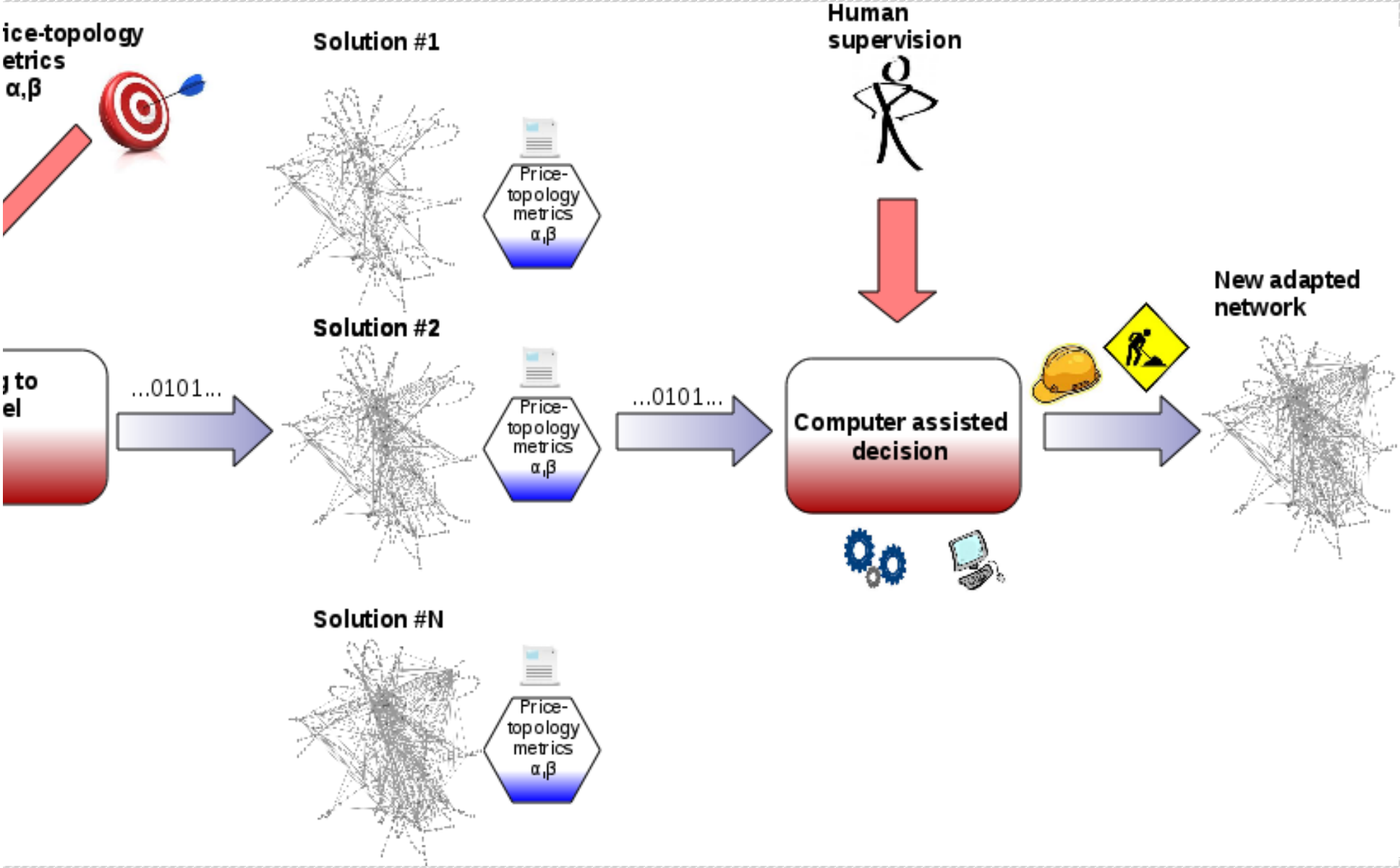
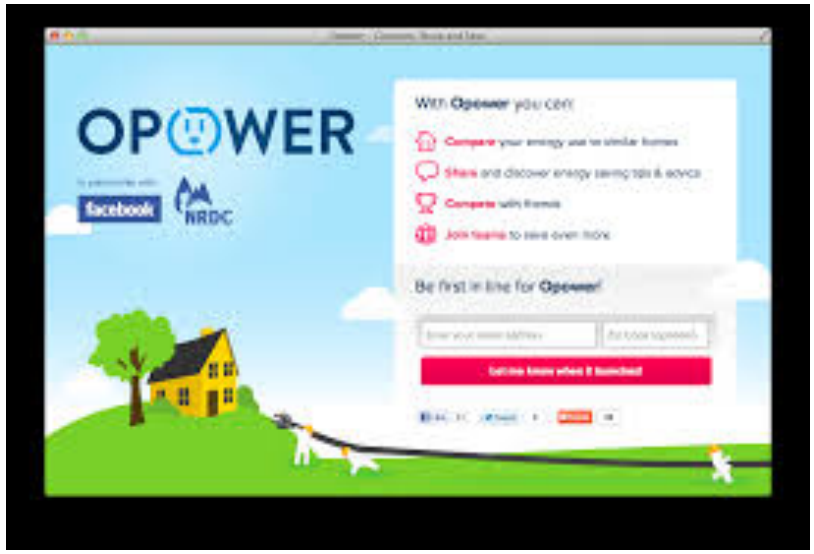


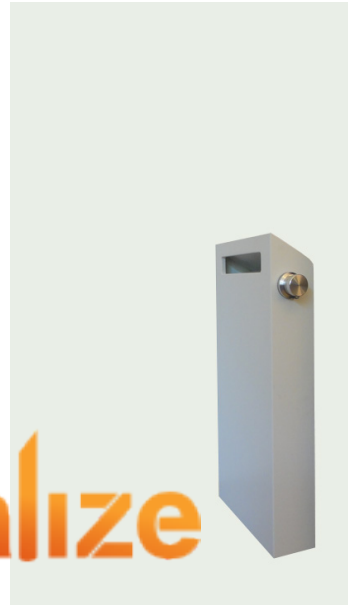
a very dynamic landscape

some examples

plum

AutoGrid





Nerdalize

OPOWER

AutoGrid presents

Turning BIG DATA into POWER

BIG DATA

generated on the smart grid is growing exponentially.

How much money and electricity can be saved through better analytics and controls?

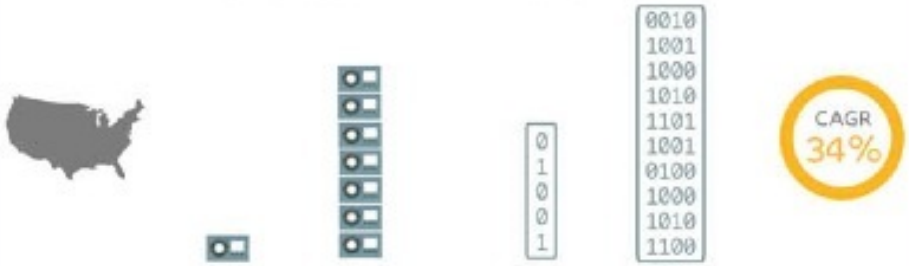
Quite a bit.

188 gigawatts

or 20% of peak power can be provided by demand response by 2019

Intelligent Electronic Devices

Unit Growth | Data Growth

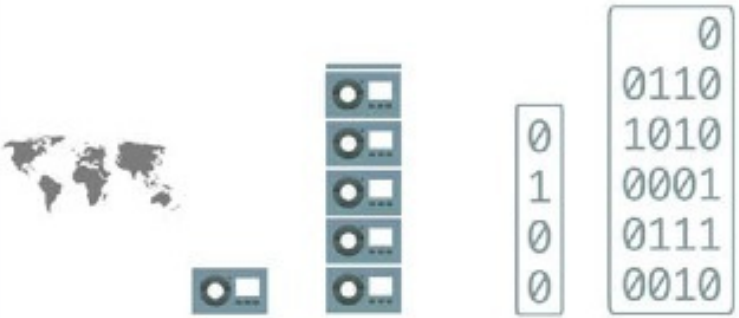


CAGR 34%

2013 2020 2013 2020

22 175 (units, millions)

46 368 (data, petabytes)



CAGR 26%

2013 2020 2013 2020

102 512 (units, millions)

214 1076 (data, petabytes)

25% of electricity was saved by consumers using smart devices in time-of-use pricing programs

1000 petabytes of data would be generated by smart meters if deployed universally in the U.S.

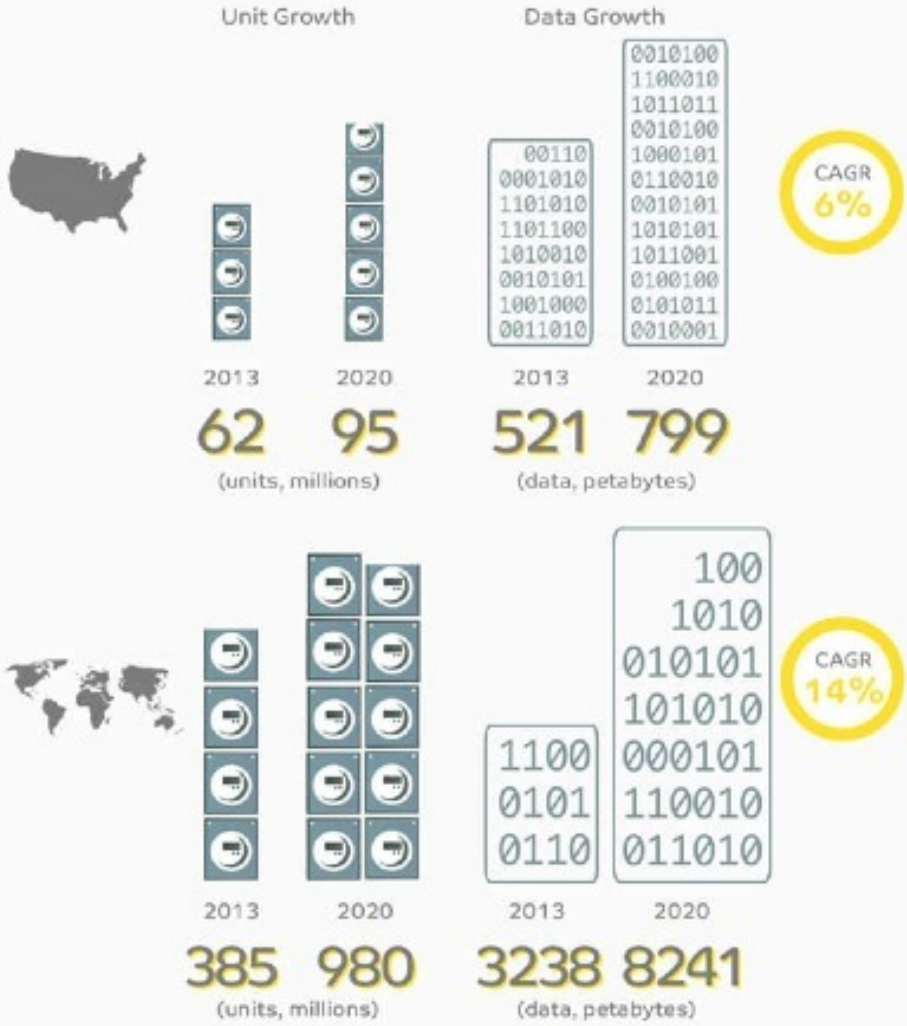
Smart Meters

Unit Growth | Data Growth

1000 petabytes
of data would be generated by smart meters if deployed universally in the U.S.

25% of electricity
was saved by consumers using smart devices in time-of-use pricing programs

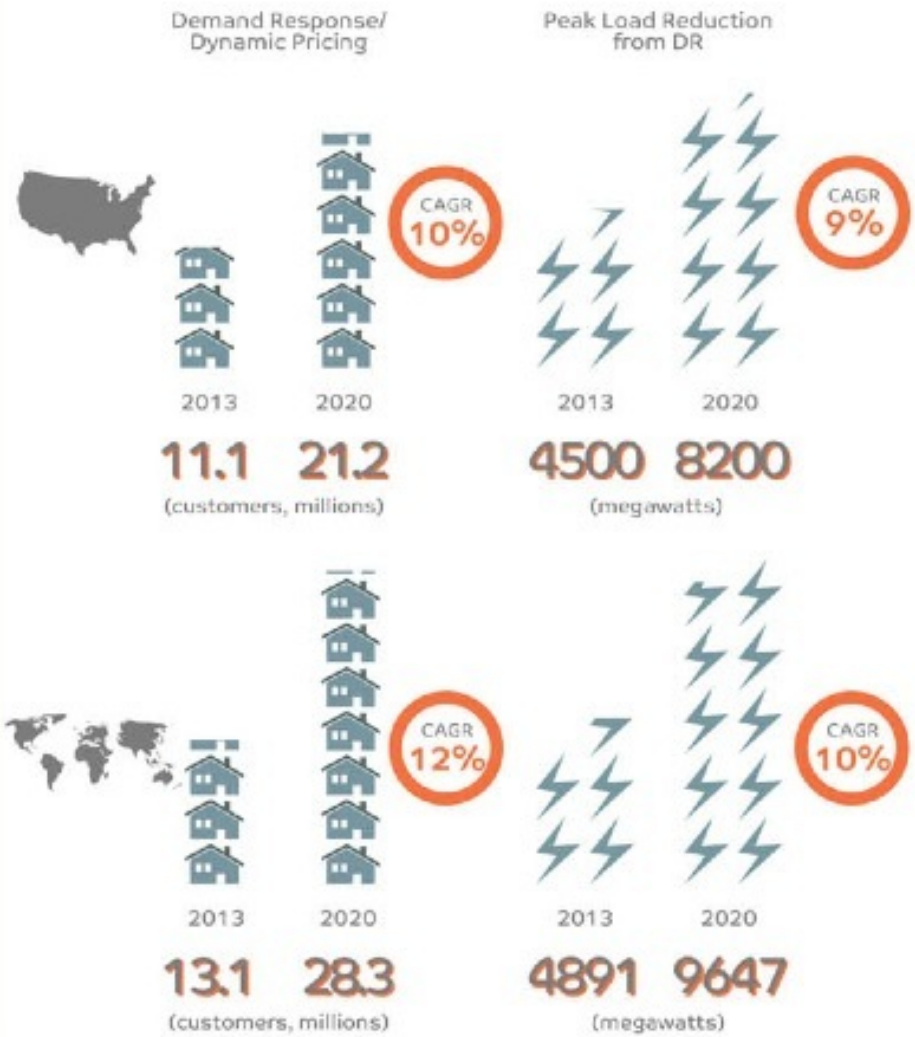
Smart Meters



8330 Libraries of Congress
worth of data is contained within 1000 petabytes

8330 Libraries of Congress
worth of data is contained within 1000 petabytes

Demand Response



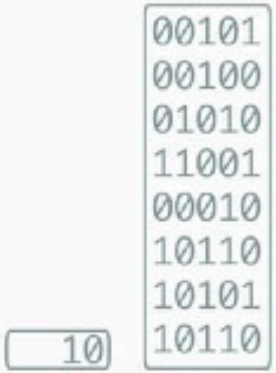
2000 peaker plants
producing 75MW each could be elimiated with 150GW demand response in the US

Electric Vehicles

Unit Growth | Data Growth

CAGR 77%

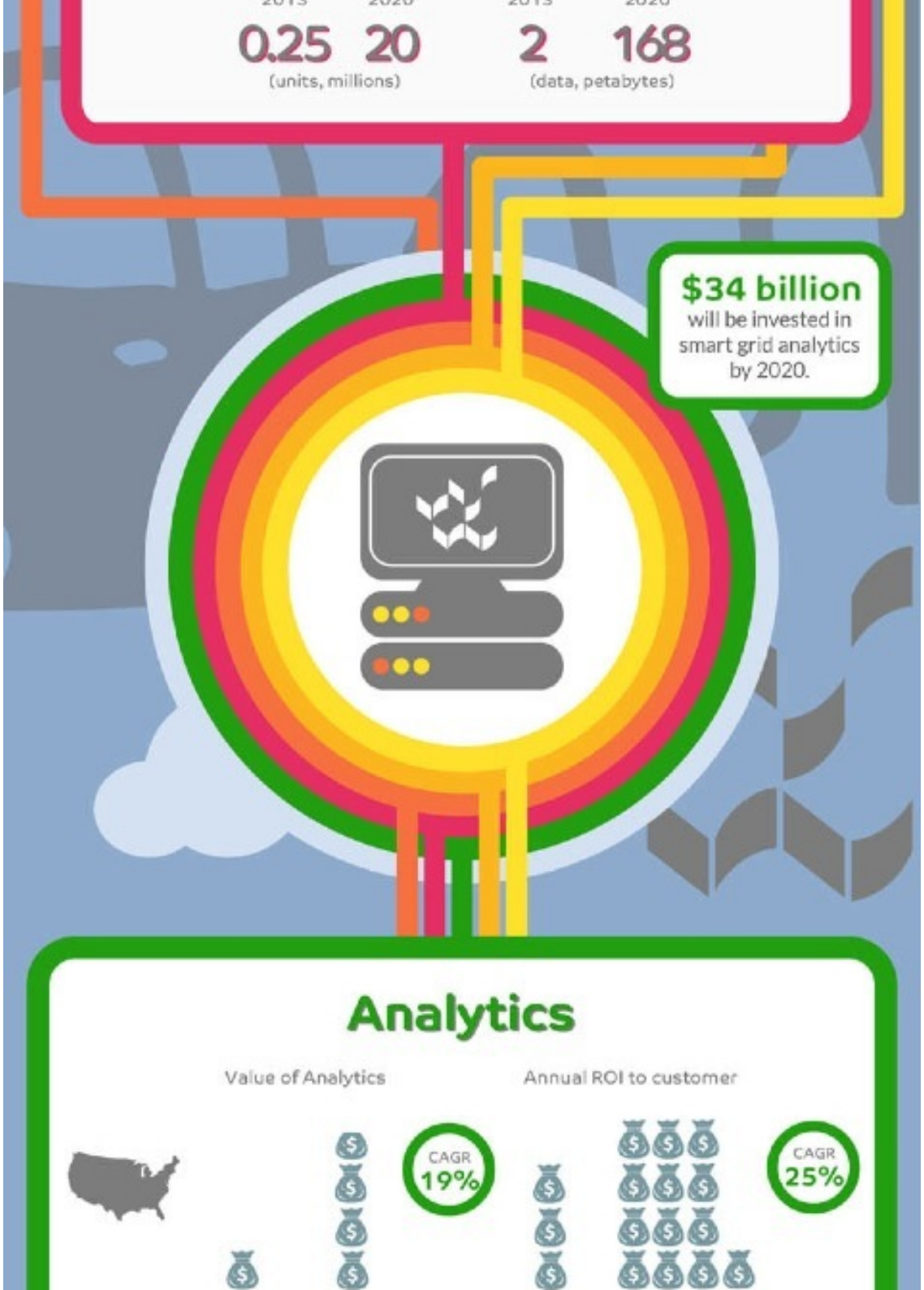
2013	2020	2013	2020
0.08	4.4	1	36
(units, millions)		(data, petabytes)	



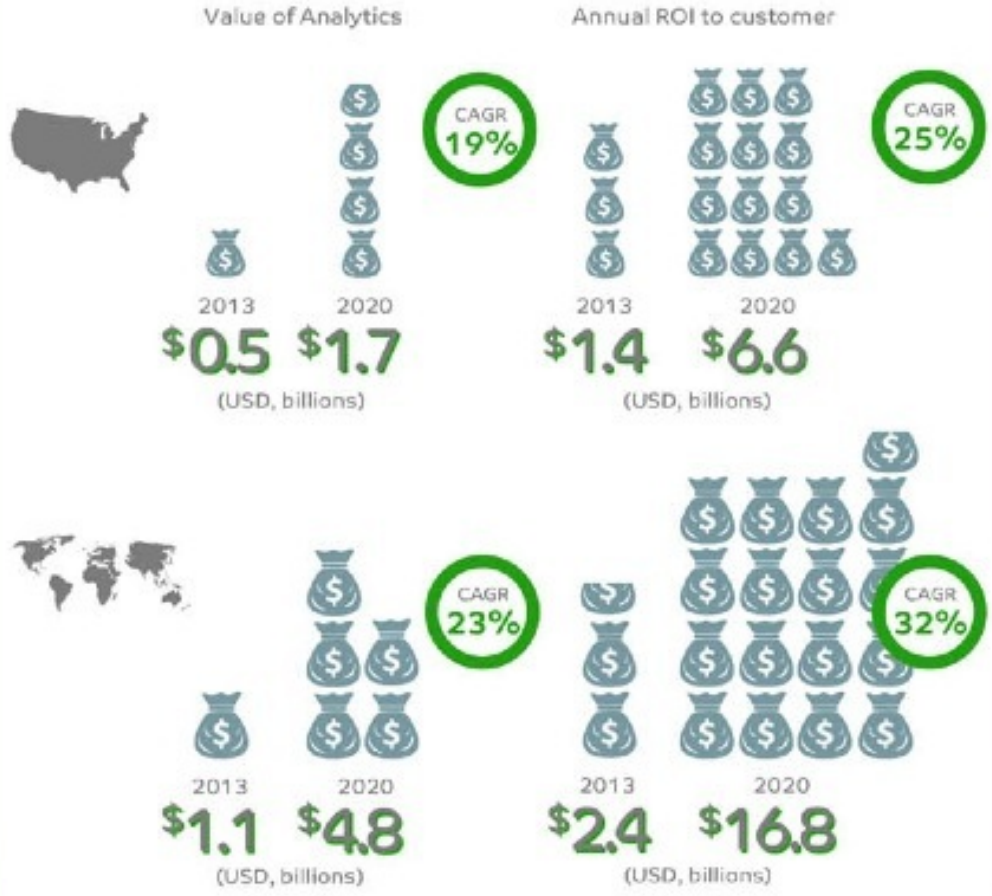
CAGR 87%

2013	2020	2013	2020
0.25	20	2	168
(units, millions)		(data, petabytes)	

$34 billion will be invested in smart grid analytics by 2020.


2013 2020
0.25 20
(units, millions)
2013 2020
2 168
(data, petabytes)
$34 billion
will be invested in smart grid analytics by 2020.
Analytics
Value of Analytics
CAGR 19%
Annual ROI to customer
CAGR 25%

Analytics



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ZPryme Research & Consulting

smartgridresearch.org

*Note: This is only collected data. It does not include back-up, billing data created from it, and reporting data created

The Data Deluge in the Energy Industry

# of meters	15 minute interval (per year)	1 minute interval (per year)	1 second interval (per year)
10,000	31.9 GB	467 GB	28.0 TB
100,000	319 GB	4.67 TB	280 TB
1,000,000	3.19 TB	46.7 TB	2.80 PB

Increasing Granularity of Data → Unprecedented Levels of Data

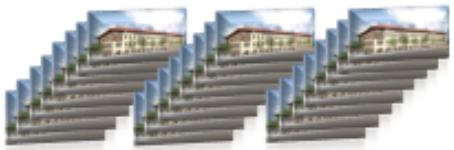
Y2E2 Building @ Stanford

1 Year

2,600 points

1 min reads

100 GB



1,000 Y2E2 Buildings @ 1 second intervals

6 Petabytes
= the entire US Library of Congress X 50!

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Office buildings and data centers?

[redacted]

Nerdalize

[redacted]

http://youtu.be/e-ZqVqS7uiM

Claim

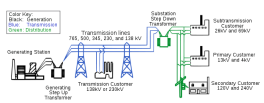
the commodification of energy passes through ICT

university of groningen

Thank you

university of groningen

Thank you



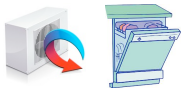










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