New Business Framework for the Energy Industry

Club of Amsterdam
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Professor of Geosciences and Energy Innovation
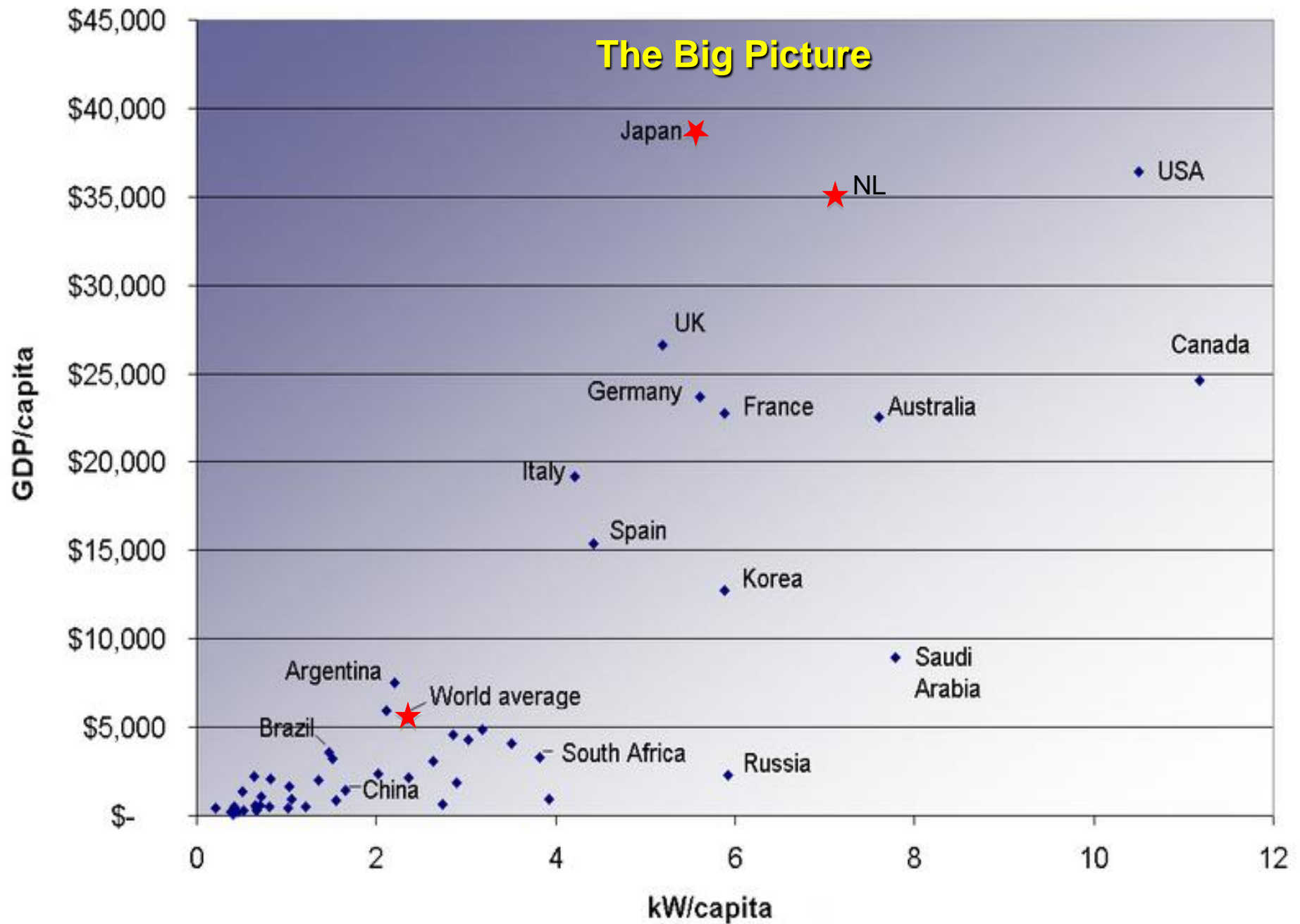**General Director Delphi Consortium**

TU Delft

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- Part I : Explosion of energy needs

- Part II : Energy and Poverty

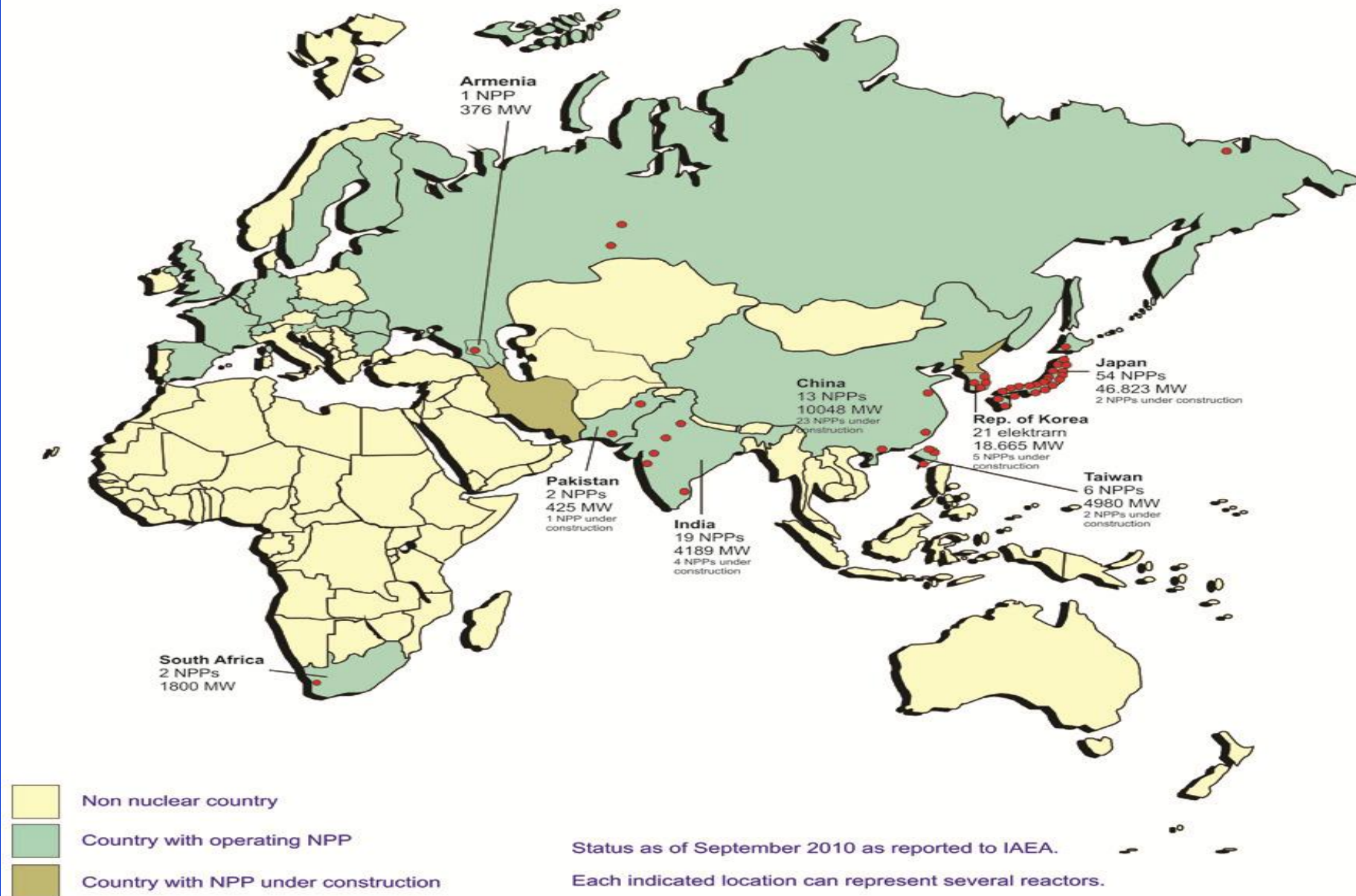- Part III : Energy and Environment

- Part IV : More to come ………

Part I:

Explosion of energy needs

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The Big Picture

A scatter plot titled "The Big Picture" showing GDP/capita (y-axis, $- to $45,000) versus kW/capita (x-axis, 0 to 12) for various countries. Labeled points include Japan, NL, USA, Canada, UK, Germany, France, Australia, Italy, Spain, Korea, Saudi Arabia, Argentina, World average, Brazil, South Africa, Russia, and China.

Nuclear Power Plants in Asija and Africa
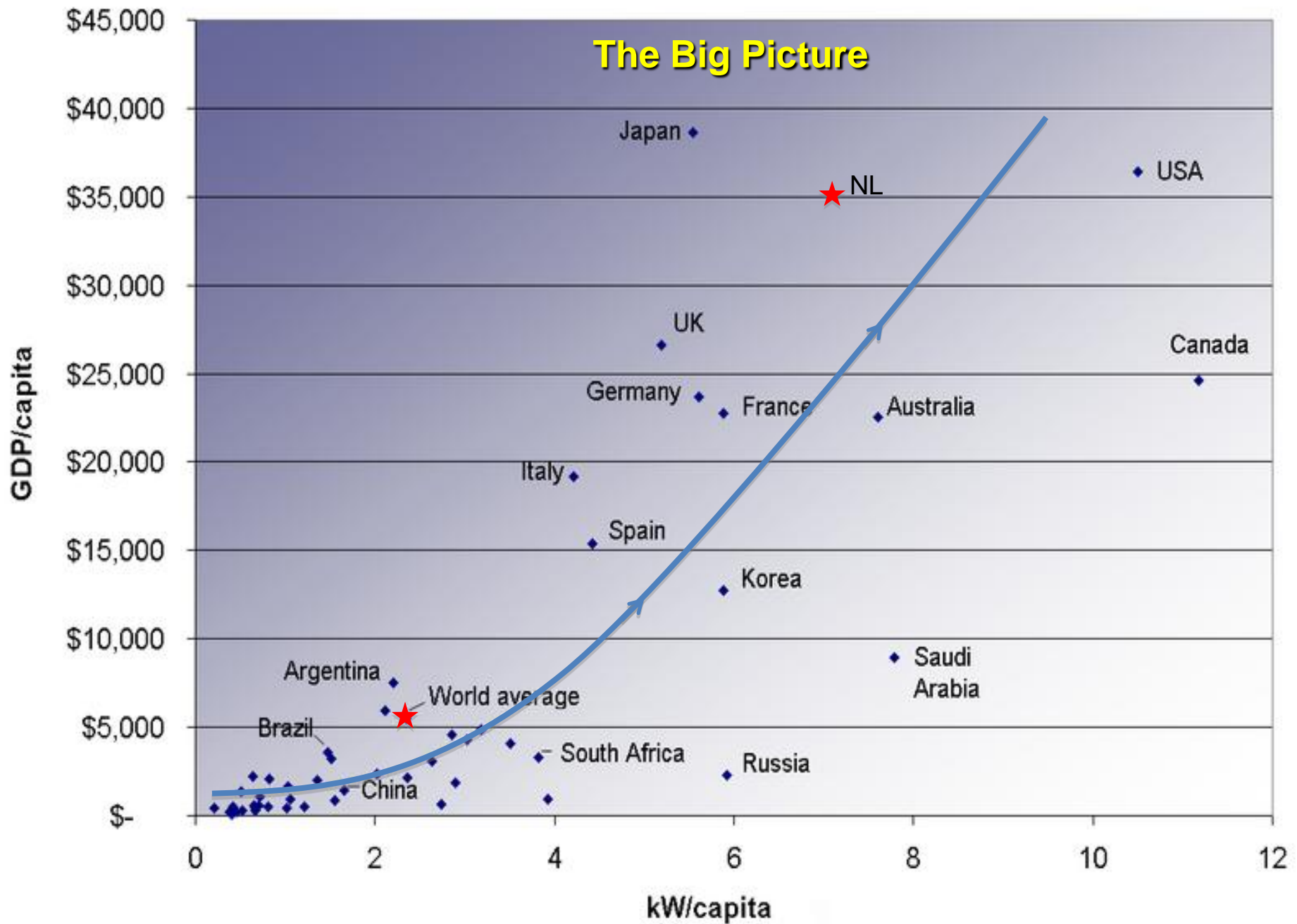
Armenia
1 NPP
376 MW

China
13 NPPs
10048 MW
23 NPPs under
construction

Japan
54 NPPs
46.823 MW
2 NPPs under construction

Rep. of Korea
21 elektrarn
18.665 MW
5 NPPs under
construction

Taiwan
6 NPPs
4980 MW
2 NPPs under
construction

Pakistan
2 NPPs
425 MW
1 NPP under
construction

India
19 NPPs
4189 MW
4 NPPs under
construction

South Africa
2 NPPs
1800 MW

Non nuclear country

Country with operating NPP

Country with NPP under construction

Status as of September 2010 as reported to IAEA.

Each indicated location can represent several reactors.

Energy Consumption

- **Average worldwide energy use per capita in one second: 2.2 kW***
  Average worldwide energy use per capita in one hour: 2.2 kWh
  Average worldwide energy use per capita in one day: 53 kWh

* In China this figure is about 2, in Europe it is 6 and in the US it is more than 11

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Energy Consumption

- **Average worldwide energy use per capita in one second: 2.2 kW**
  Average worldwide energy use per capita in one hour: 2.2 kWh
  Average worldwide energy use per capita in one day: 53 kWh

- **Every second we use worldwide:**
  $(2.2 \times 10^3) \times (6.7 \times 10^9)$ = 15 terawatt

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Energy Consumption

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  Average worldwide energy use per capita in one hour: 2.2 kWh
  Average worldwide energy use per capita in one day: 53 kWh

- Every second we use worldwide:
  $$(2.2 \times 10^3) \times (6.7 \times 10^9) = 15 \text{ terawatt}$$

- **If we aim at 5 kW per capita (increased prosperity in emerging economies) and we assume that the world population will increase to 10. 10^9 (improved life expectance in developing countries), then we need every moment:**
  $$(5 \times 10^3) \times (10 \times 10^9) = 50 \text{ terawatt}$$

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Energy Consumption

- Average worldwide energy use per capita in one second: 2.2 kW
  Average worldwide energy use per capita in one hour: 2.2 kWh
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- If we aim at 5 kW per capita (increased prosperity in emerging economies) and we assume that the world population will increase to 10. 10^9 (improved health in developing countries), then we need every second:
$$(5 \times 10^3) \times (10 \times 10^9) = 50 \text{ terawatt}$$

- **Worst case scenario: 6 x 10 = 60 terawatt (factor 4)**
  Best case scenario   : 4 x   9 = 36 terawatt (factor 2.4)

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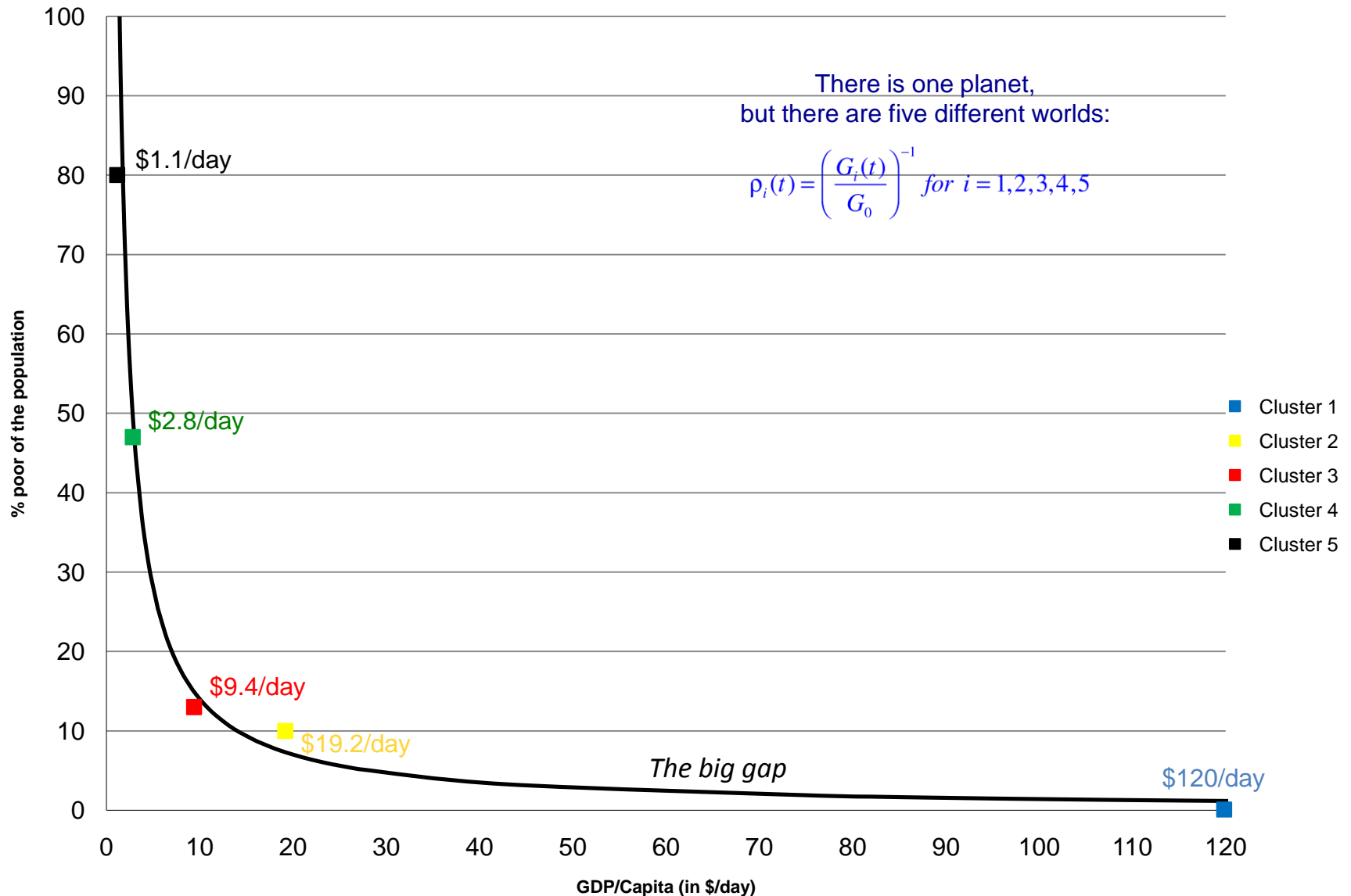Explosion of Energy Consumption
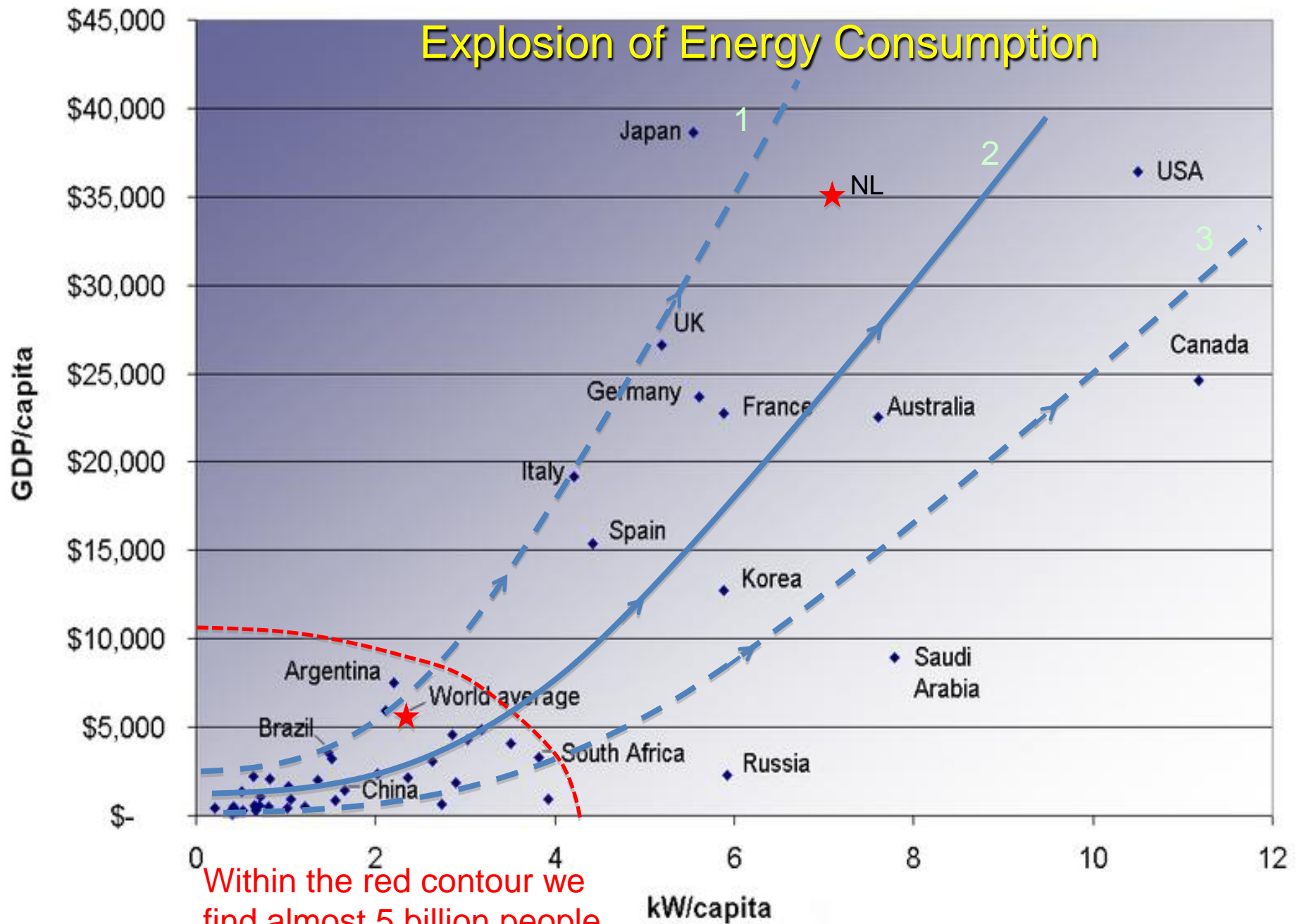
Part II:

Energy and poverty

Planet Earth: five global clusters

- The world's population can be subdivided into five different categories of nations, leading to five global clusters with distinctly different poverty ratios
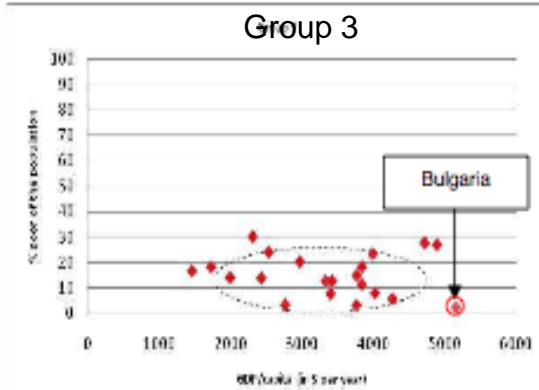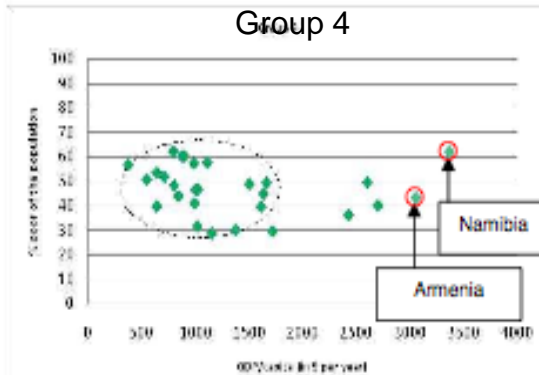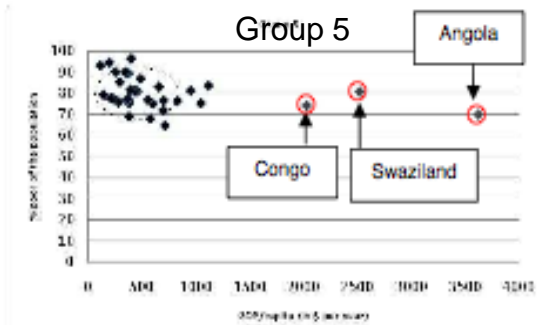
GDP/cap vs poverty ratio: *GPR-curve*

There is one planet,
but there are five different worlds:

$$\rho_i(t) = \left(\frac{G_i(t)}{G_0} \right)^{-1} \; for \; i = 1,2,3,4,5$$

% poor of the population

GDP/Capita (in $/day)

$1.1/day

$2.8/day

$9.4/day

$19.2/day

The big gap

$120/day

■ Cluster 1
■ Cluster 2
■ Cluster 3
■ Cluster 4
■ Cluster 5

Looking inside each cluster of nations

Group 5

Angola
Congo
Swaziland

Group 4

Namibia
Armenia

Group 3

Bulgaria

Group 2

Botswana
Trinidad

Group 1

Norway
Luxembourg

Group 5: "the no-have survivors"
GDP/Capita:	$450/year
%poor:	80%
%world pop:	33%
%world GDP:	3%
Data points:	34

Group 4: "the resource-rich careless"
GDP/Capita:	$1.050/year
%poor:	47%
%world pop:	32%
%world GDP:	8%
Data points:	28

Group 3: "the factory of the world"
GDP/Capita:	$3.250/year
%poor:	13%
%world pop:	7%
%world GDP:	3%
Data points:	21

Group 2: "The oil-driven rulers"
GDP/Capita:	$7.750/year
%poor:	10%
%world pop:	12%
%world GDP:	12%
Data points:	18

Group 1: "Welfare society"
GDP/Capita:	$42.000/year
%poor/pop:	0%
%world pop:	15%
%world GDP:	74%
Data points:	24
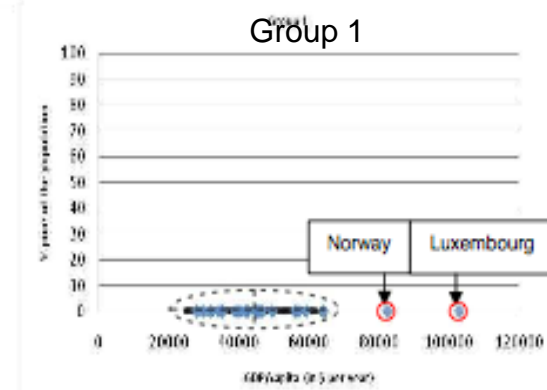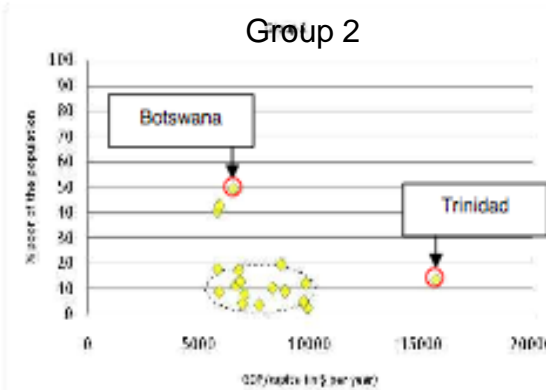
GDP/Capita: rounded to $50

%poor to total: rounded to %

Outliers(group): Norway, Luxembourg(1), Trinidad and Tobago, Saint Lucia, Botswana, South Africa (2), none(3), Namibia,Armenia (4), Angola, Swaziland, Congo (5)

Population size of each cluster (100% = 6.8 billion)

There is one planet,
but there are five different worlds

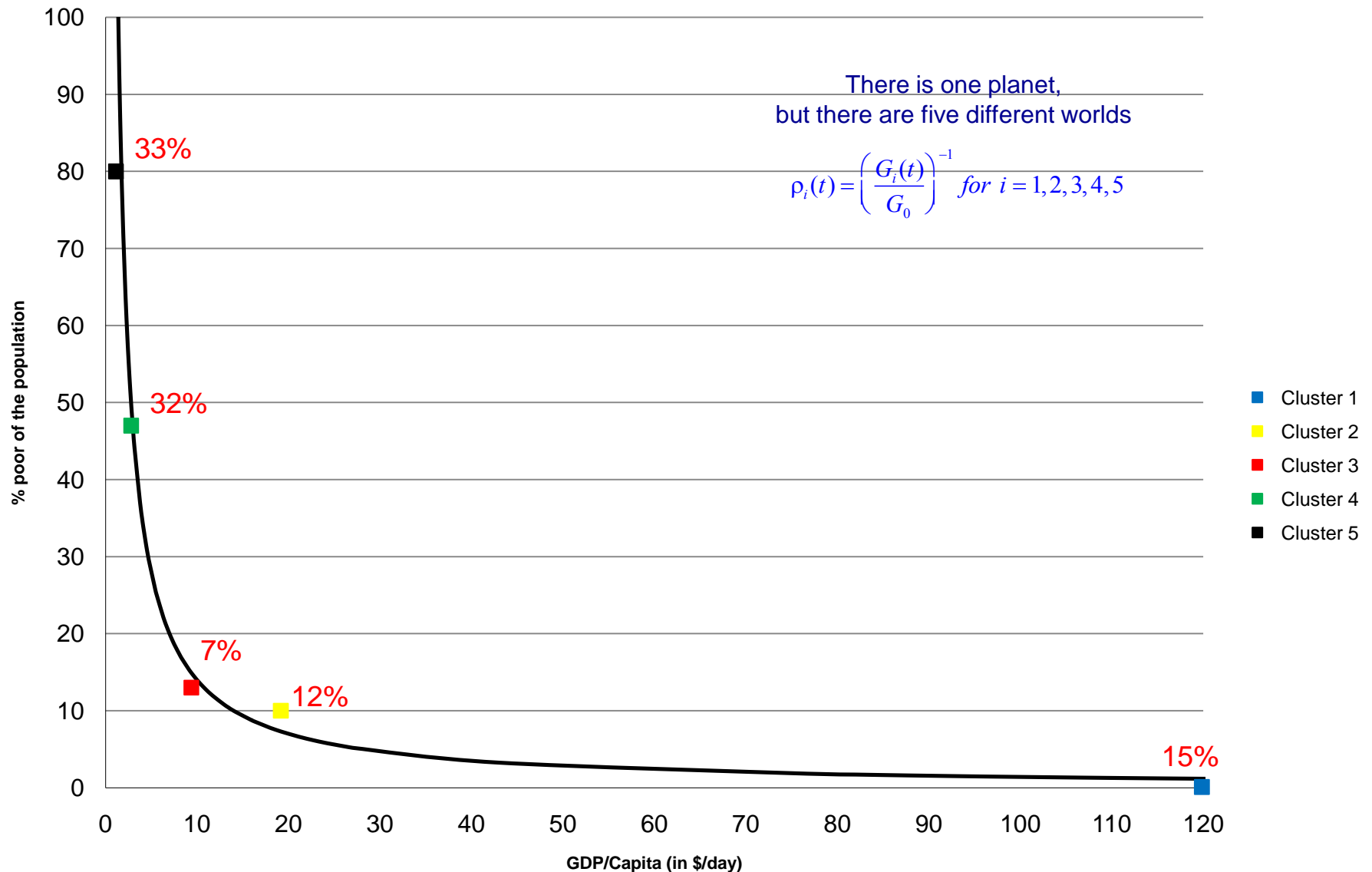$$\rho_i(t) = \left(\frac{G_i(t)}{G_0} \right)^{-1} \quad for \ i = 1, 2, 3, 4, 5$$

% poor of the population (y-axis)

GDP/Capita (in $/day) (x-axis)

33%

32%

7%

12%

15%

Legend:
- Cluster 1
- Cluster 2
- Cluster 3
- Cluster 4
- Cluster 5

Life expectancy of each cluster

% poor of the population

53 year

63 yr

72 yr

70 yr

80 yr

GDP/Capita (in $/day)

There is one planet,
but there are five different worlds

$$\rho_i(t) = \left(\frac{G_i(t)}{G_0}\right)^{-1} \; for \; i = 1,2,3,4,5$$

- Cluster 1
- Cluster 2
- Cluster 3
- Cluster 4
- Cluster 5
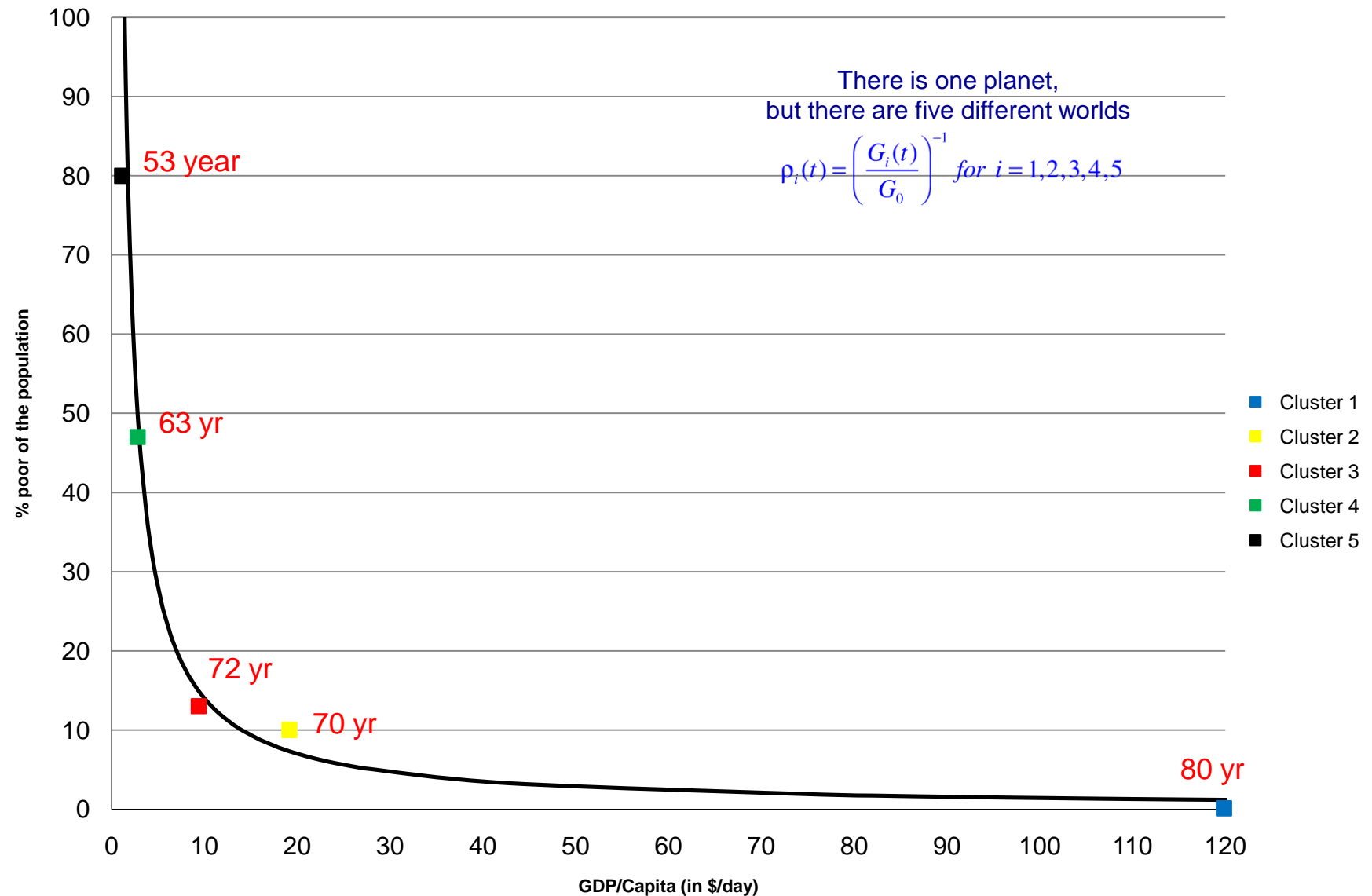
Median age of each cluster

There is one planet,
but there are five different worlds

$$\rho_i(t) = \left(\frac{G_i(t)}{G_0} \right)^{-1} \text{ for } i = 1,2,3,4,5$$

% poor of the population

GDP/Capita (in $/day)

18.8 yr
23.3 yr
27.9 yr
28.9 yr
40.5 yr

Cluster 1
Cluster 2
Cluster 3
Cluster 4
Cluster 5
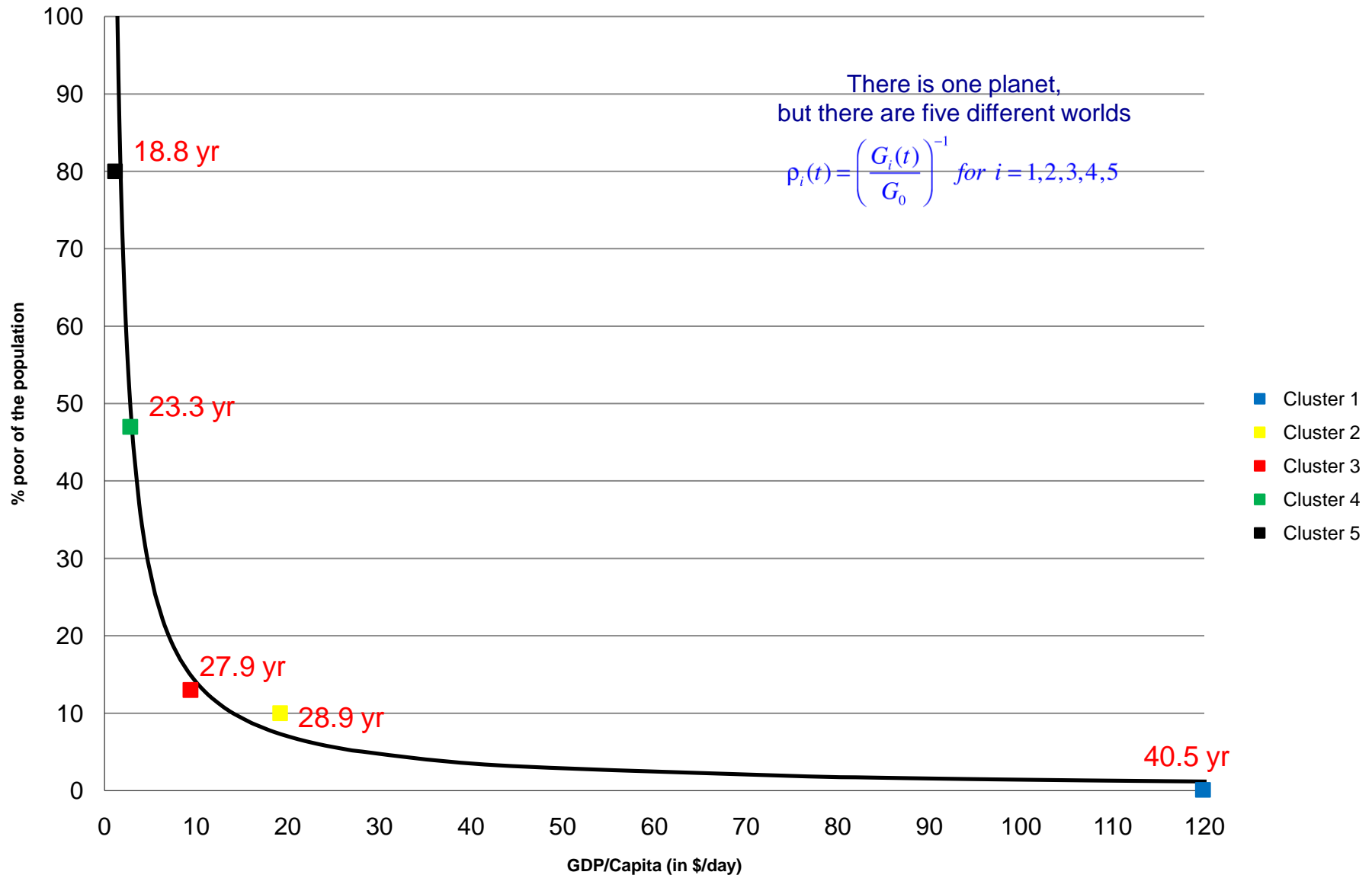
Planet Earth consists of five socio-economic regimes
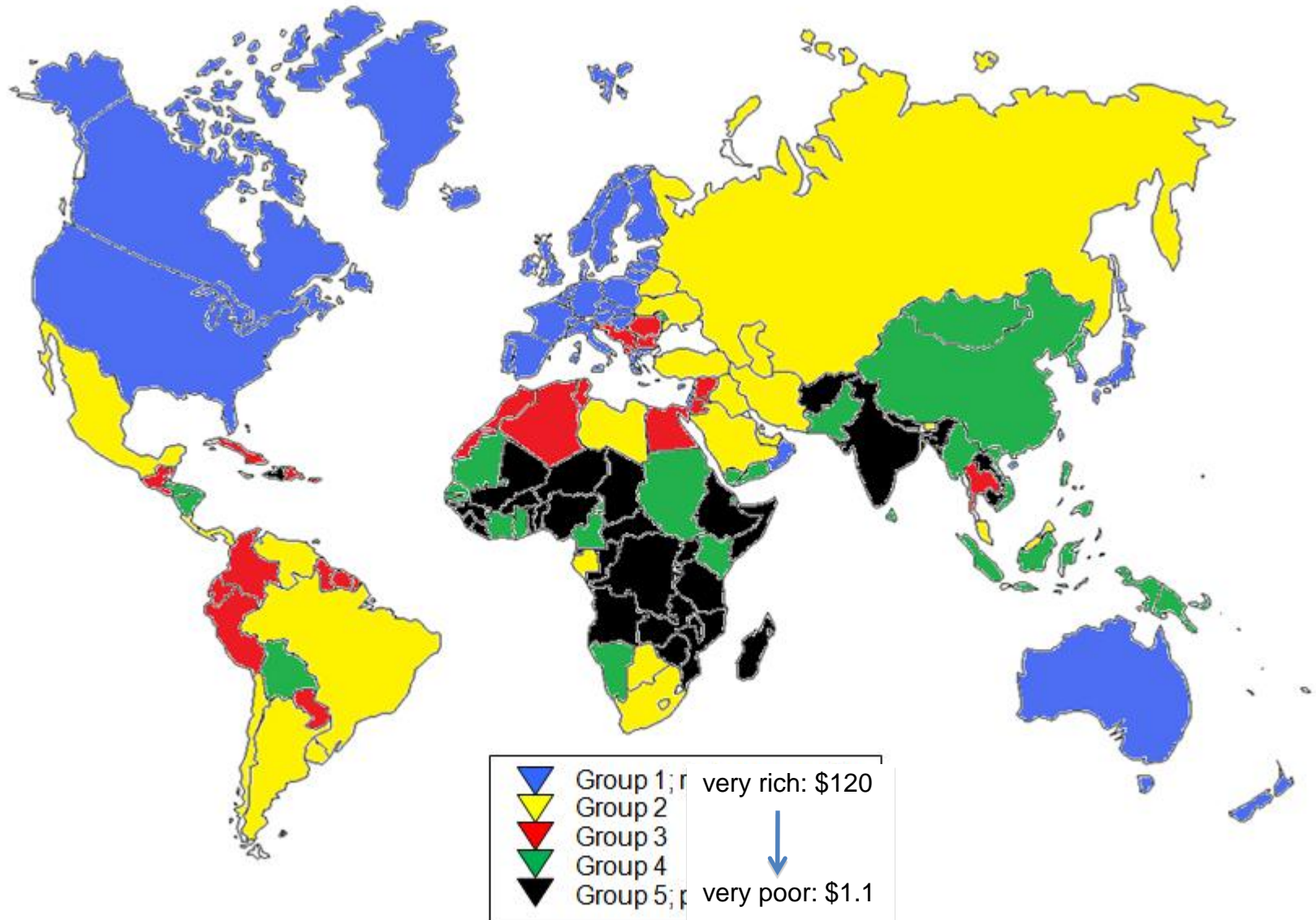
Group 1; r... very rich: $120
Group 2
Group 3
Group 4
Group 5; p... very poor: $1.1

Important Observations

- For a decrease in global poverty, the GDP/cap must increase: economic development programme

Higher labour productivity leads to more prosperity
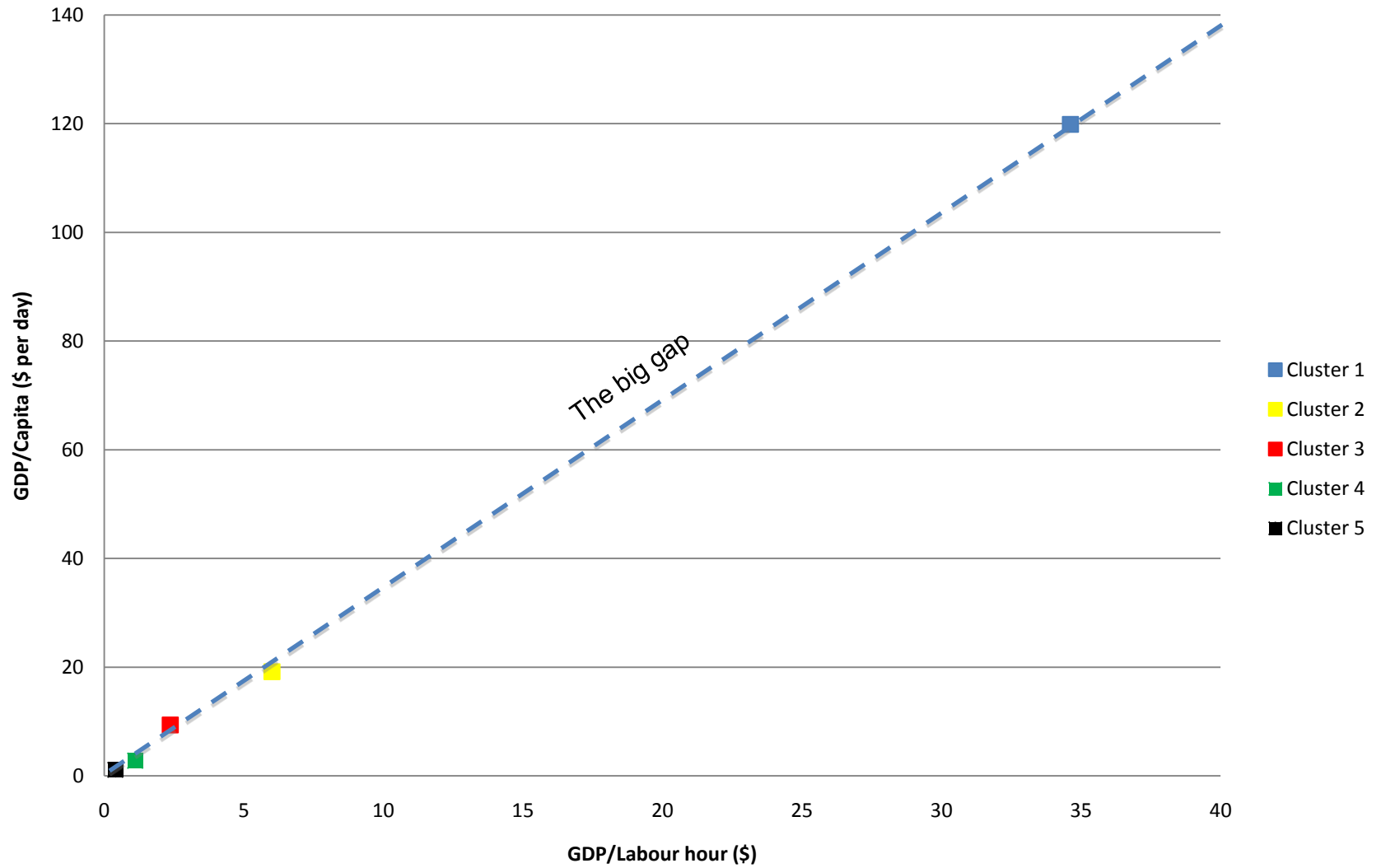
GDP/Capita ($ per day) vs GDP/Labour hour ($)

The big gap

Cluster 1
Cluster 2
Cluster 3
Cluster 4
Cluster 5

Important Observations

- For a decrease in global poverty, the GDP/cap must increase: economic development programme

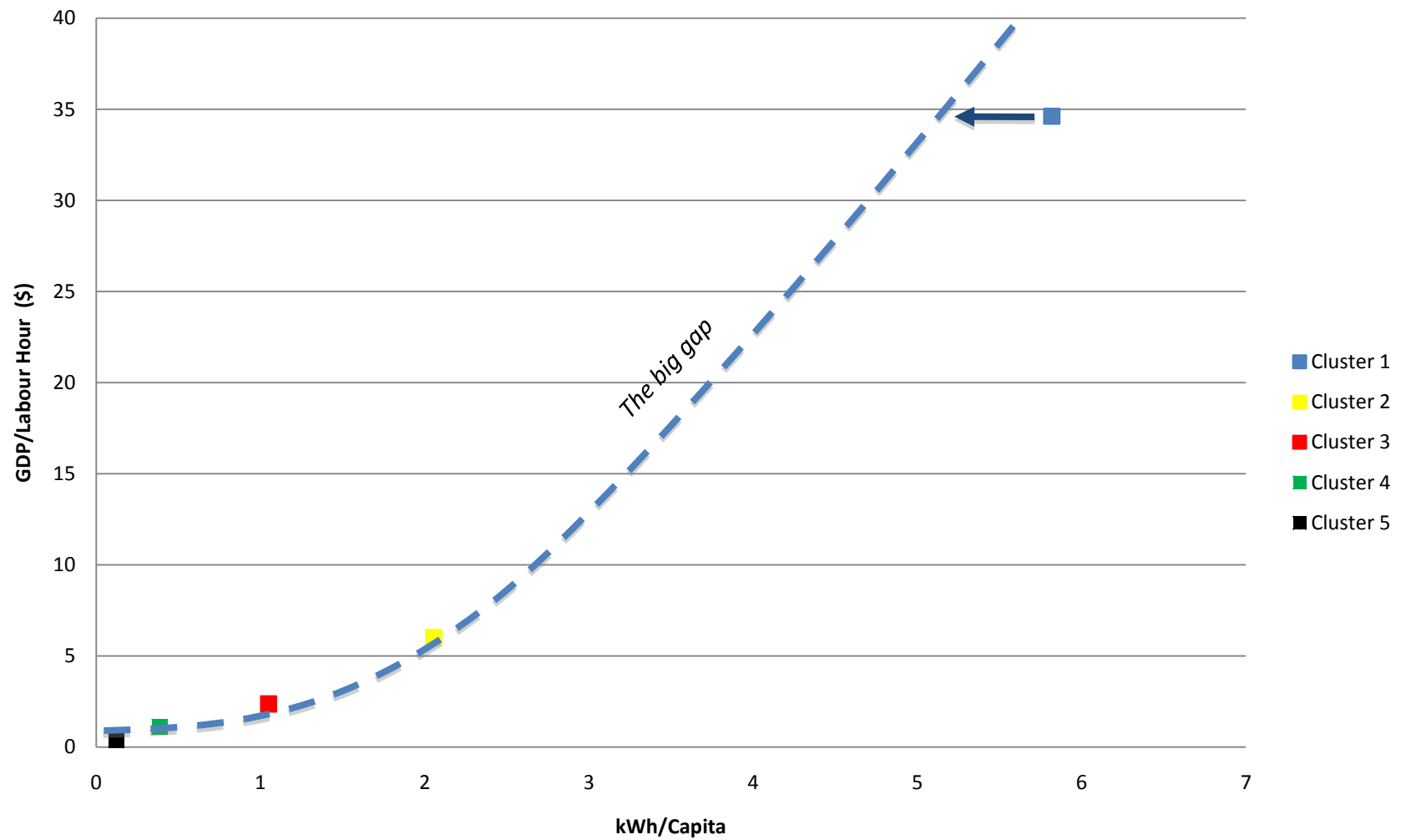- The GDP/cap increases *linearly* with the labor productivity (GDP/Lhr): tools and skills
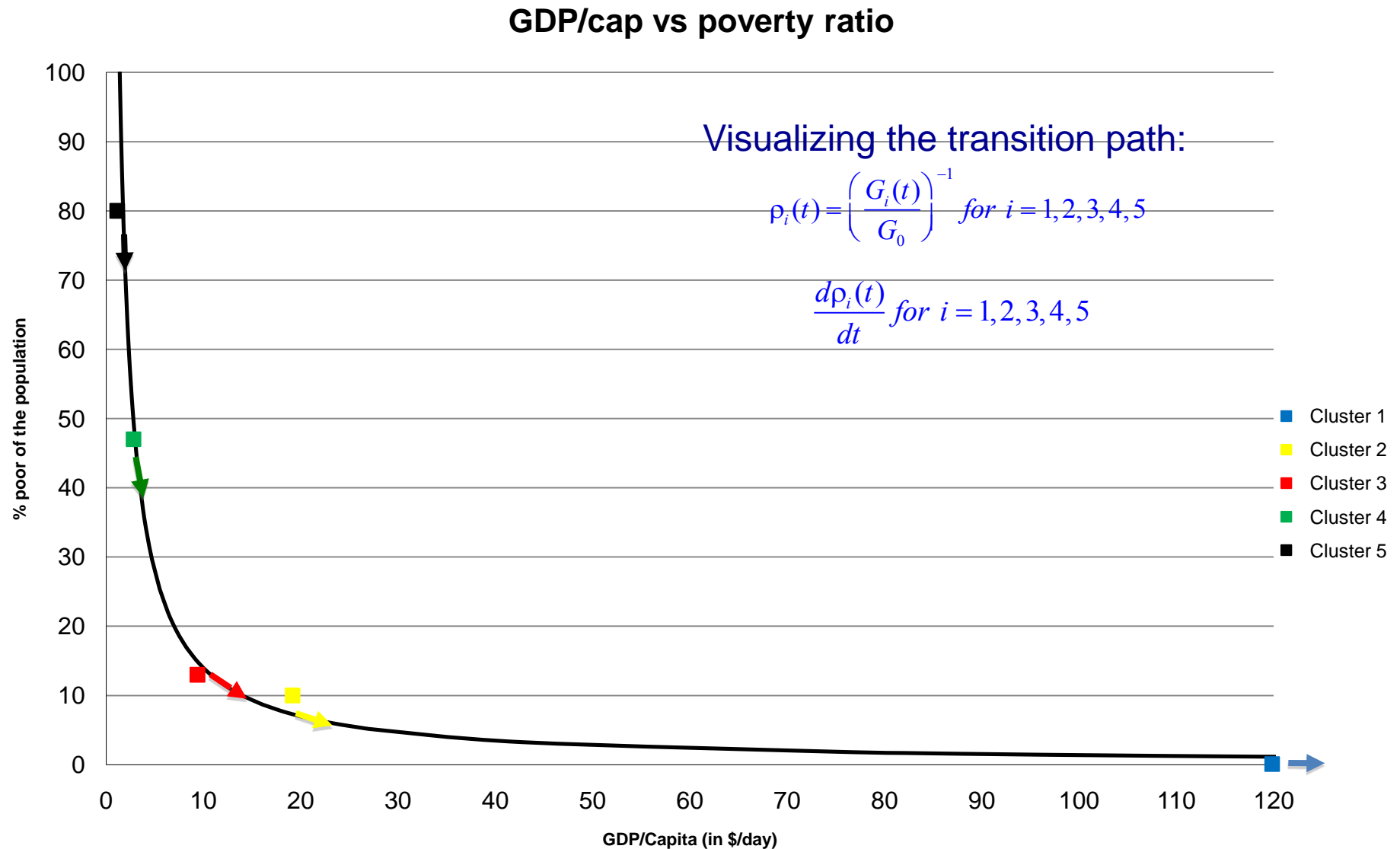
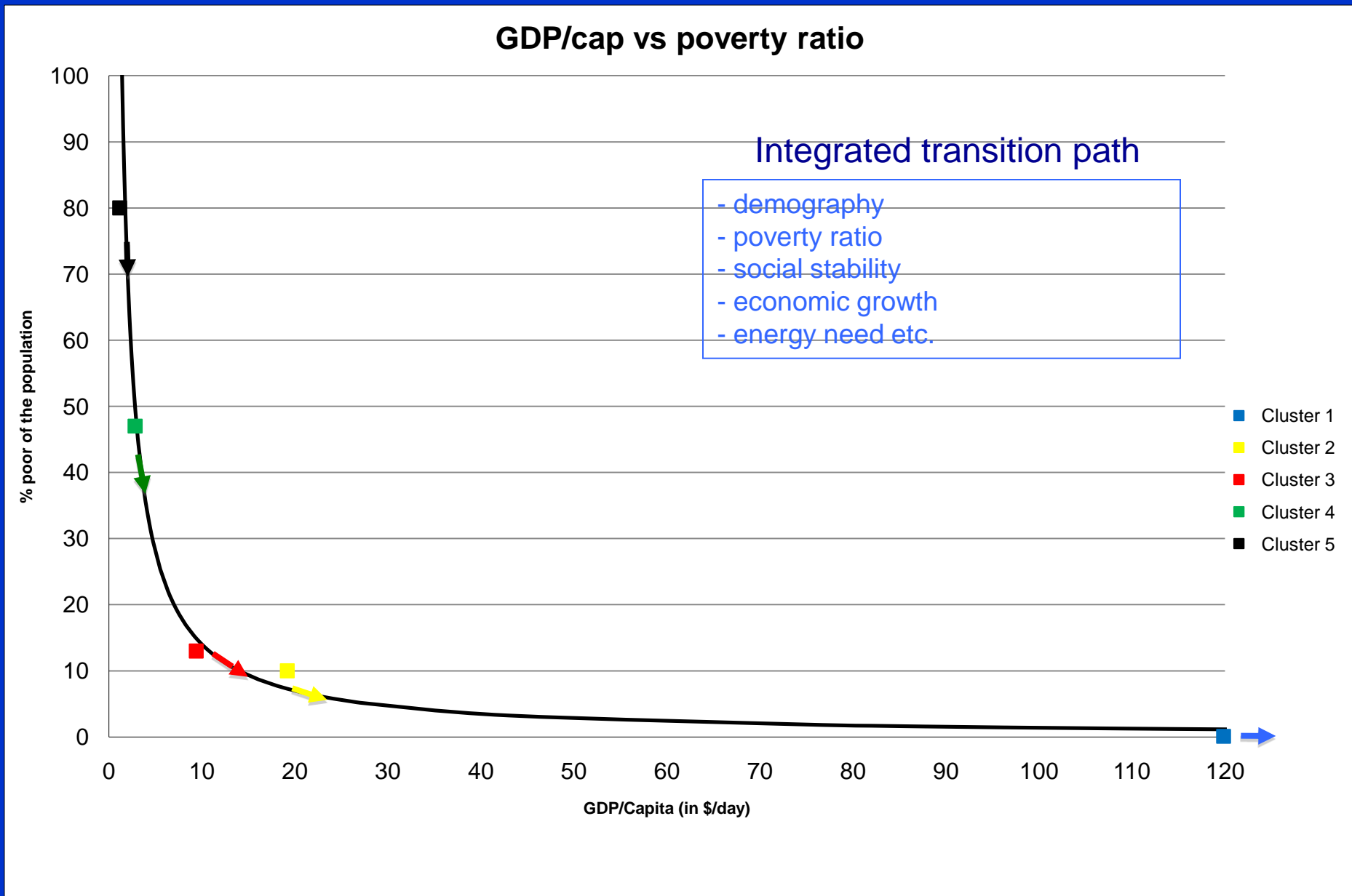For higher labour productivity we need much more energy

Important Observations

- For a decrease in global poverty, the GDP/cap must increase: economic development programme

- The GDP/cap increases *linearly* with the labor productivity (GDP/Lhr): technology and skills

- The labour productivity increases *exponentially* with the energy consumption (kWh/cap): advanced technology needs energy

Forecasting World Poverty: snapshot shows transition path!

GDP/cap vs poverty ratio

Visualizing the transition path:

$$\rho_i(t) = \left(\frac{G_i(t)}{G_0}\right)^{-1} \ for \ i = 1, 2, 3, 4, 5$$

$$\frac{d\rho_i(t)}{dt} \ for \ i = 1, 2, 3, 4, 5$$

% poor of the population

GDP/Capita (in $/day)

- Cluster 1
- Cluster 2
- Cluster 3
- Cluster 4
- Cluster 5

Cluster based forecasting: *socio-economic system approach*

GDP/cap vs poverty ratio

Integrated transition path

- demography
- poverty ratio
- social stability
- economic growth
- energy need etc.

- Cluster 1
- Cluster 2
- Cluster 3
- Cluster 4
- Cluster 5

Y-axis: % poor of the population (0 to 100)
X-axis: GDP/Capita (in $/day) (0 to 120)

Using the rate of change of each cluster along the GPR-curve, the total energy demand can be forecasted in an integrated socio-economic manner

Conclusion: five global clusters

- The world's population can be subdivided into five different categories of nations, leading to five global clusters with distinctly different socio-economic regimes

Solution to poverty: access to energy

- The world's population can be subdivided into five different categories of nations, leading to five global clusters with distinctly different socio-economic regimes

- The world's poverty decreases with increasing energy consumption according to an exponential law, making *access to energy* a vital component in the solution of the poverty problem

Success: more energy consumption

- The world's population can be subdivided into five different categories of nations, leading to five global clusters with distinctly different socio-economic regimes

- The world's poverty decreases with increasing energy consumption according to an exponential law, making *access to energy* a vital component in the solution of the poverty problem

- Growth of the world energy consumption is accelerated by success of the UN poverty programme

Part III:

Energy and Environment

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System Presentation of the Energy Economy

GDP ← P_e ← Q_e ← F_e ← N

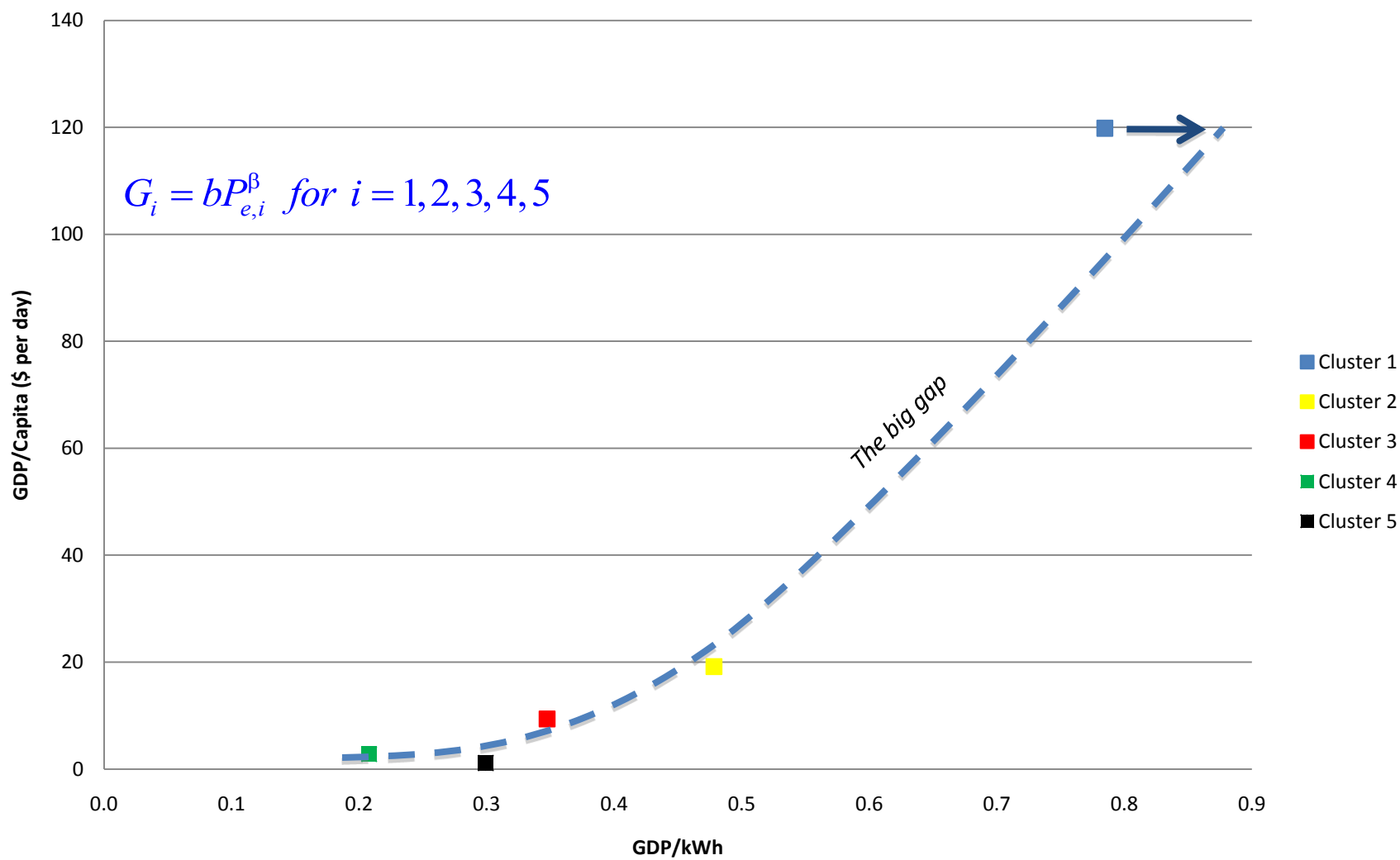$$GDP = \frac{k\$}{kW} \times \frac{kW}{kton} \times \frac{kton}{N} \times N$$

or

$$GDP = P_e \times Q_e \times F_e \times N$$

More energy productivity leads to more prosperity

$$G_i = bP_{e,i}^{\beta} \ \ for \ i = 1,2,3,4,5$$

The big gap

GDP/Capita ($ per day)

GDP/kWh

- ■ Cluster 1
- ■ Cluster 2
- ■ Cluster 3
- ■ Cluster 4
- ■ Cluster 5

More energy productivity leads to more prosperity

Visualizing the transition path:

$$G_i(t) = bP_{e,i}^{\beta}(t) \ for \ i = 1, 2, 3, 4, 5$$

Rate of change: $\dfrac{dG_i(t)}{dt} for \ i = 1, 2, 3, 4, 5$

Legend:
- Cluster 1
- Cluster 2
- Cluster 3
- Cluster 4
- Cluster 5

Y-axis: GDP/Capita ($ per day)
X-axis: GDP/kWh
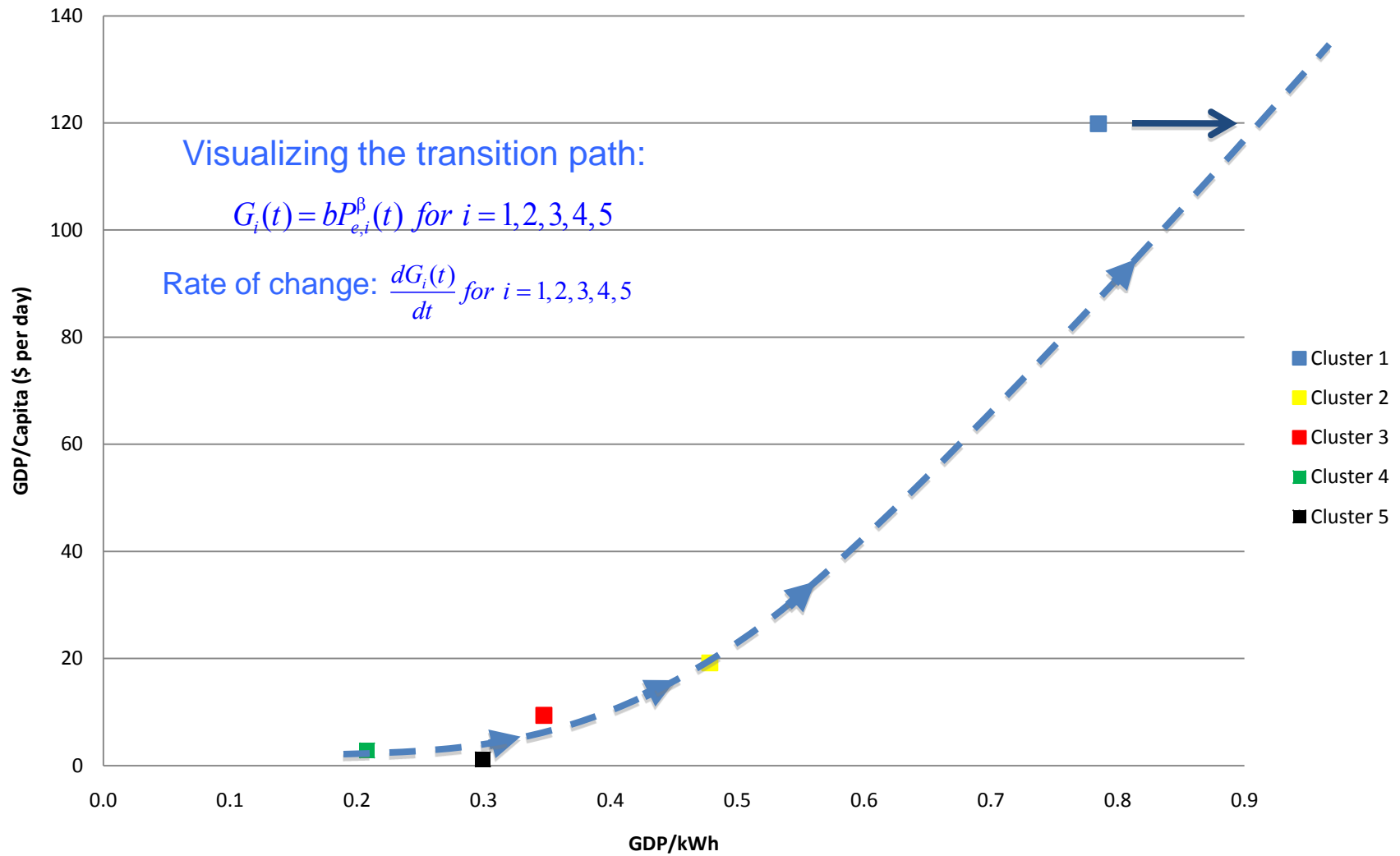
Traditional Economic Growth

$$G = GDP/N$$

$$\frac{\Delta G(t)}{G(t)} = \frac{\Delta P_e(t)}{P_e(t)} + \frac{\Delta Q_e(t)}{Q_e(t)} + \frac{\Delta F_e(t)}{F_e(t)}$$

- Raise energy productivity $(\Delta \mathrm{P}_e > 0)$

- Increase amount of energy per emitted kton $(\Delta \mathrm{Q}_e > 0)$

- Accept increase in footprint $(\Delta \mathrm{F}_e > 0)$

A lot of detailed information of each cluster is available; the model brings it together

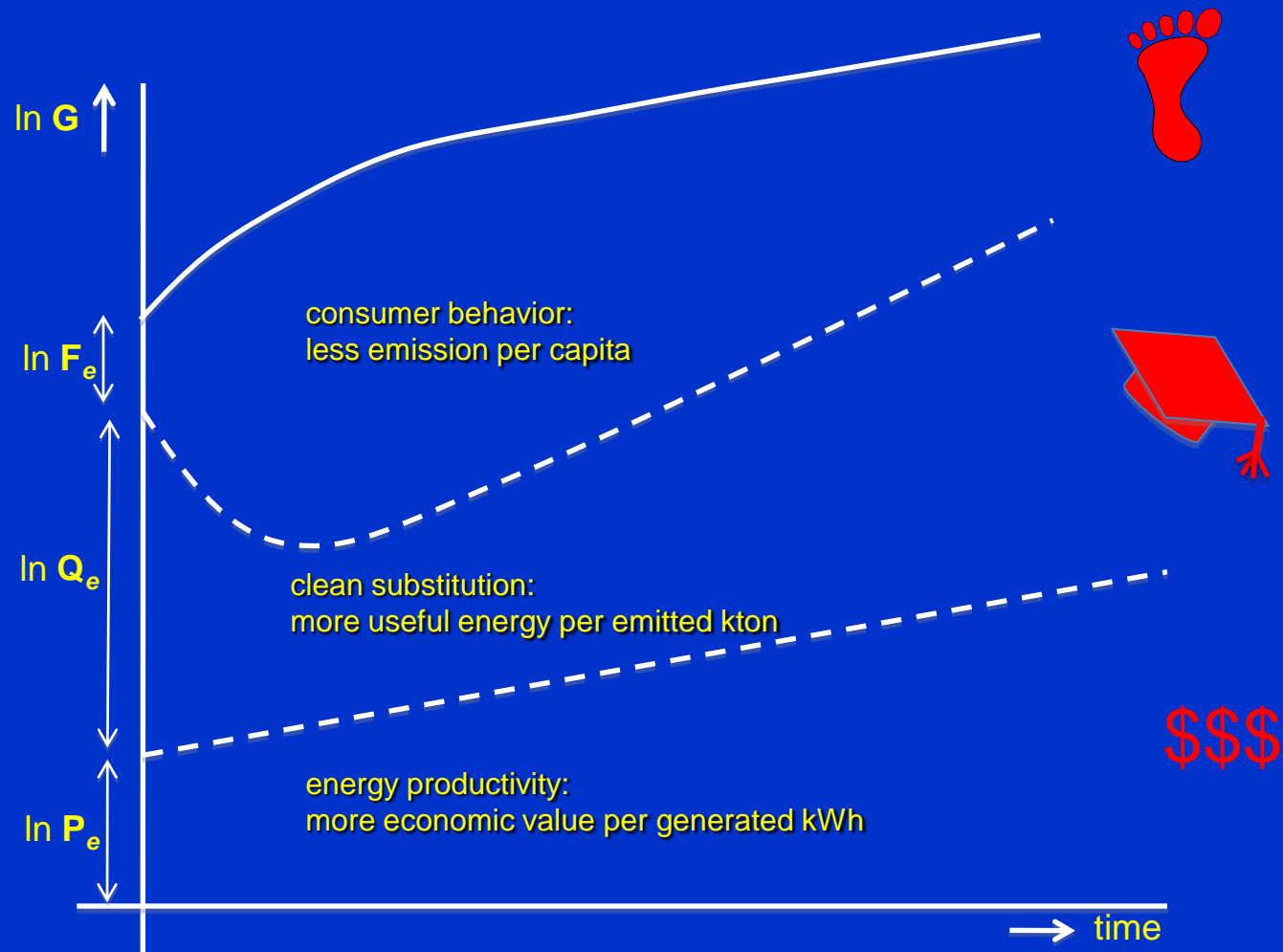# Sustainable Economic Growth: 'Green GDP'

$$G = GDP/N$$

$$\frac{\Delta G(t)}{G(t)} = \frac{\Delta P_e(t)}{P_e(t)} + \frac{\Delta Q_e(t)}{Q_e(t)} + \frac{\Delta F_e(t)}{F_e(t)}$$

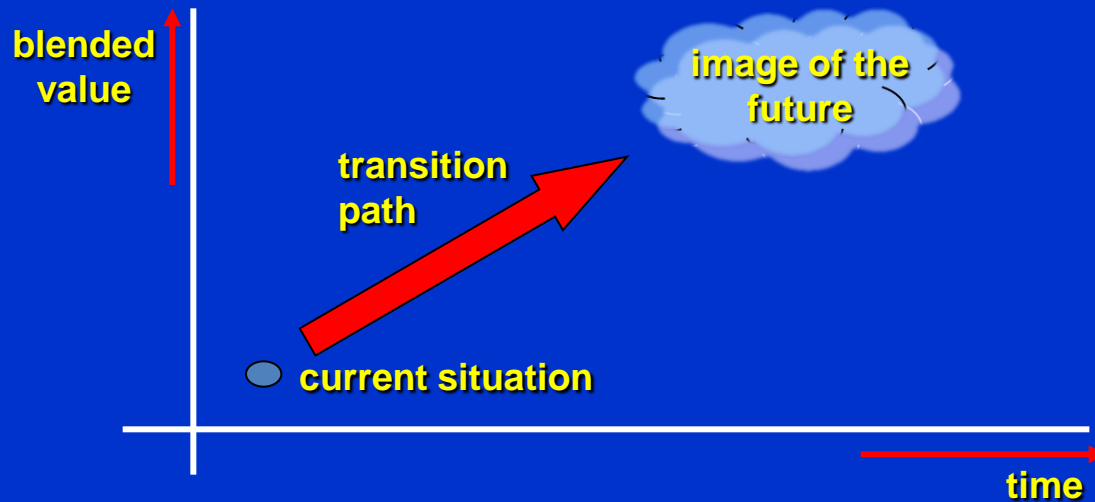Energy transition:
decrease footprint ($\Delta F_e < 0$)

with the constraint that ($\Delta G > 0$)

Increasing Prosperity ánd Decreasing the Footprint
(optimized for each socio-economic regime)

ln **G** ↑

ln **F$_e$**

consumer behavior:
less emission per capita

ln **Q$_e$**

clean substitution:
more useful energy per emitted kton

ln **P$_e$**

energy productivity:
more economic value per generated kWh

→ time

$$$

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Part IV:

More to come ....

Vision Building

blended value

image of the future

transition path

current situation

time

- *Multi-value targets*

- *Flexible transition paths*

- *Self-organized workflows*

Multi-value target for the energy industry:
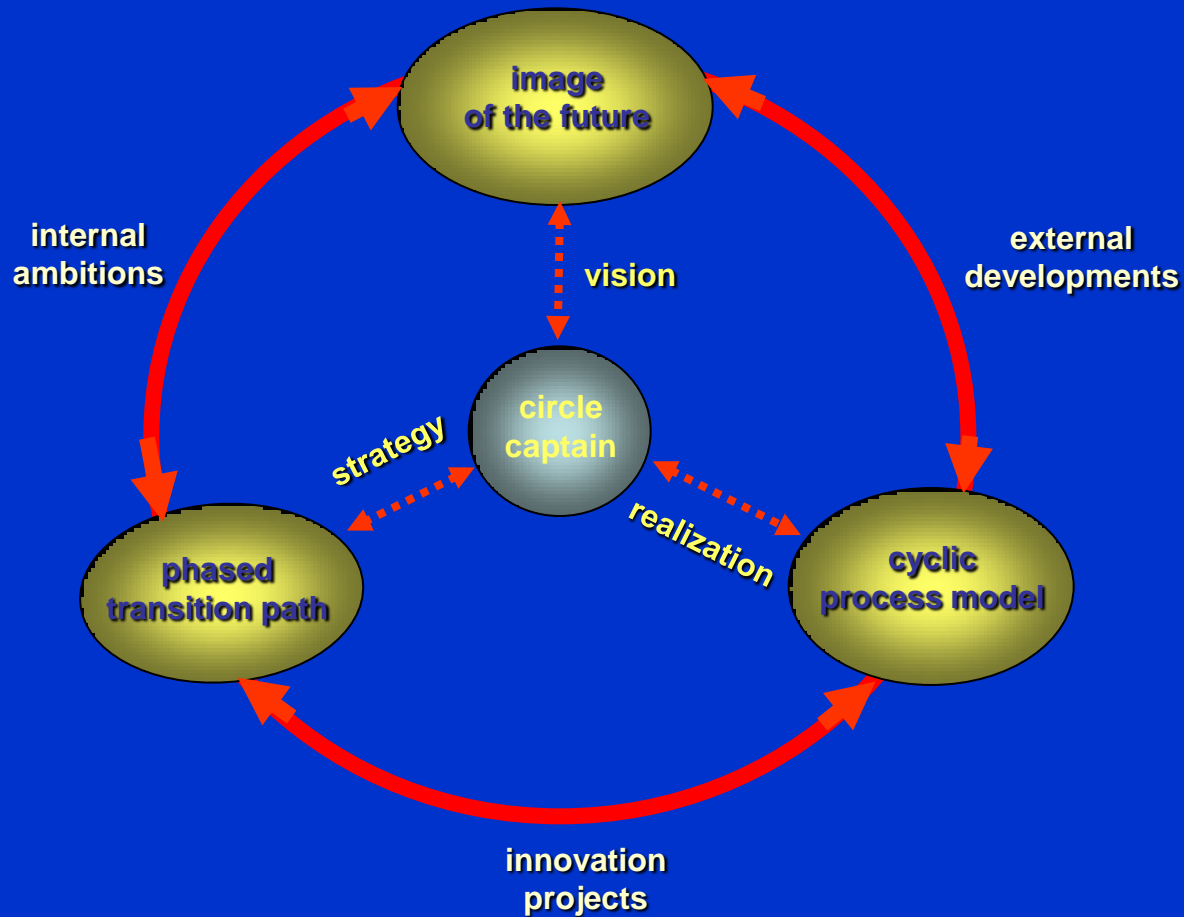
Green Energy for everybody at affordable prices

There is more to come ………..

Connect the energy transition path with the poverty transition path

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There is more to come ………..

Connect the energy transition path with the environmental transition path

Shell's Future Leadership

Shell's Future Leadership

focus on
multi-value targets

build
GPR-scenarios

image
of the future

internal
ambitions

external
developments

vision

circle
captain

strategy

realization

phased
transition path

cyclic
process model

innovation
projects

optimize the
energy mixes

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