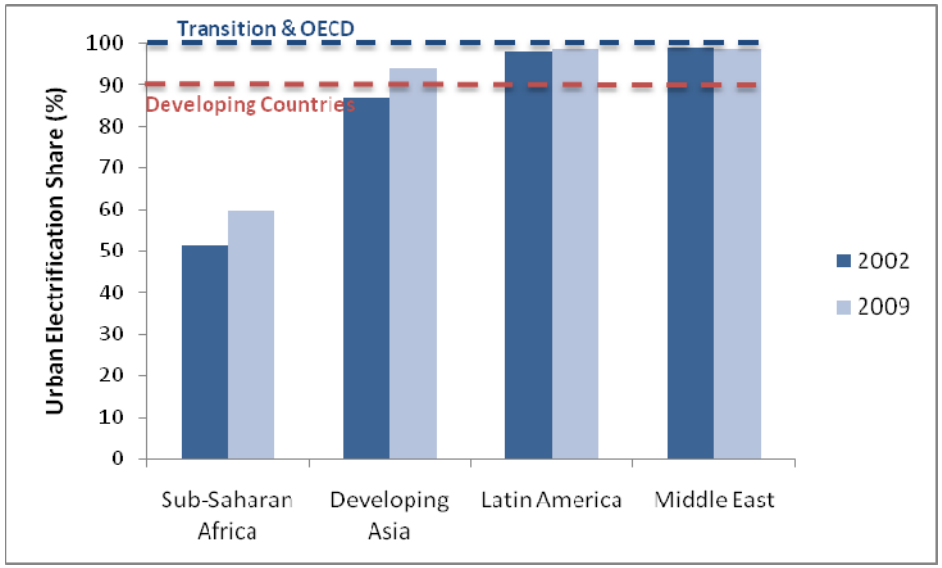
Economic comparison of distributed technologies and grid extension, potential financial schemes I.

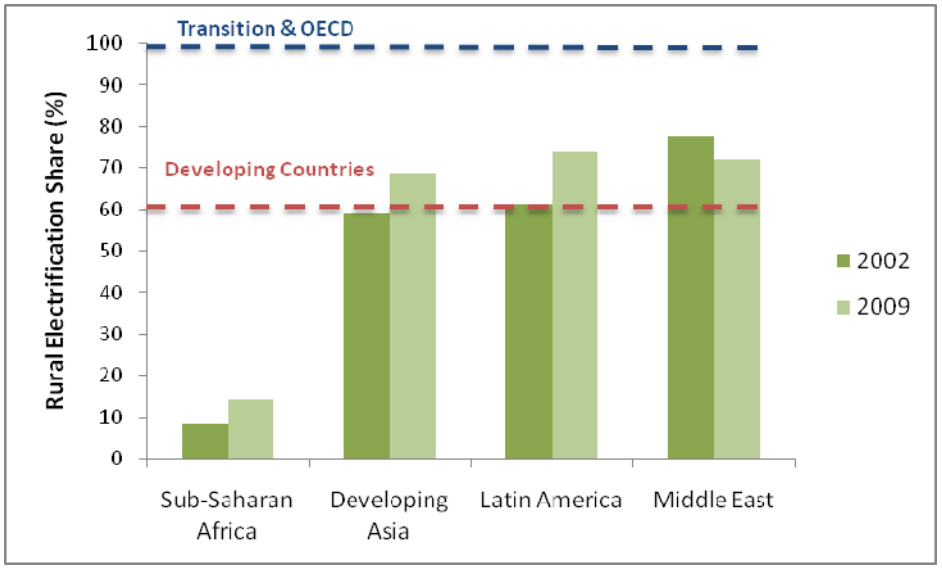
Sándor Szabó

JRC

Economic comparison of distributed technologies and grid extension

Evolution of electrification share for (a) urban and (b) rural areas (2002-2009)





Source: Data compiled from IEA, World Energy Outlook 2010

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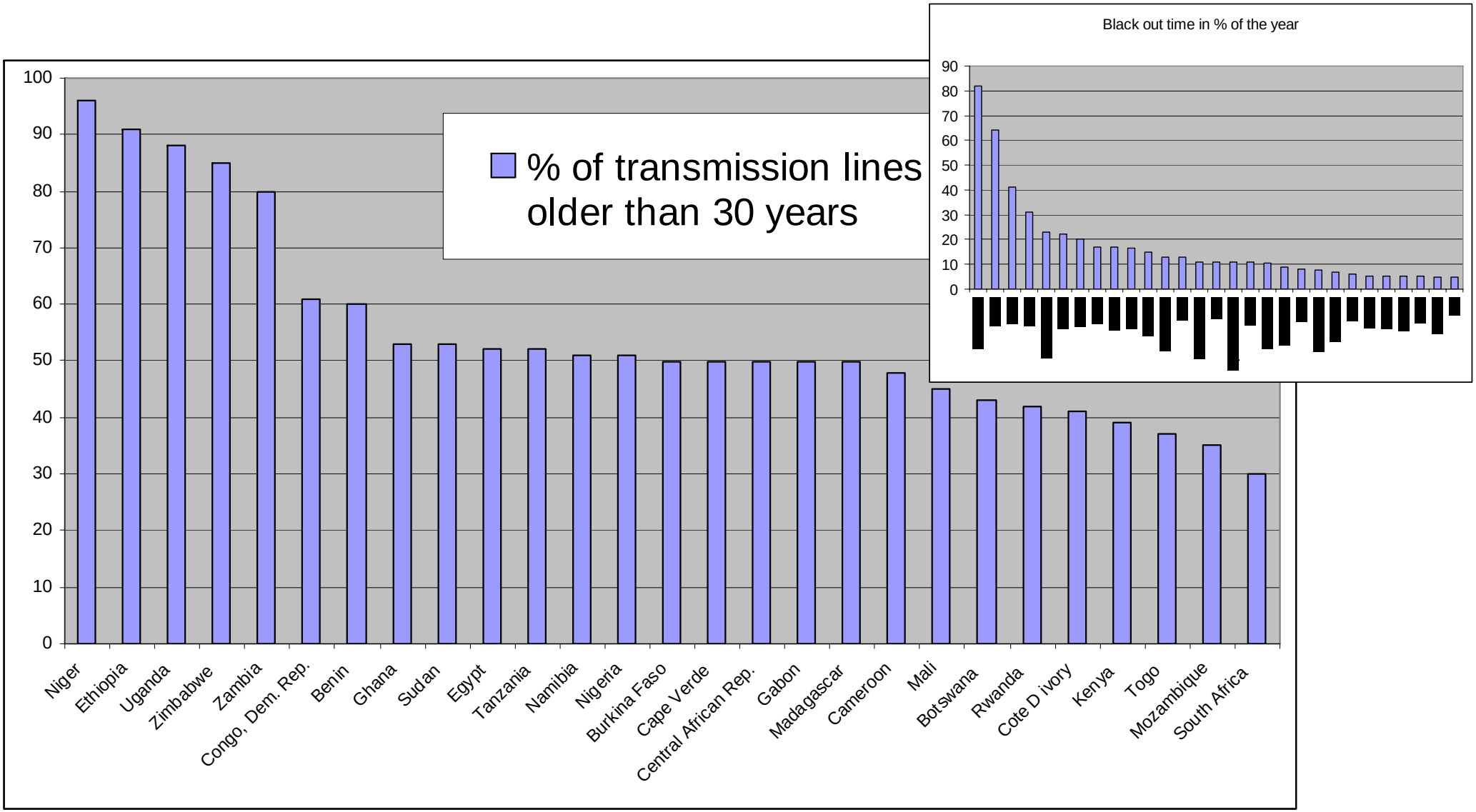
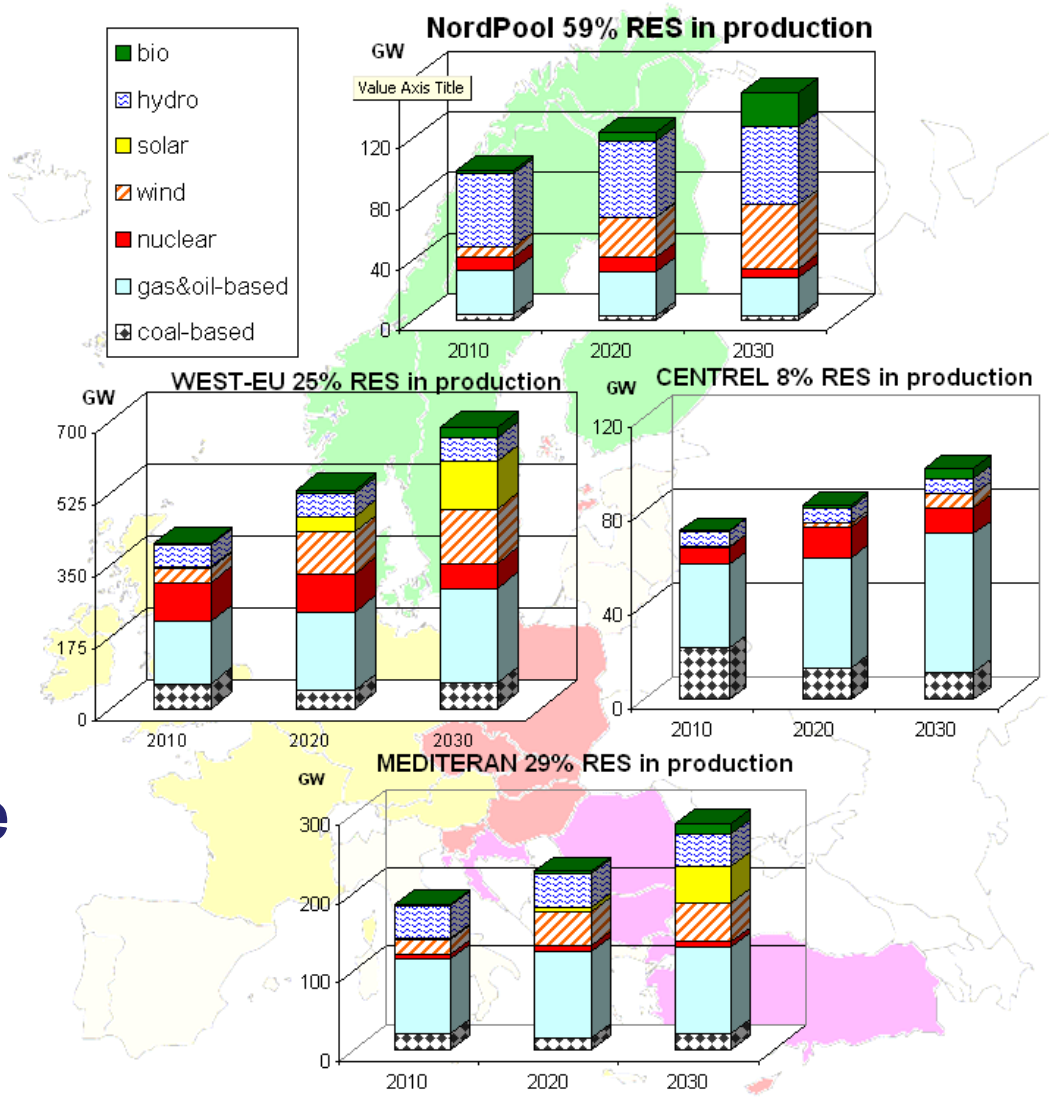
The grid status parameters in Africa



The existing grid infrastructure makes a huge difference between the Planning of Renewable Energy Sources (RES) in Europe and in Africa. In Europe all RES can be feed into the grid without excessive integration costs. It is not the case in Africa.



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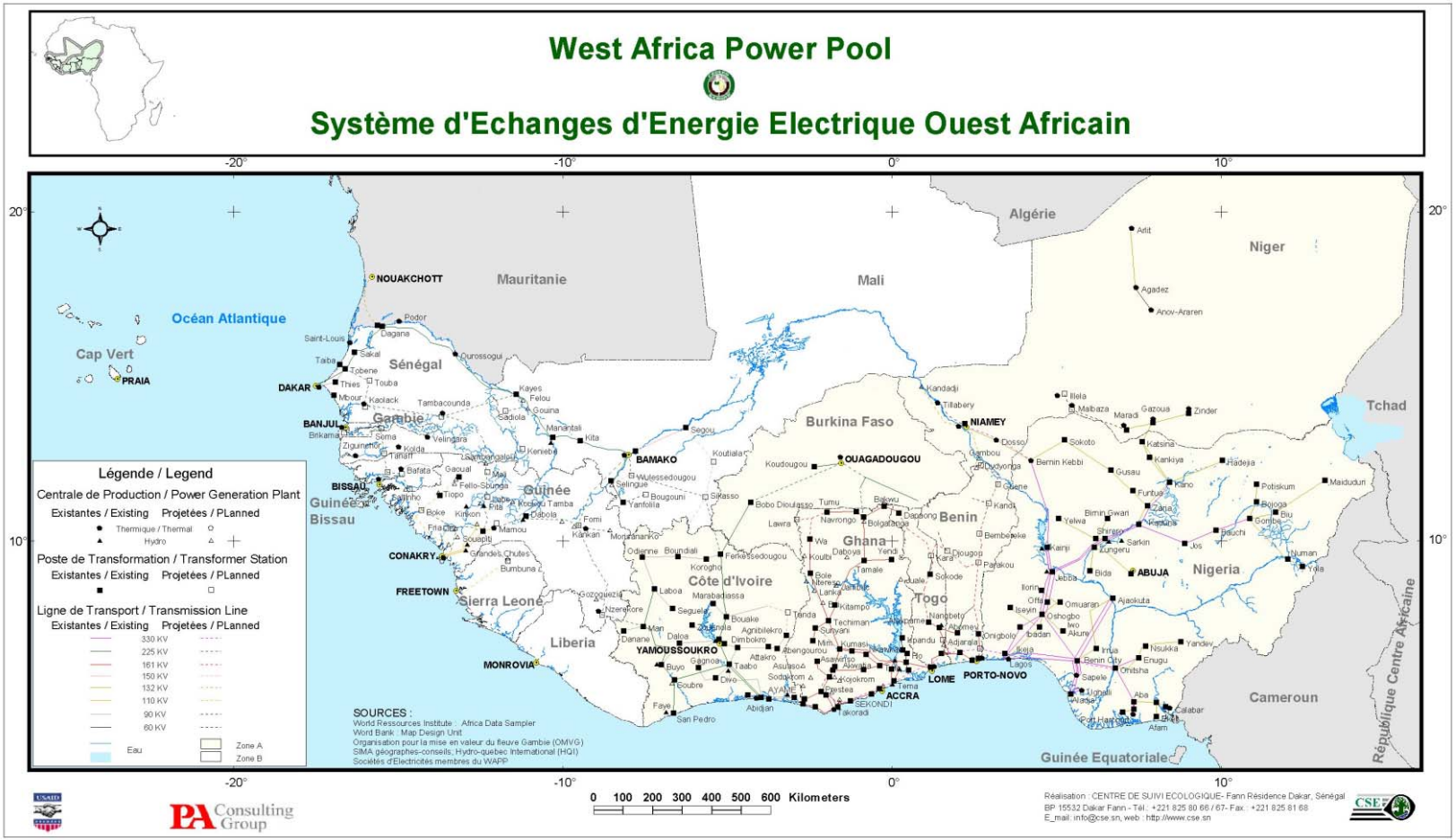
Collecting available grid maps …



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…but in digital form

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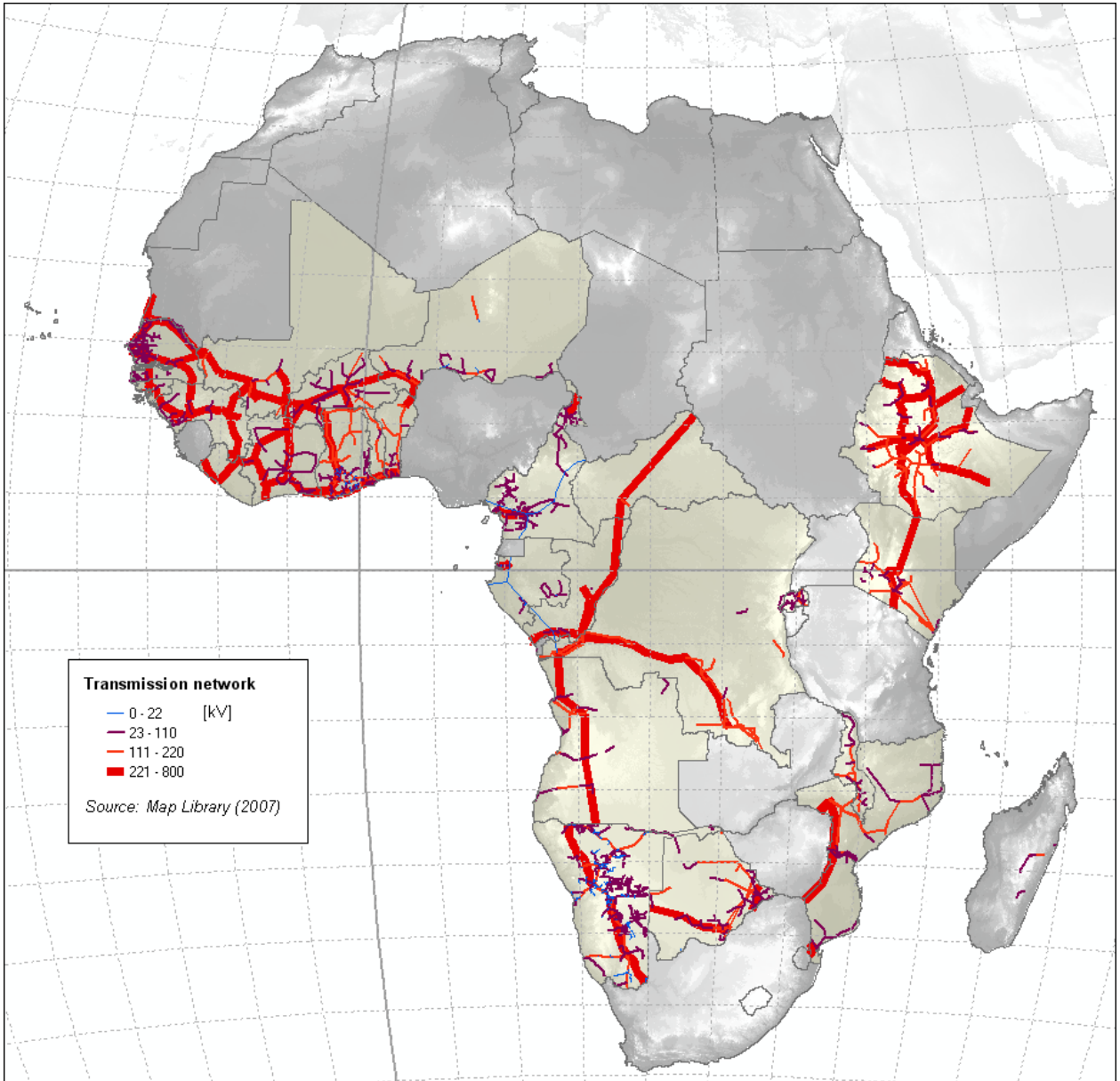
Aggregation of the maps to continental level



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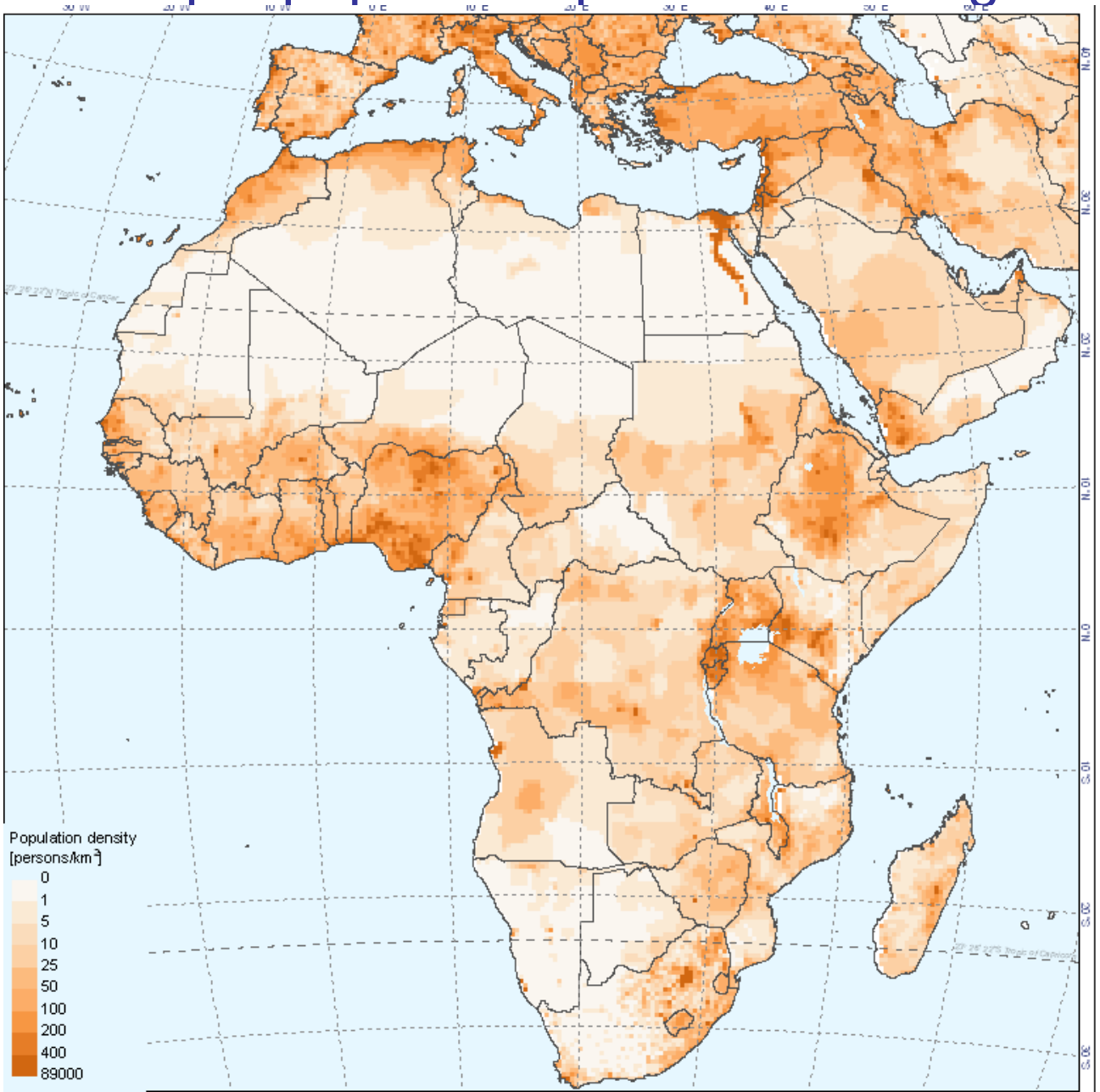
Africa has a unique population pattern with huge rural areas



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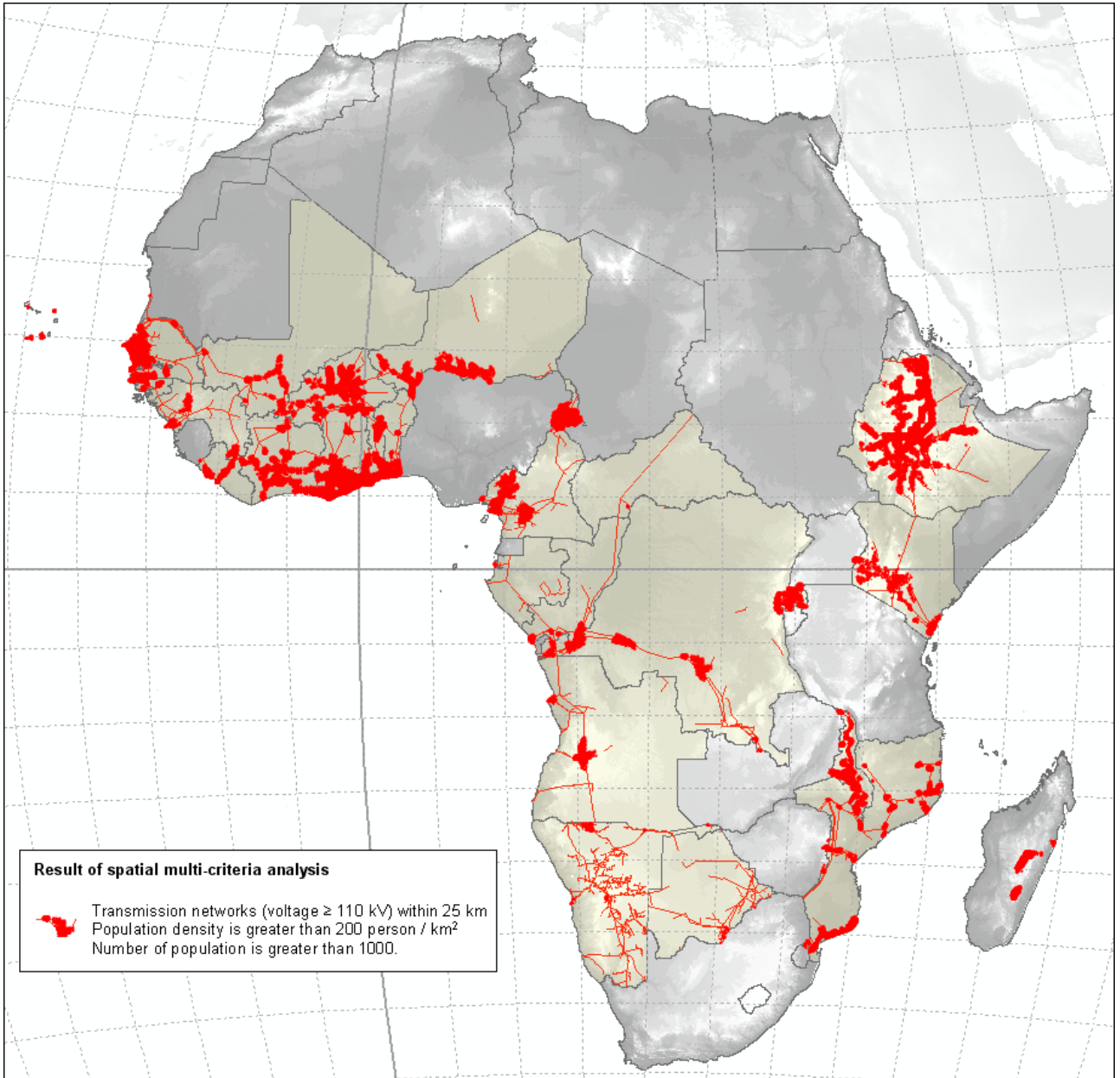
The grid is extended to the places with the high density population



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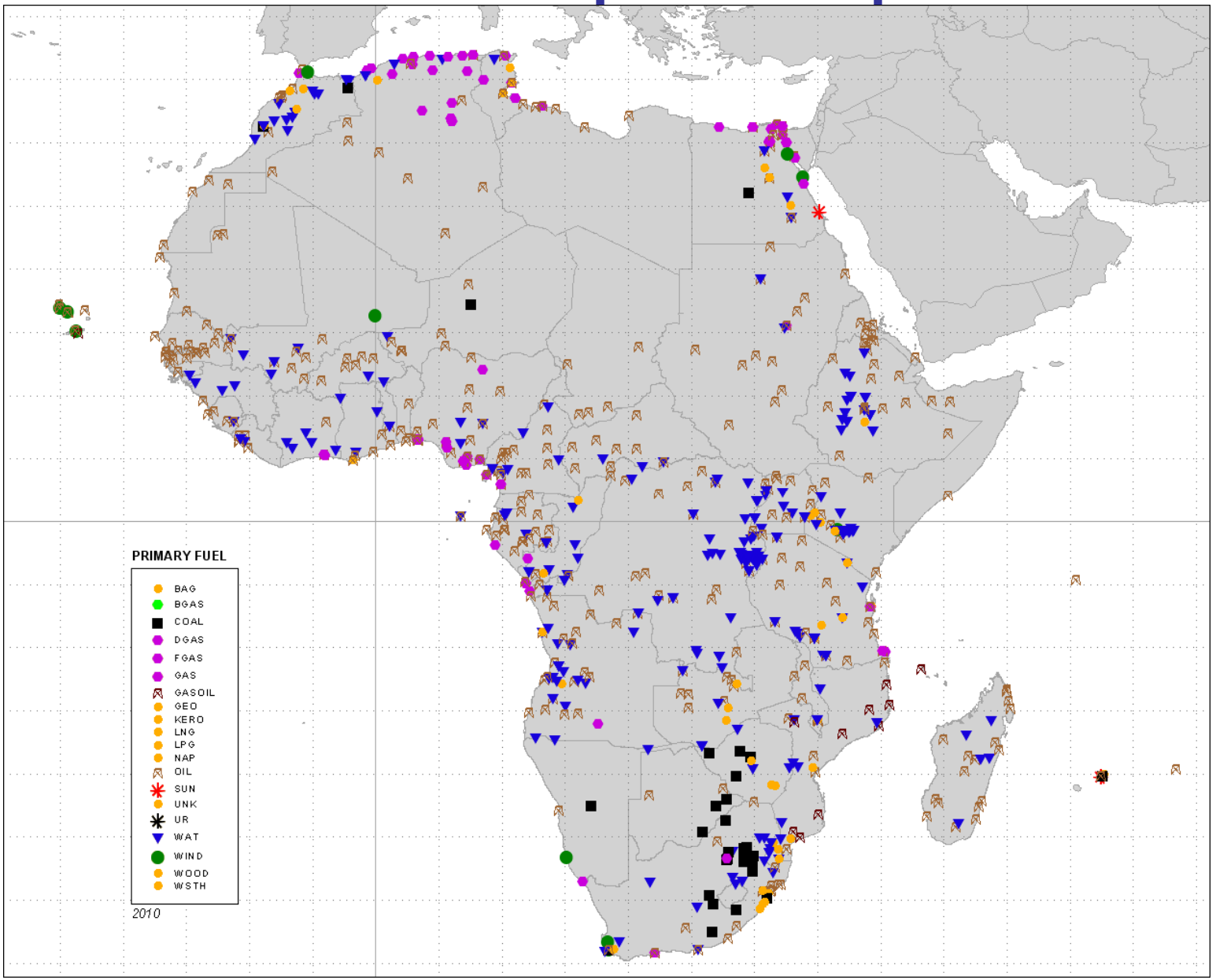
Conventional power plants



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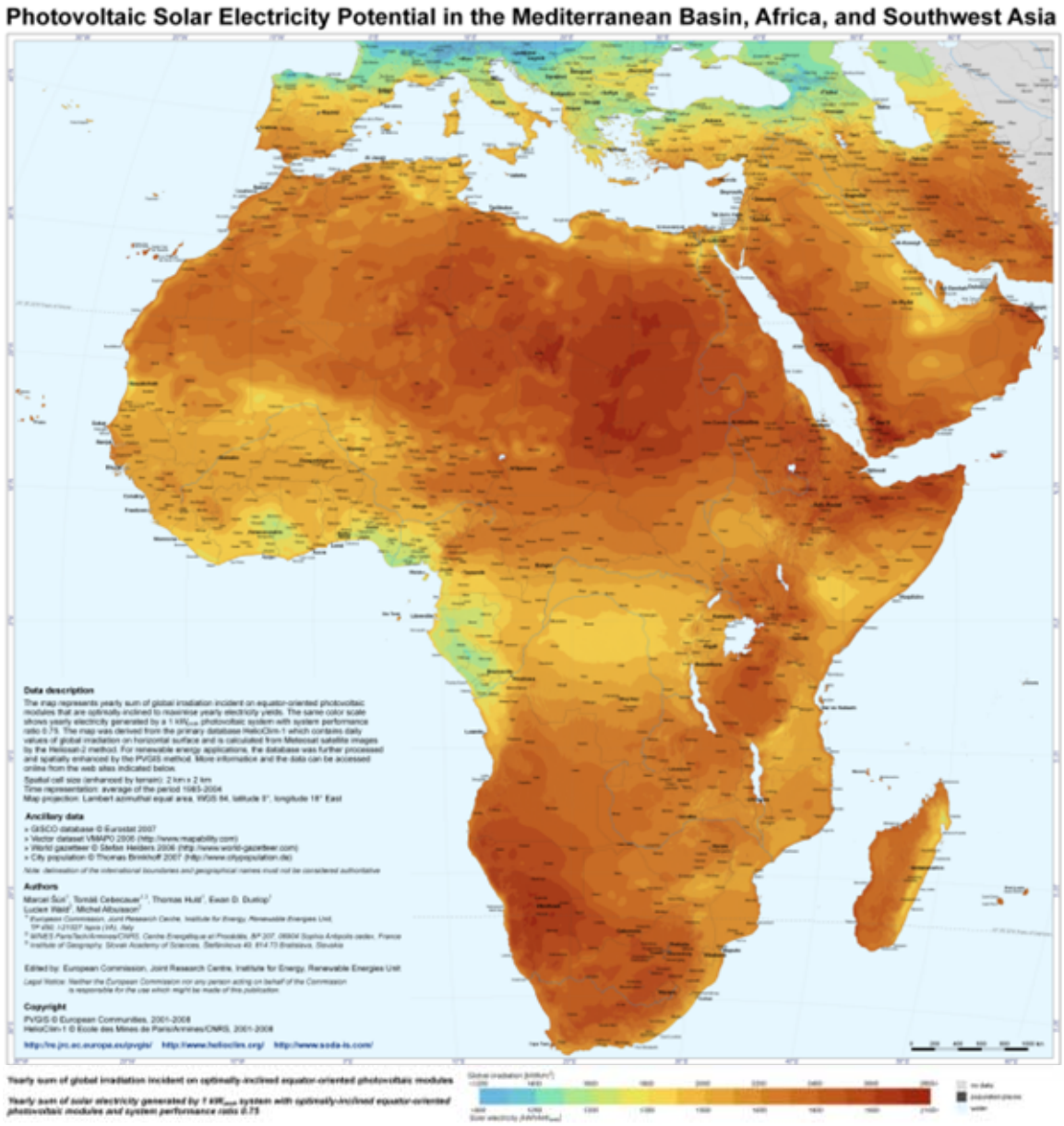
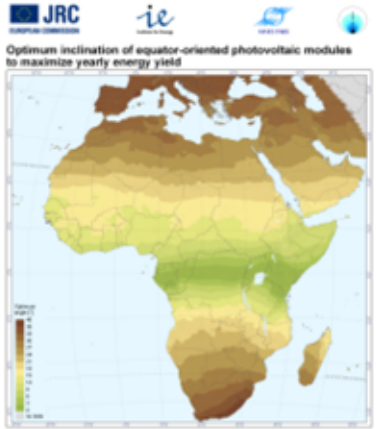
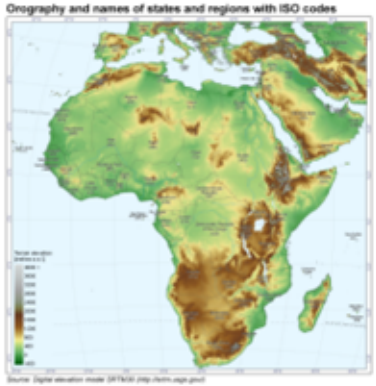
Accurate geographical information: strengthening the knowledge on solar, wind, hydro and biomass resources and their efficient use

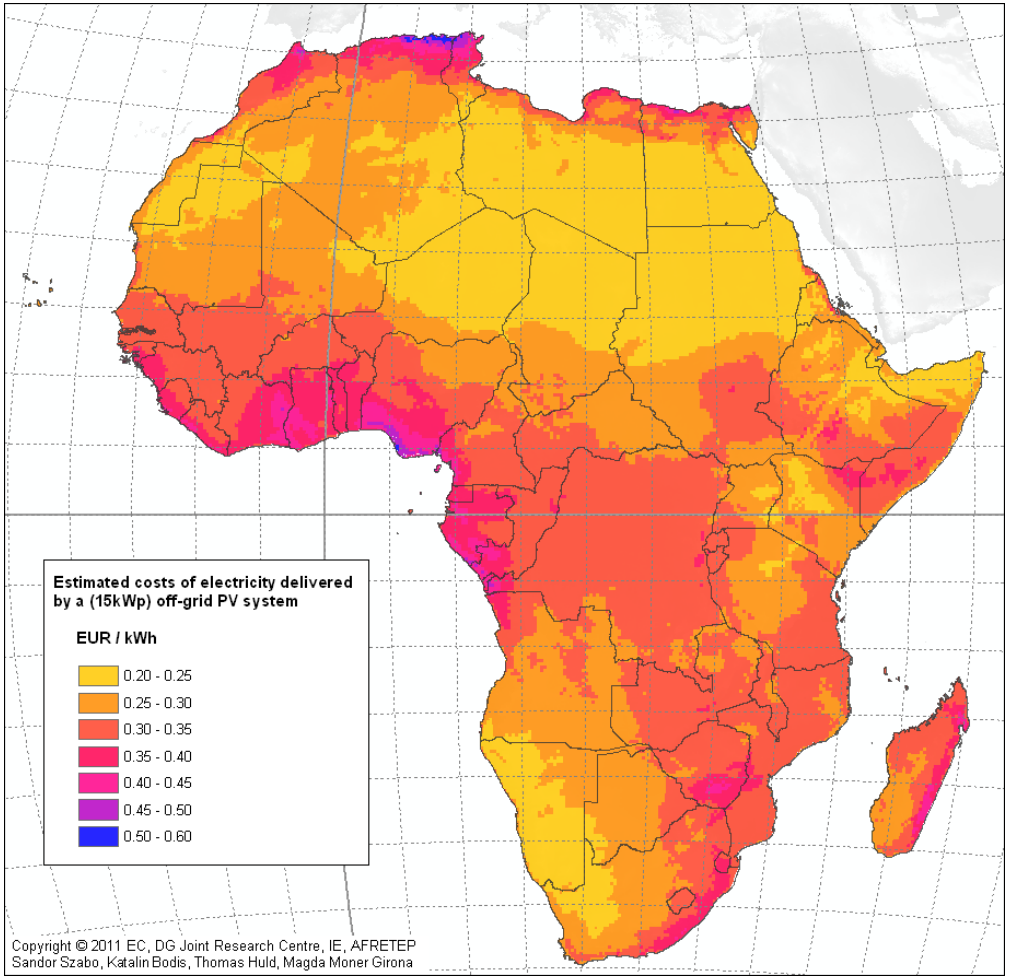






Solar resources

Estimated cost of the electricity delivered by a 15 kWp off-grid PV system



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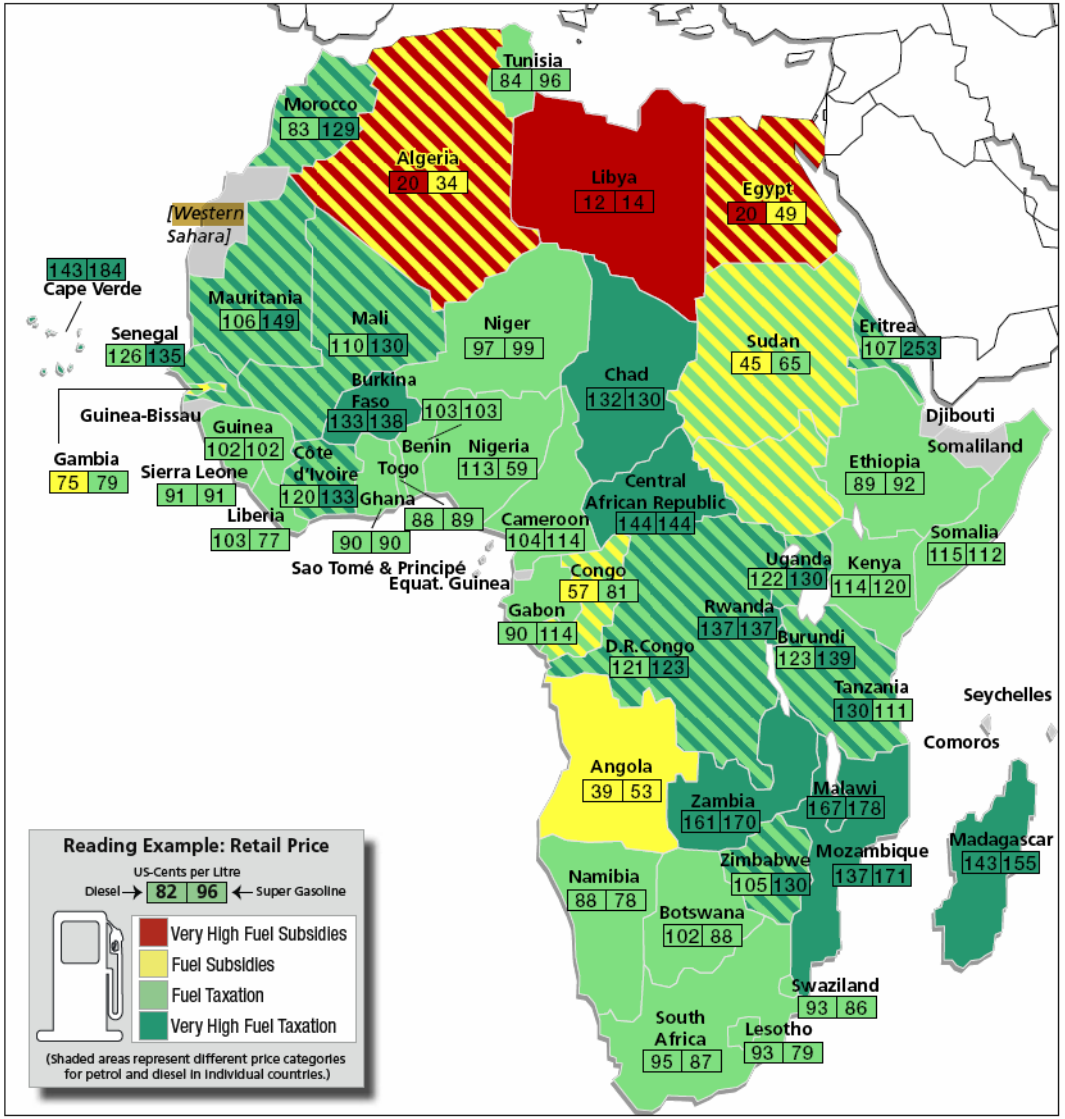
Retail diesel prices

2.1.1 Retail fuel prices in Africa
as of November 2008 (in US cents/litre)



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Travel time to major cities

Travel time map and accessibility model by Andrew Nelson. Agglomeration Index by Hiroshugu Uchida (The World Bank, URI) and Andrew Nelson. Land cover data from the Global Land Cover 2000 Project, http://www-gem.jrc.ec.europa.eu/glc2000. UN urban population data from the United Nations World Urbanization Prospects, http://esa.un.org/unup.

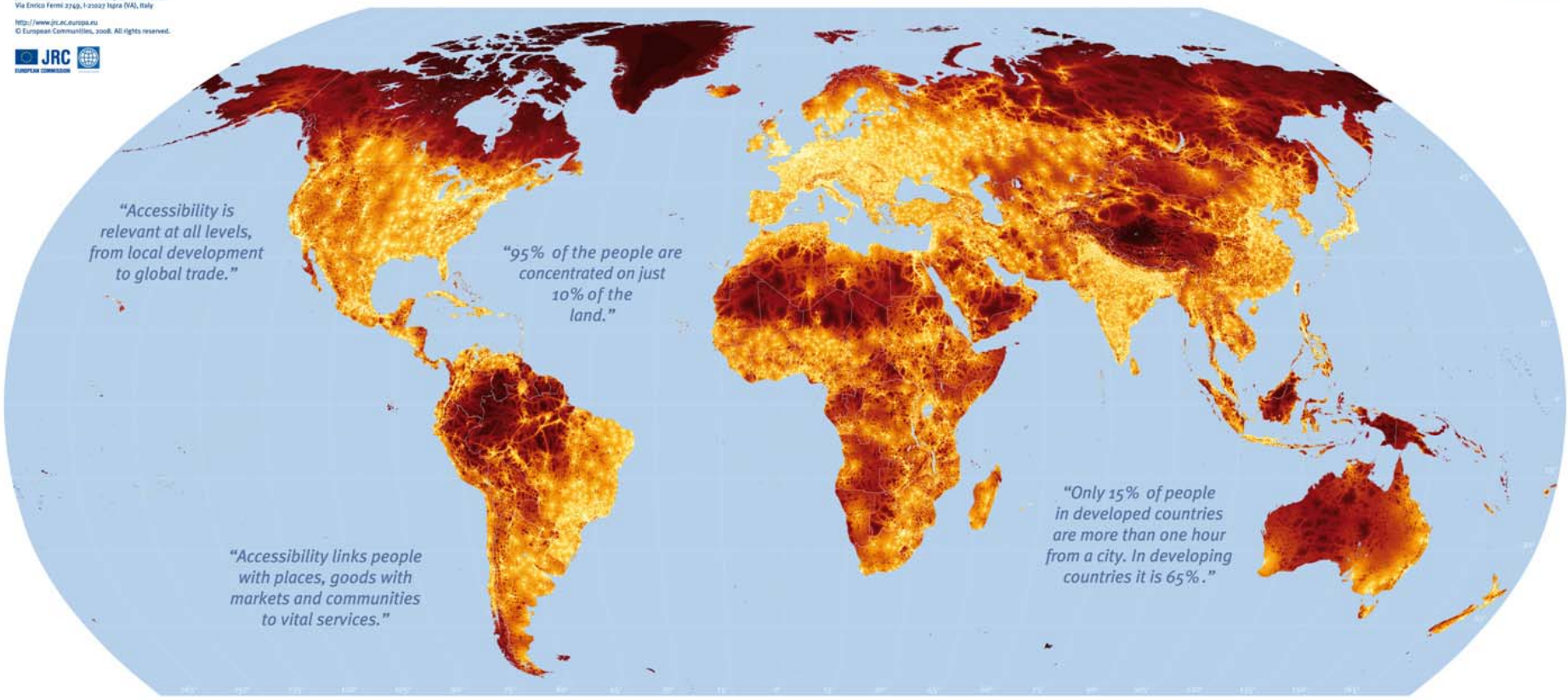
Global Environment Monitoring Unit
Institute for Environment and Sustainability
Joint Research Centre of the European Commission
Via Enrico Fermi 2749, I-21027 Ispra (VA), Italy

http://www.jrc.ec.europa.eu

Working title: Travel time to major cities: A global map of Accessibility

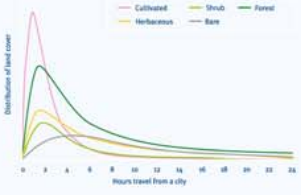
JRC47352
ISBN 978-92-79-09771-3
Catalogue number LB-30-08-671-EN-C

Language: EN
DOI: 10.2788/95835



Land cover patterns around cities

Travel time zones around a city can be used to define regions where particular economic activities are likely to take place. Almost 60% of all cultivated land is within two hours of a city. As urban areas expand, there is huge pressure to convert agricultural land to urban uses, and to convert more distant forests, grasslands and shrublands to agriculture. These patterns of land use around urban areas mirror one of the most important models of economic geography, Johann Heinrich von Thünen's model of The Isolated State, which links transport costs to land value.



Travel time in hours and days to the nearest city of 50,000 or more people

0 1 2 3 4 6 8 12 18 24 36 2d 3d 4d 5d 10d

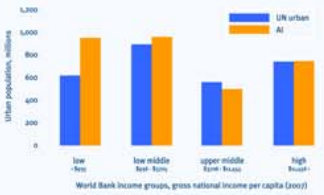
Travel time to major cities: A global map of Accessibility

Developed by the European Commission's Joint Research Centre for the World Bank's World Development Report 2009 "Reshaping Economic Geography".

Map colours represent travel time to the nearest city (8,518 cities with 50,000 or more people in the year 2000). Modes of travel are land and water based. The data resolution is 30 arc seconds. The map projection is Robinson. Digital datasets, the accessibility model, input data and more information at http://www-tem.jrc.ec.europa.eu/accessibility. The World Development Report is available at http://econ.worldbank.org. The delineation of national boundaries must not be considered authoritative.

Agglomeration Index (AI): A new measure of urban concentration and a more urbanised world

There is no standard definition of 'urban'. A new Agglomeration Index (World Bank & JRC), based on this Accessibility map, suggests that the global urban population in 2000 was 3.21 billion compared to the UN's total of 2.85 billion (53%, compared to 47% of the world). Most of the difference is in the developing world. This alternative definition of urbanisation suggests that the world may have passed the urbanisation tipping point – more people living in urban areas than in rural areas – much earlier than the 2007/8 estimate.



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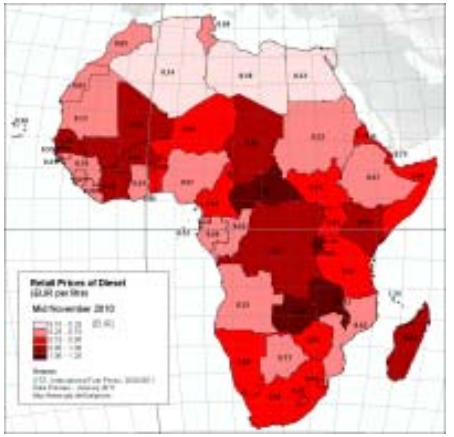
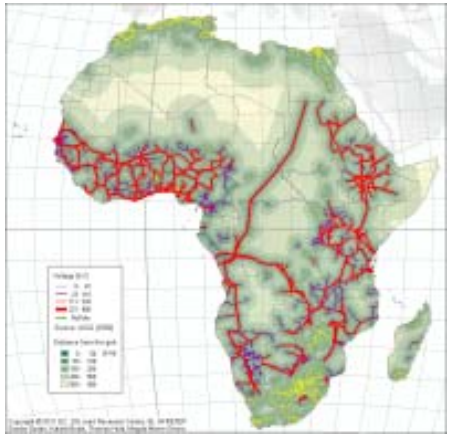
Socio - economic data layers

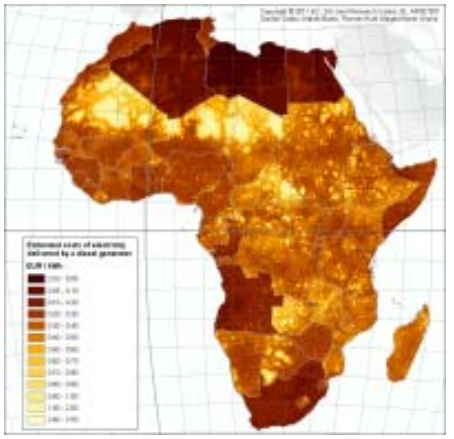
Populated places



National diesel prices



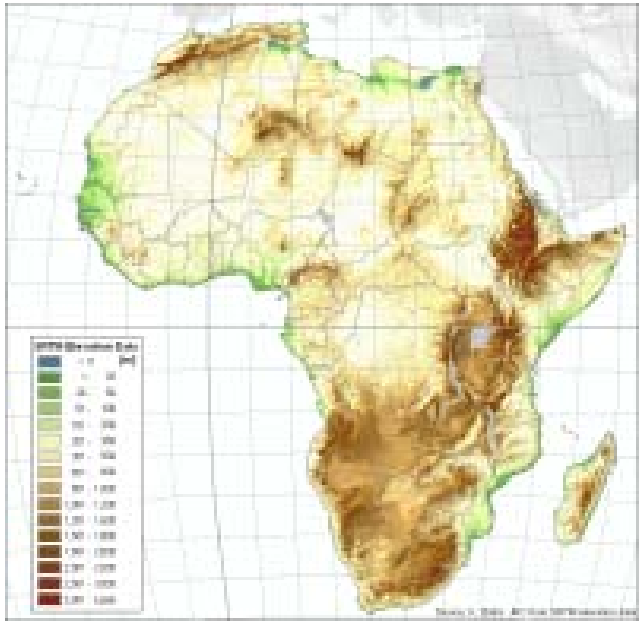
Distance from electricity gris



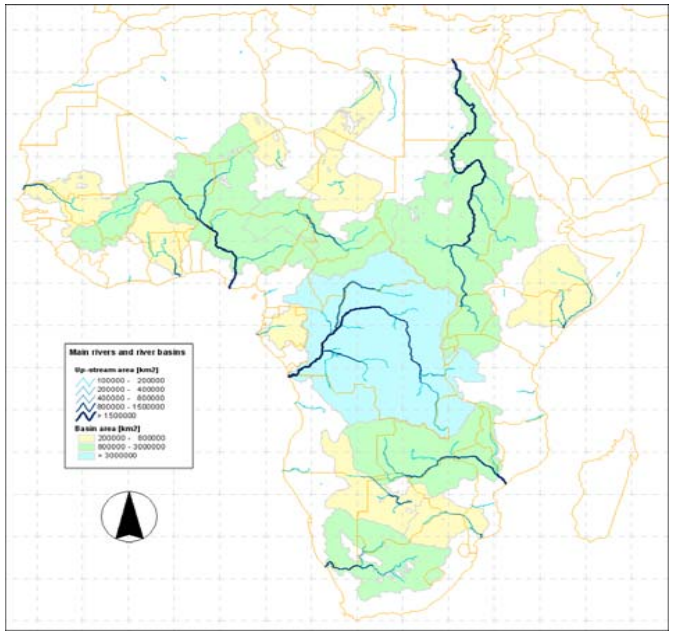
Diesel generated electricity cost including transport

PHYSICAL GEOGRAPHICAL DATA LAYERS

Digital Elevation Model (SRTM)



River network



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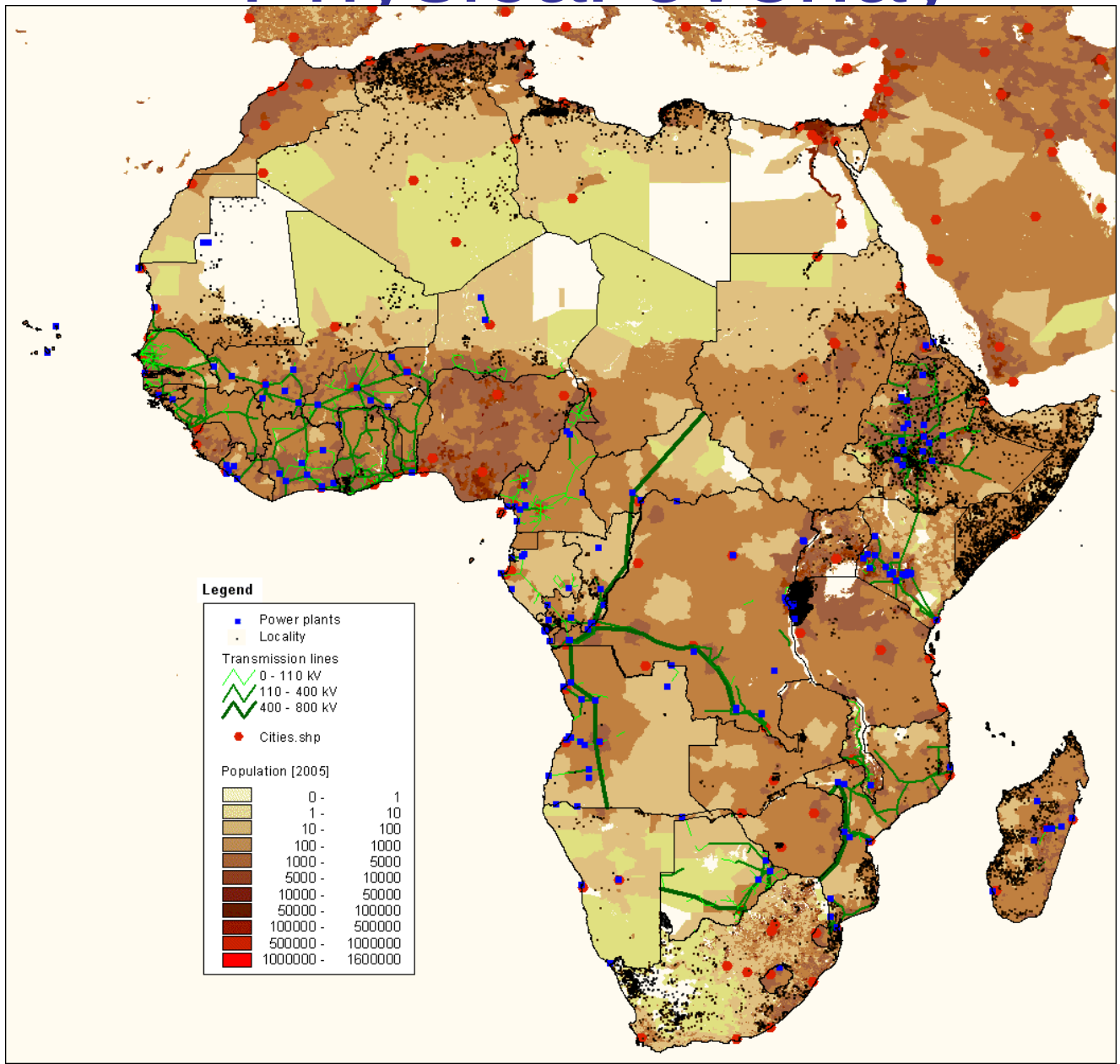
Physical overlay



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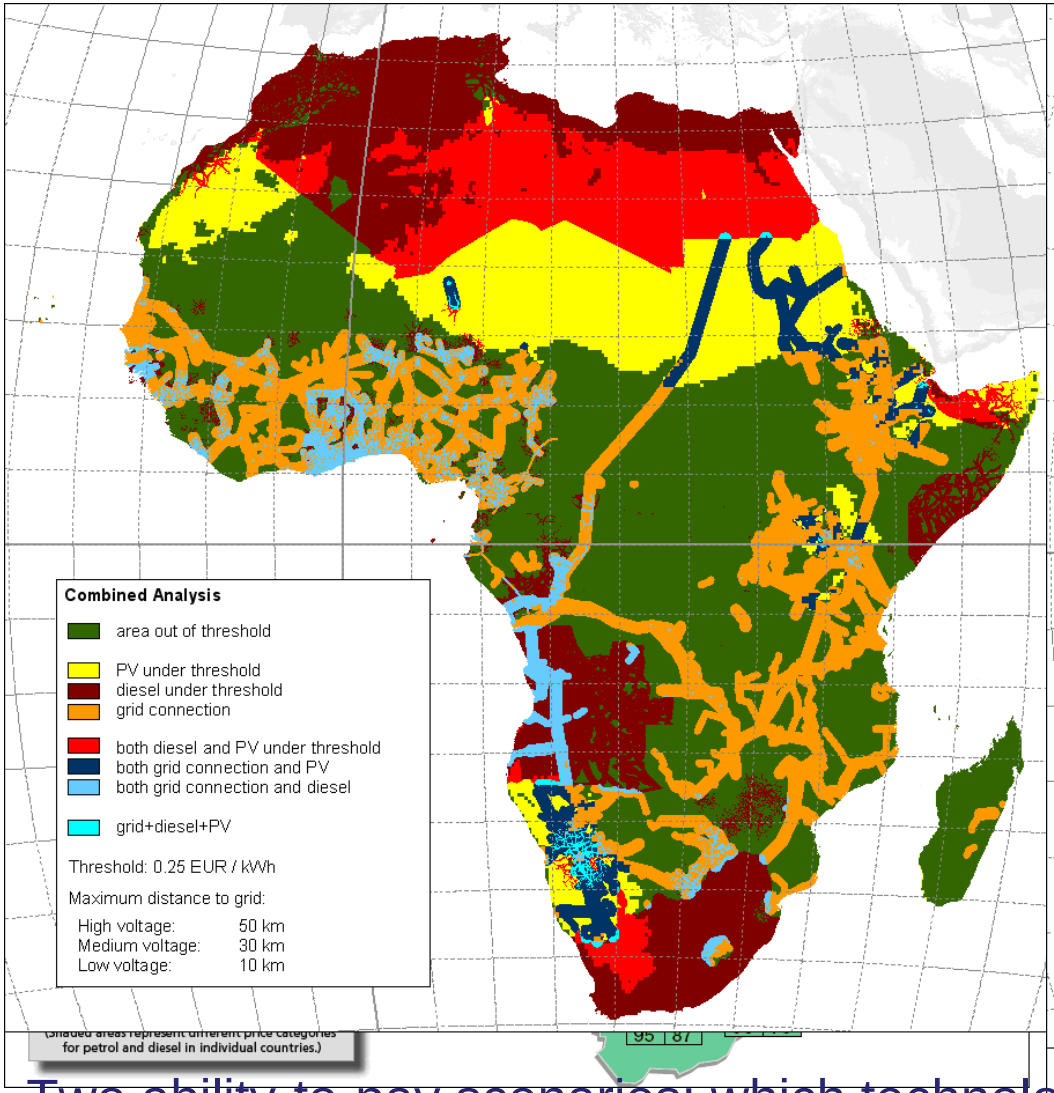
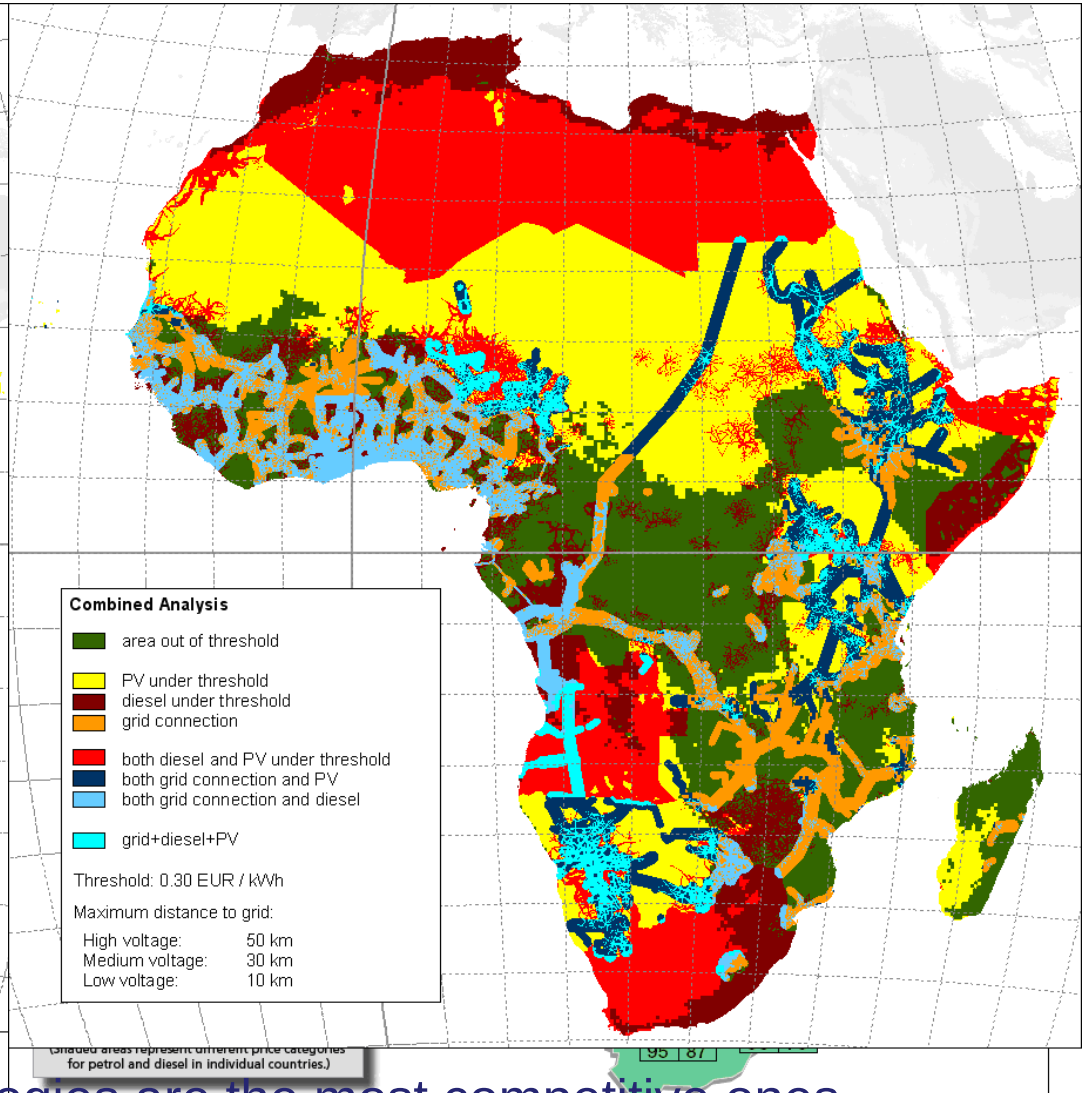
Resulting maps





Two ability-to-pay scenarios: which technologies are the most competitive ones

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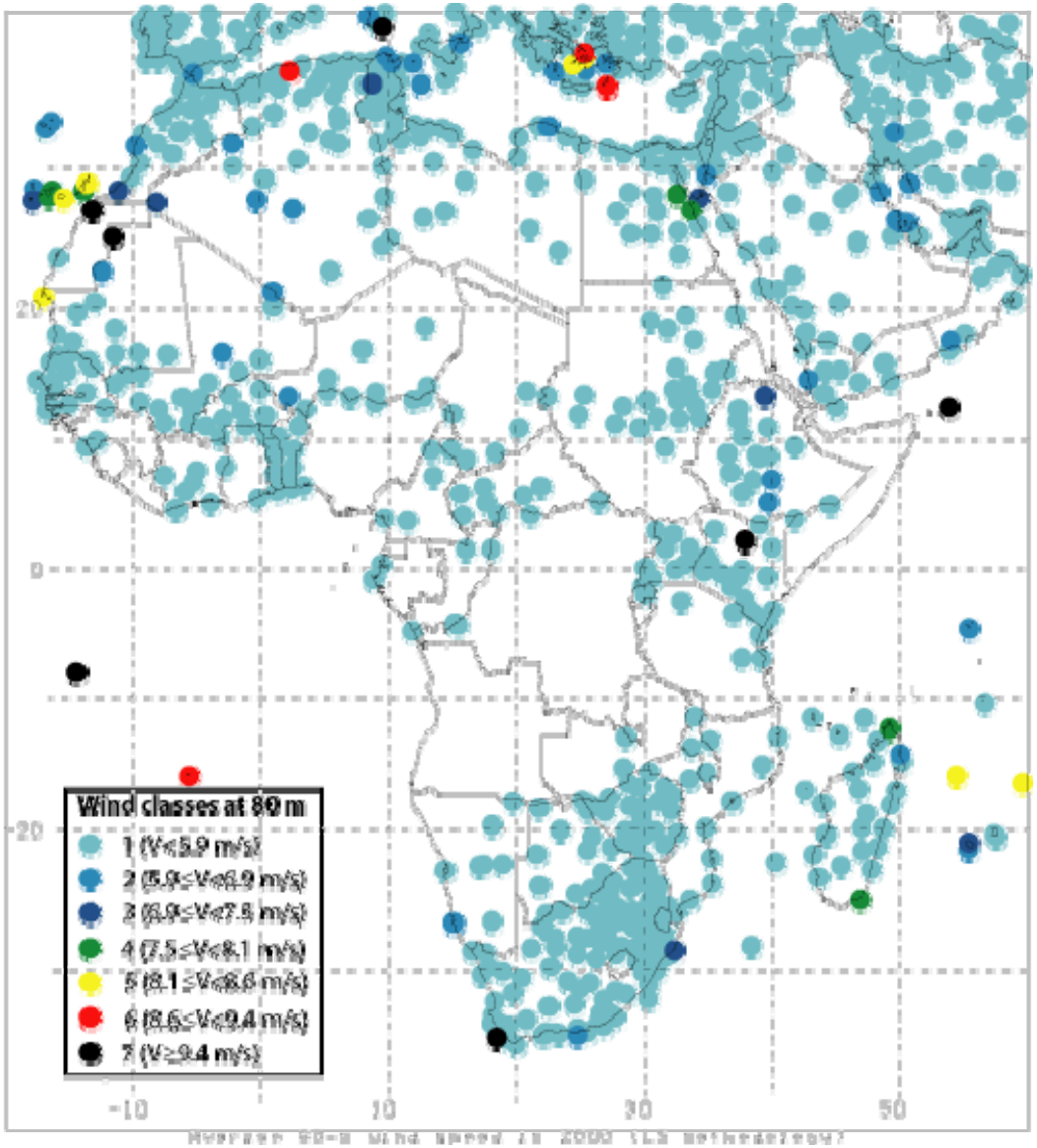
Future extensions …



From Wind resource mapping …

……to Land cover for biomass

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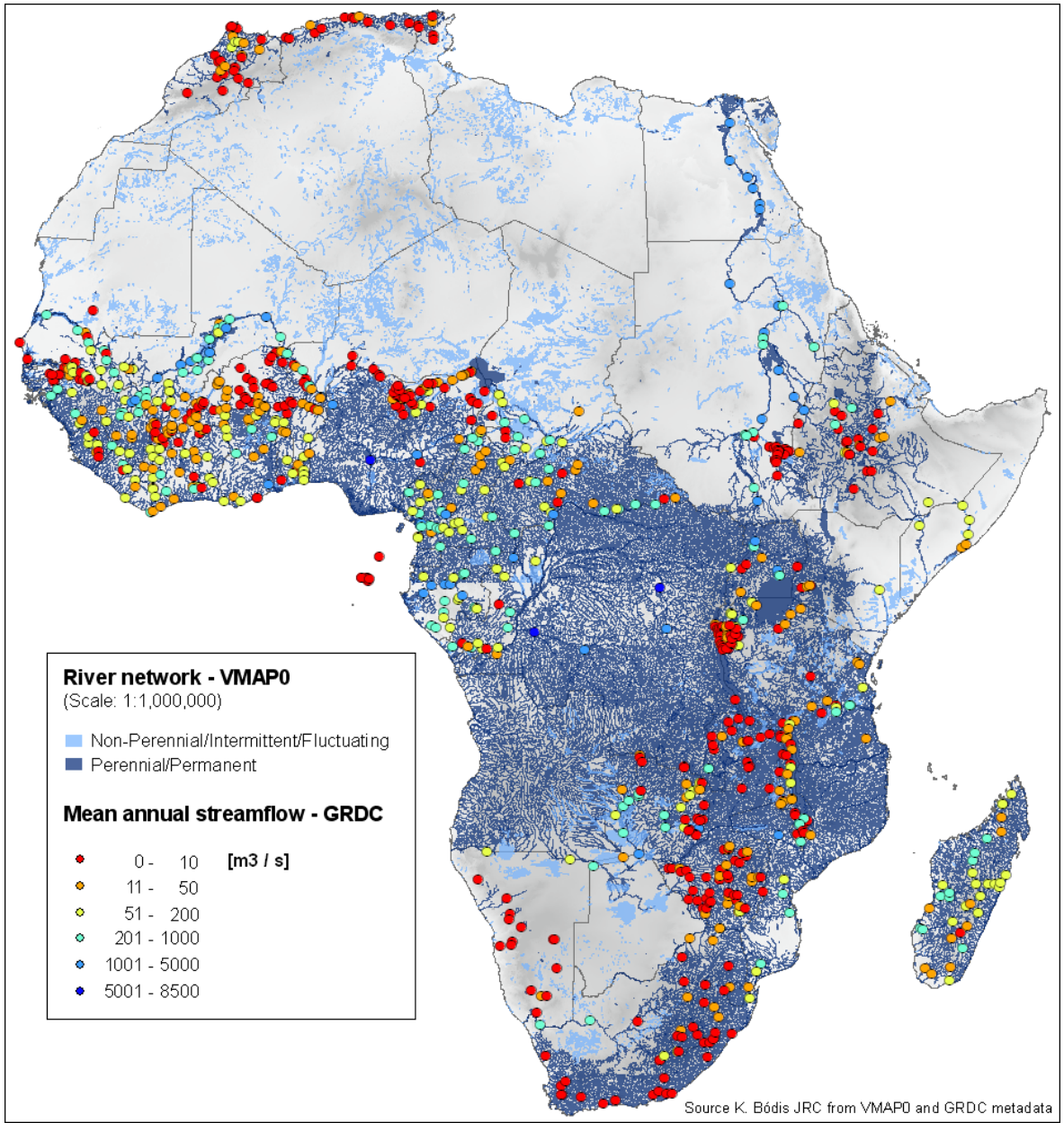
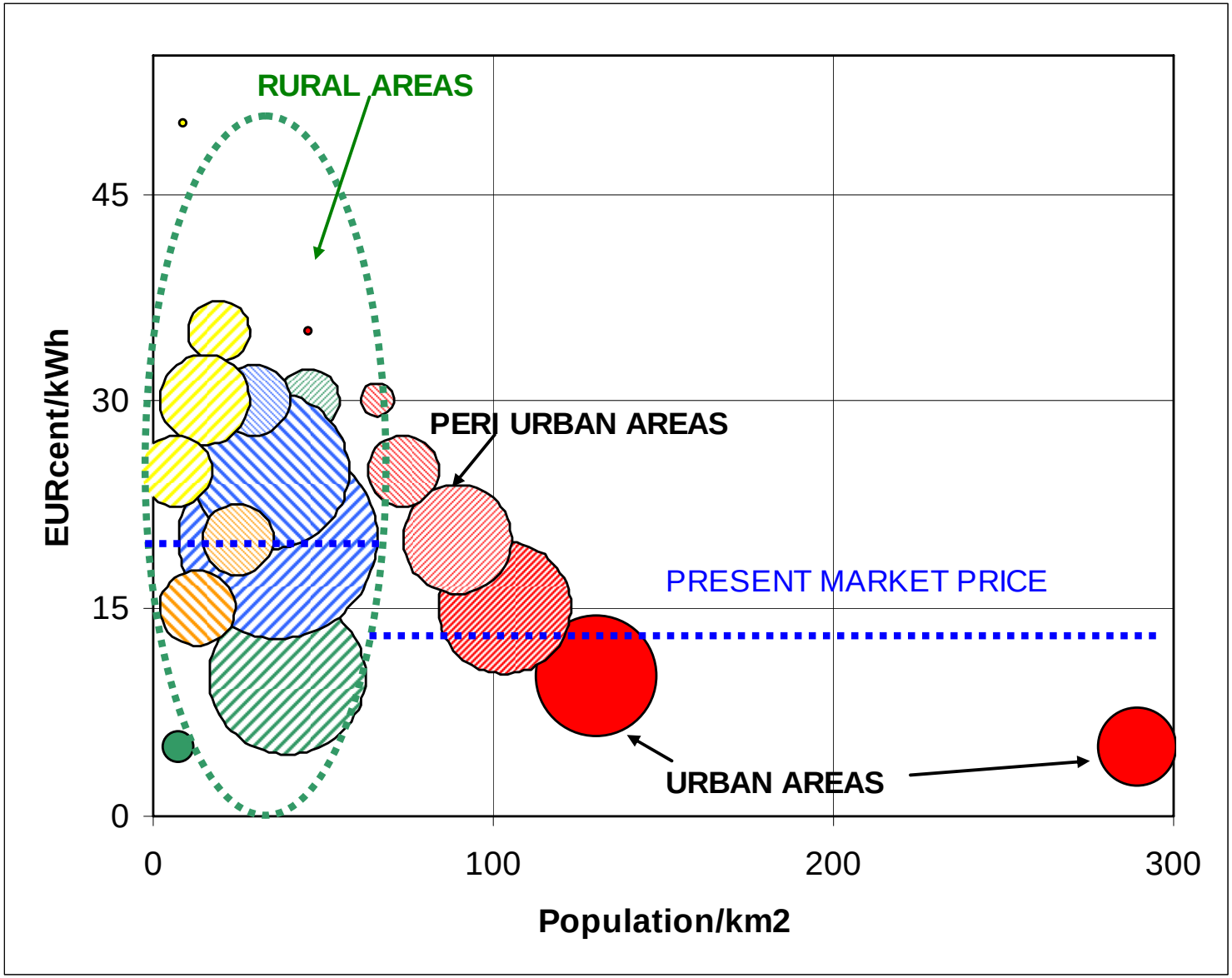
Extending the methodology to mini hydro option



Social/economic and physical characteristics strongly determine the least cost option and also their potential

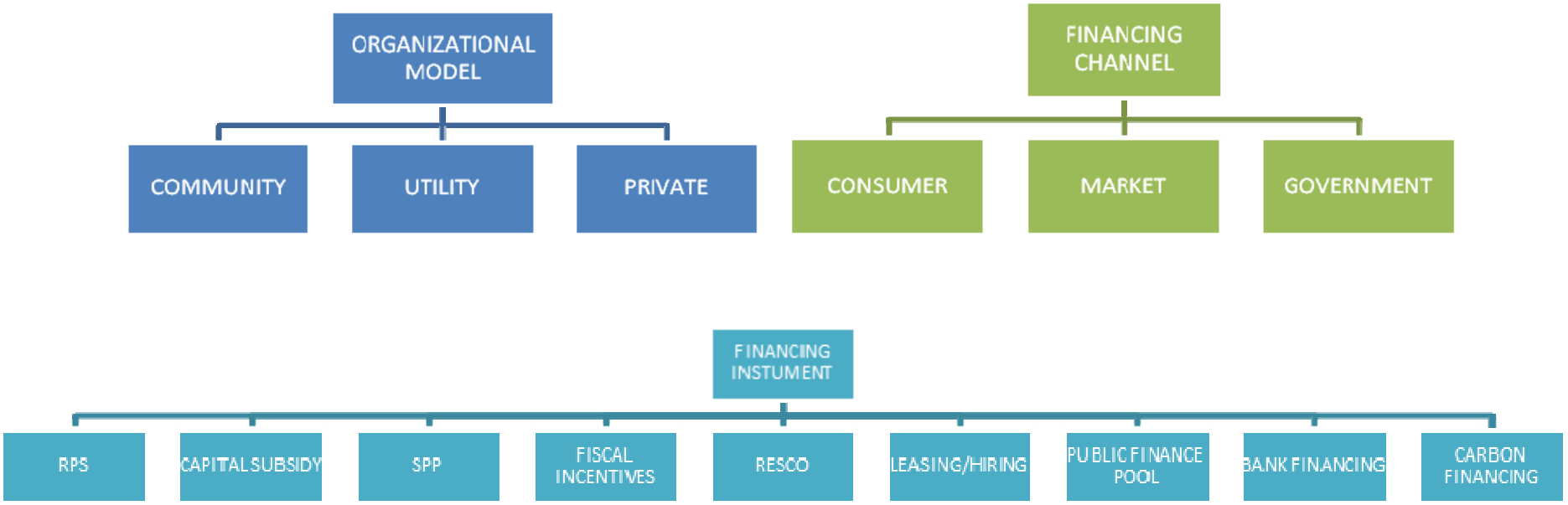


Economic comparison of distributed technologies and grid extension, potential financial schemes II.

Sándor Szabó

JRC

Financial schemes for distributed generation



- **Organizational *model***: defined as regulatory, legislative and policy conditions;
- **Financing channel**: defined as the source of financing and how the financing is channelled;
- **Financing instrument**: defined as the specific delivering method of financing.

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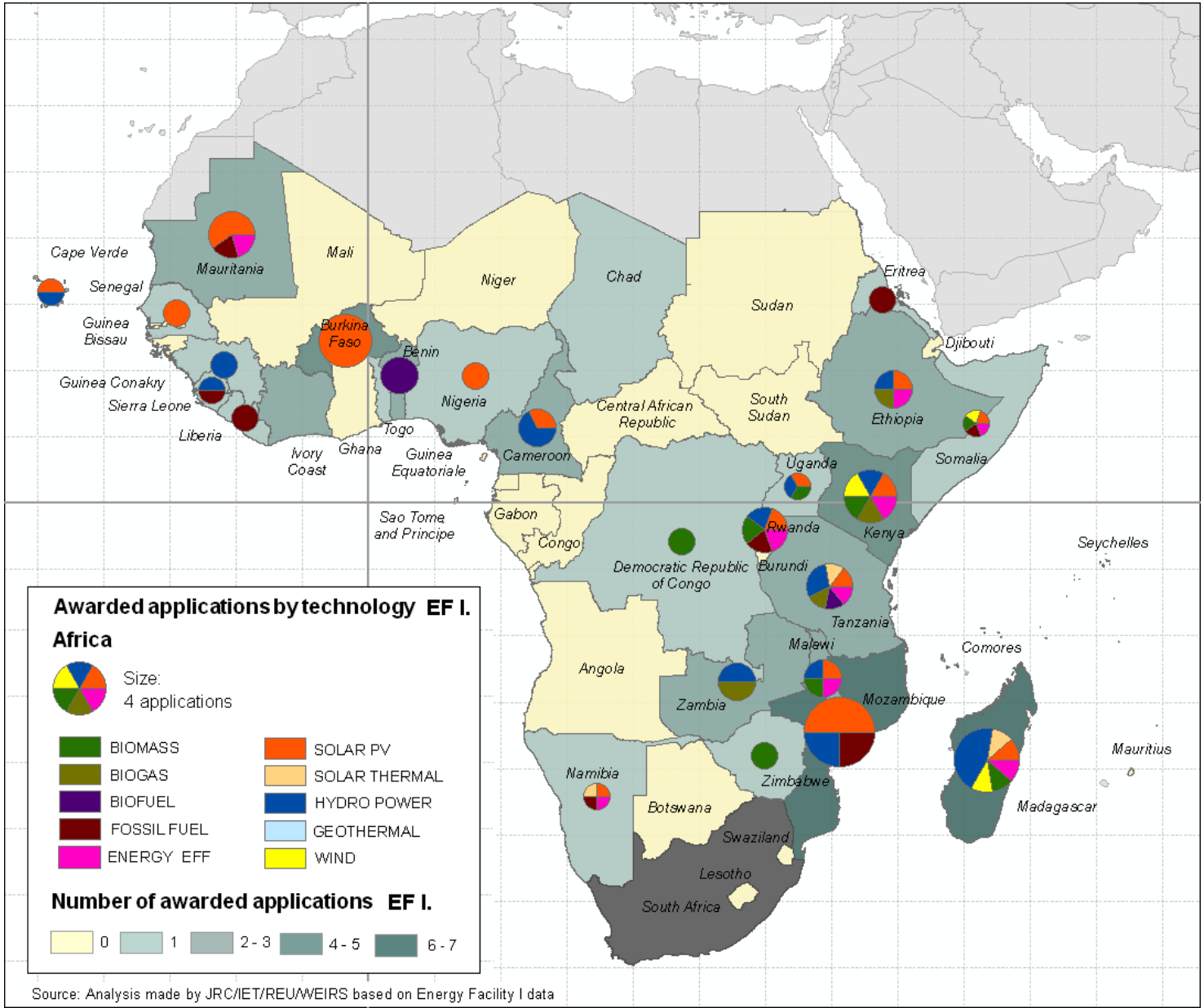
Technology distribution of Energy Facility Projects



Source: Analysis made by JRC/IET/REU/WEIRS based on Energy Facility I data

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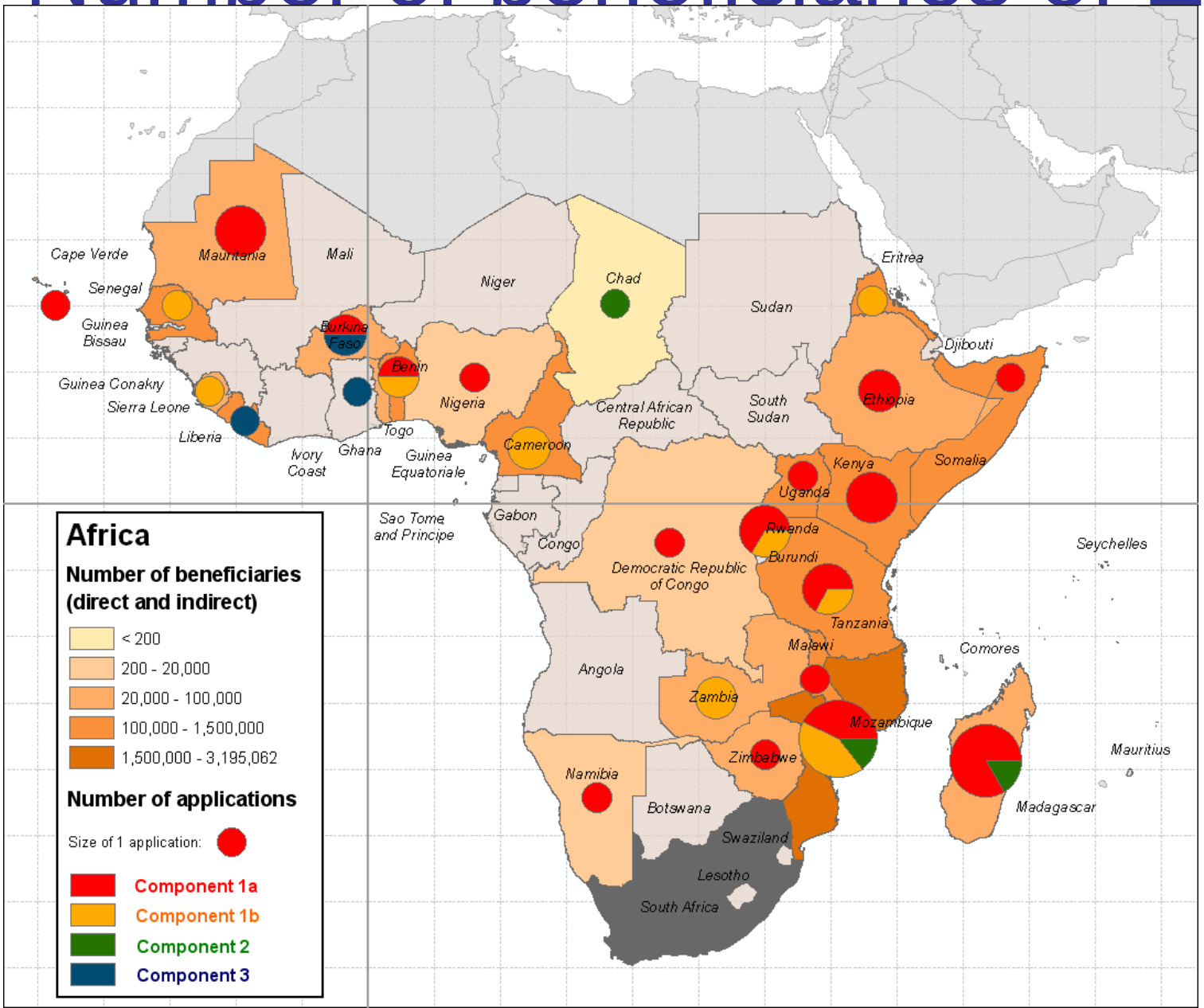
Number of beneficiaries of EF I



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Cash flow for a Gambian hybrid project with different FiT

The Gambia (Darsilami) PV 15 KWp+1 generator of 15kW **20 years RPT**

Inputs in red Output blue

Inputs		**€/kWh**	
Development Fund		€ 345,780	0.6
		€ 288,150	0.5
		€ 230,520	0.4
		€ 172,890	0.3
		€ 115,260	0.2
		€ 57,630	0.1
		€ 57,630	0.0

Total amount in 20 years

Initial capital inv	$	152,750	€ 117,500	Private investment for Capacity mini-grid (distribution+hybrid) (15PVkW+battery storage+15kW gen)
Total Investment	$	255,418	€ 196,475	total minigrid initial investments and manual costs

total RPT 0.4 230,520 total RPT 0.3 172,890

100% RPT Subsidy

6% Long term loan, Development Fund rate

Levelized cost of energy: 0.65 €/kWh

Expected rate of return for the investor

WACC (without taxes) 6%

Initial capital cost	($)	(€)	
PV	87,750	67,500	87750
battery+ inverter+	45,500	35,000	45500
genset 15 kW	19,500	15,000	19500
distribution, meters	23,400	18,000	23400
manual costs (45%of the project)	79,268	60,975	79268
Total mini-grid (distribution+hybrid)	**255,418**	**196,475**	255418
Hybrid system	**152,750**	**117,500**	

€/kWh	Net investment minigrid (€/Wp)	Net investment hybrid (€/Wp)	NPV (20 years)	IRR	payback (years)	NPV of RPT flow (€)
0.6	6.5	3.9	104,049	15.9%	5	€11.39
0.5		3.9	70,999	12.9%	6	€9.49
0.4		3.9	37,948	9.8%	7	€7.59
0.3		3.9	4,898	6.5%	9	€5.70
0.2		3.9-	28,153	2.8%	11	€3.80
0.1		3.9-	61,204	-1.4%	24	€1.90
0.0		3.9-	94,254	-6.6%	-2	€0.00

15% 0.98%of electricity produced by RET

Electricity produced

PV (covering 13% Load) 15 System size (kWp) 2160 Yield (kWh/kWp)

Diesel 15 System size (kWp) 50

Specific fuel consumption 0.465L/kWh

750 kWh produced by generators

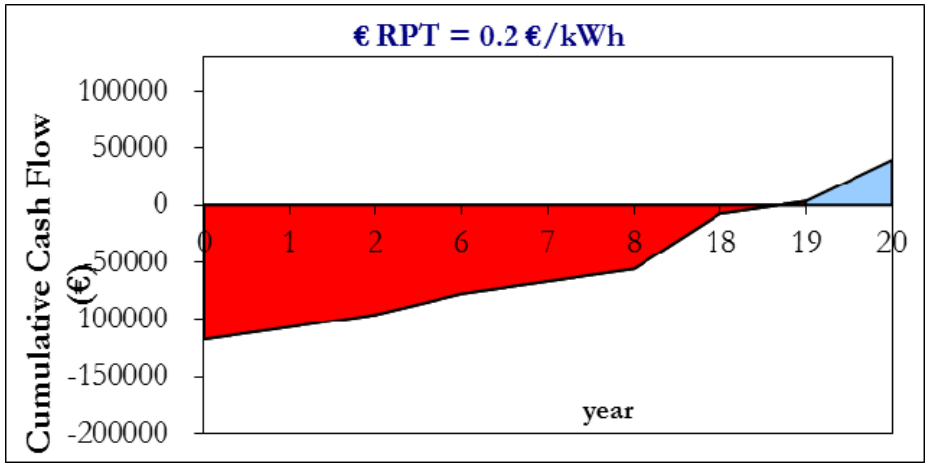
28,815 kWh produced yearly by PV (15kW)

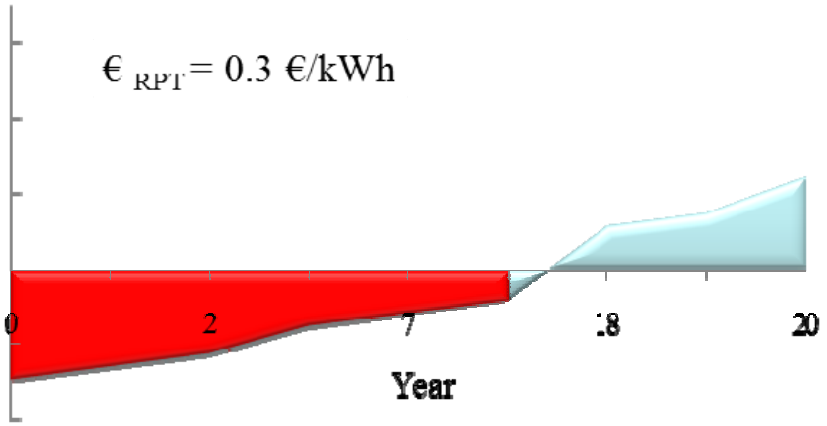
29,385 total kWh produced yearly

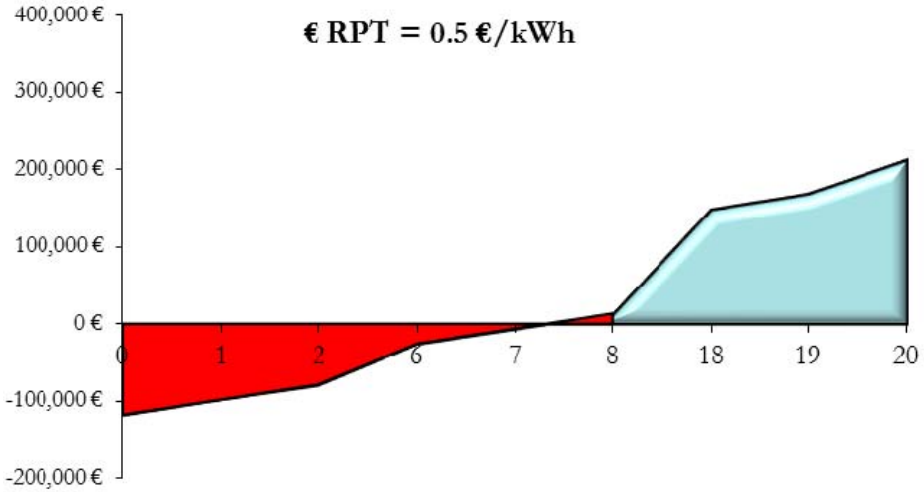
0.2 Local electricity price(€/kWh)

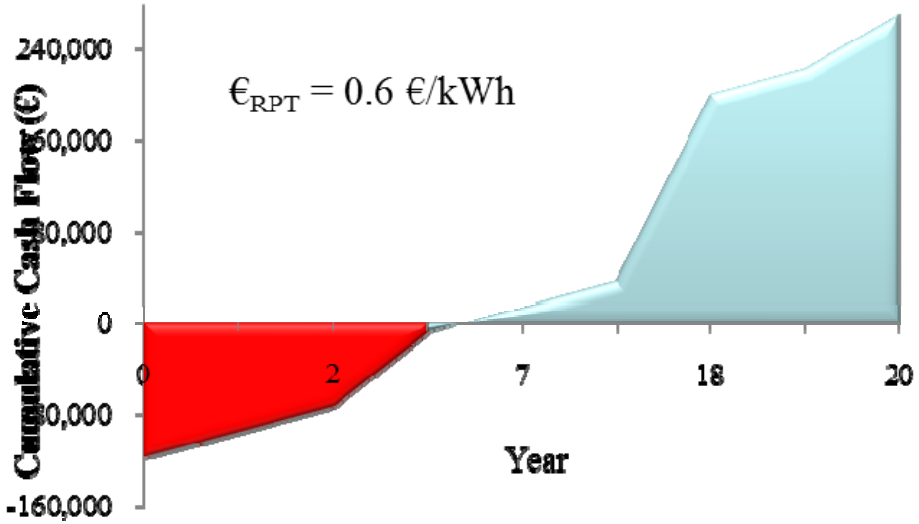
		1	2	3	7	8	9	18	19	20
	Discount factor-WACC	1	0.943	0.890	0.705	0.665	0.627	0.350	0.331	0.312
0.6	PV	-117,500	21,107	19,913	-1,851	14,880	14,038	-920	7,395	14,880
0.5	PV	-117,500	18,389	17,348	-3,883	12,963	12,230	-1,930	6,442	13,982
0.4	PV -Discounted Cash Flow (10%)	-117,500	15,670	14,783	-5,914	11,047	10,422	-2,939	5,490	13,084
0.3	PV	-117,500	12,952	12,219	-7,945	9,131	8,614	-3,949	4,538	12,185
0.2	PV	-117,500	10,234	9,654	-9,977	7,214	6,806	-4,958	3,585	11,287
0.1	PV	-117,500	7,515	7,090	-12,008	5,298	4,998	-5,968	2,633	10,388
0.0	PV	-117,500	4,797	4,525	-14,040	3,382	3,190	-6,977	1,681	9,490
0.6	Cumulative Cash Flow (€)	-€117,500	-€95,126	-€72,753	-€8,258	€14,116	€36,490	€200,226	€222,600	€270,324
0.5	Cumulative Cash Flow (€)	-€117,500	-€98,008	-€78,516	-€25,547	-€6,055	€13,438	€148,359	€167,852	€212,694
0.4	Cumulative Cash Flow (€)	-€117,500	-€100,889	-€84,279	-€42,836	-€26,225	-€9,614	€96,492	€113,103	€155,064
0.3	Cumulative Cash Flow (€)	-€117,500	-€103,771	-€90,042	-€60,125	-€46,396	-€32,666	€44,625	€58,355	€97,434
0.2	Cumulative Cash Flow (€)	-€117,500	-€106,652	-€95,805	-€77,414	-€66,566	-€55,718	-€7,242	€3,606	€39,804
0.1	Cumulative Cash Flow (€)	-€117,500	-€109,534	-€101,568	-€94,703	-€86,737	-€78,770	-€59,109	-€51,142	-€17,826
0.0	Cumulative Cash Flow (€)	-€117,500	-€112,415	-€107,331	-€111,992	-€106,907	-€101,822	-€110,976	-€105,891	-€75,456

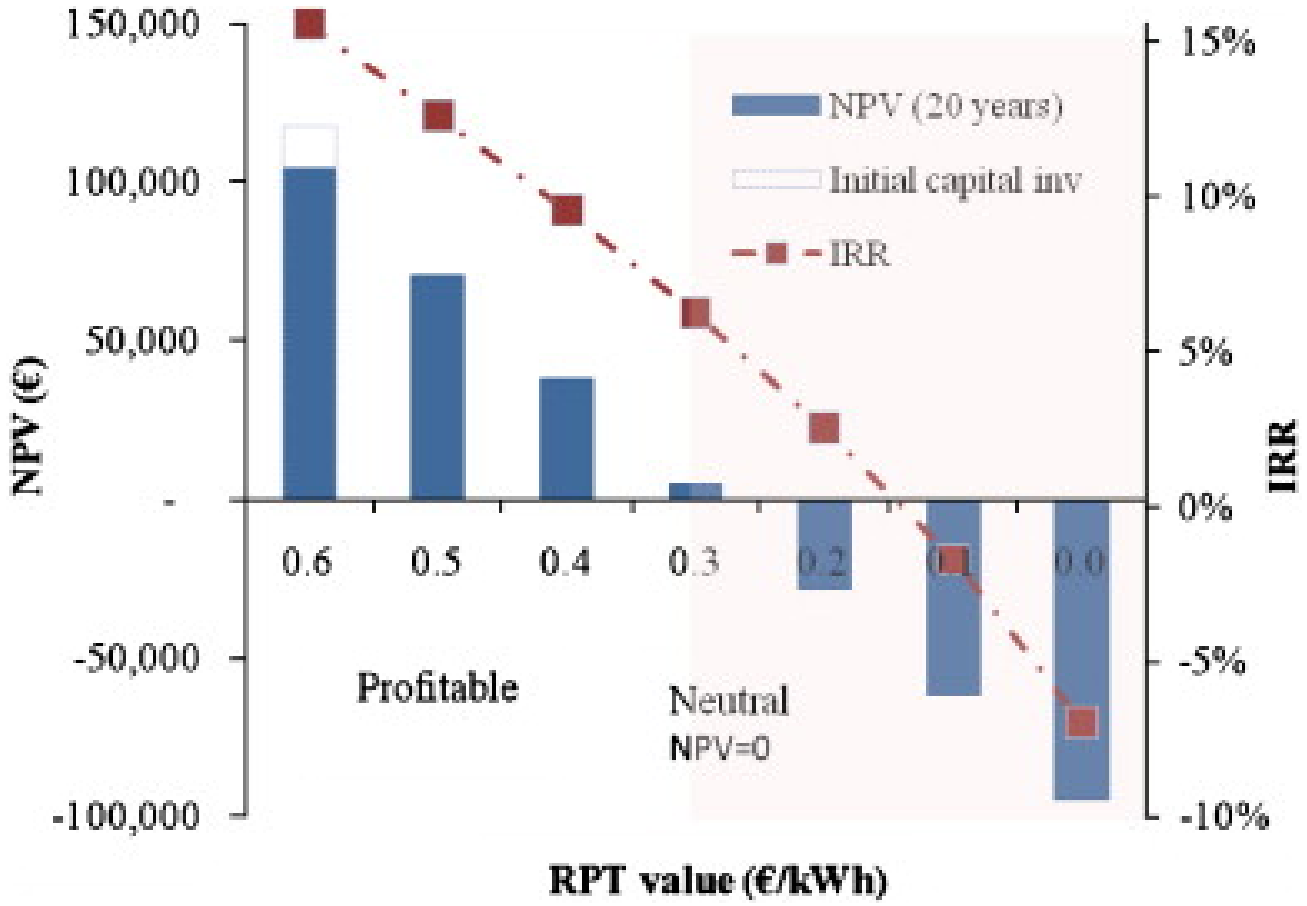
Cash flow diagram





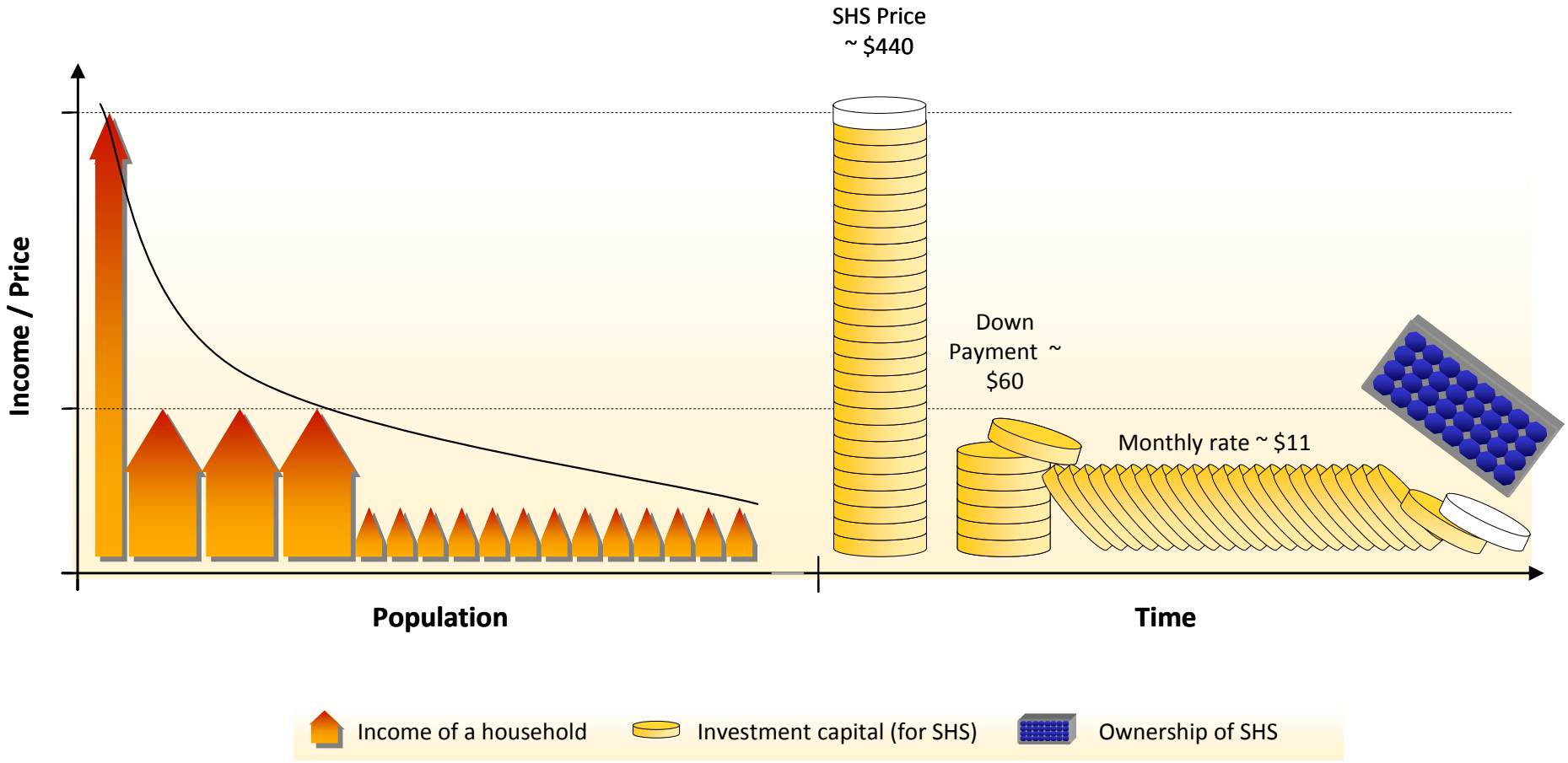




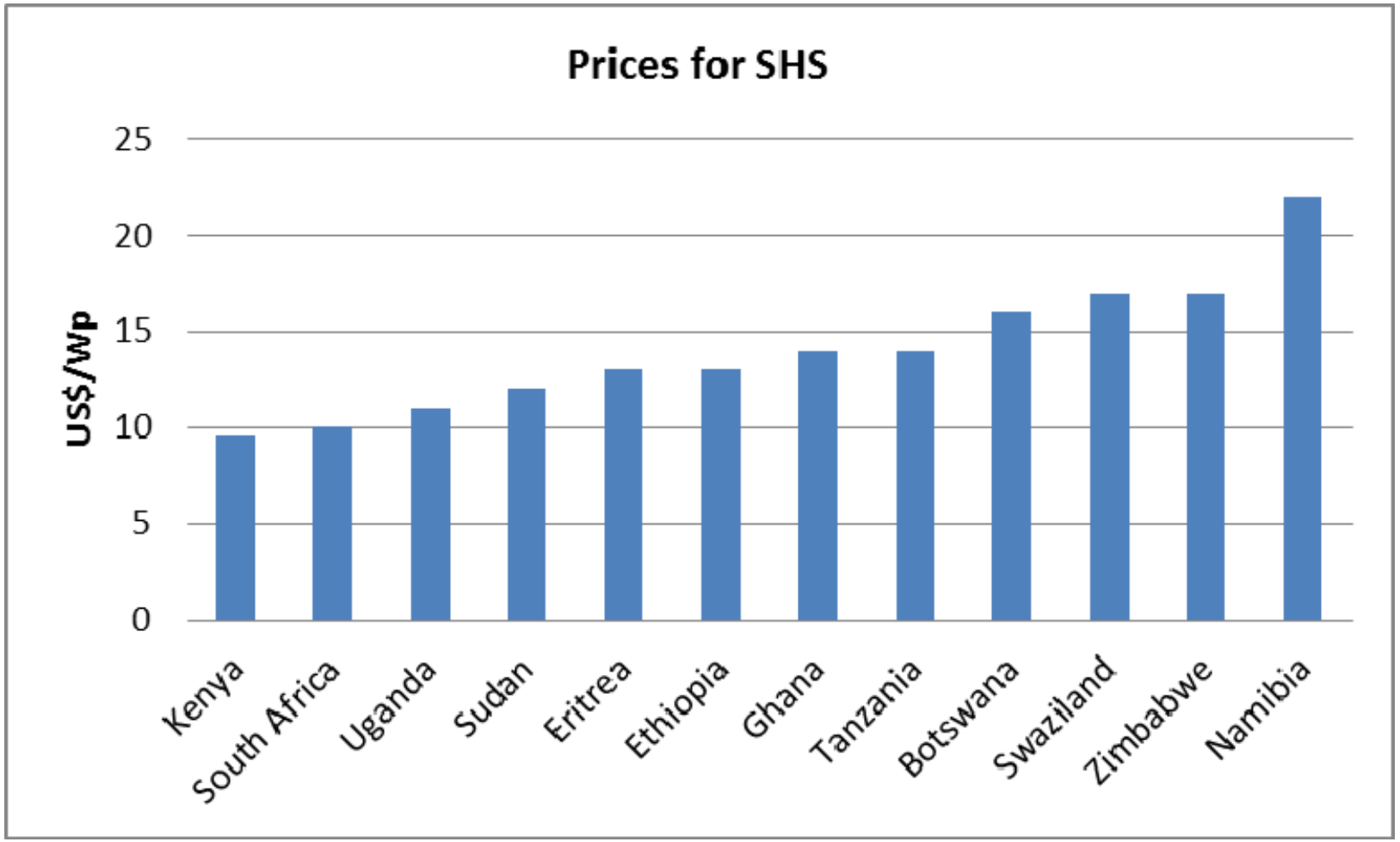


RPT analysis: NPV values (€) corresponding to each RPT value (€/kWh) considered with their respective IRR (%)

Solar home system ownership cost



Source: ARE, 2009



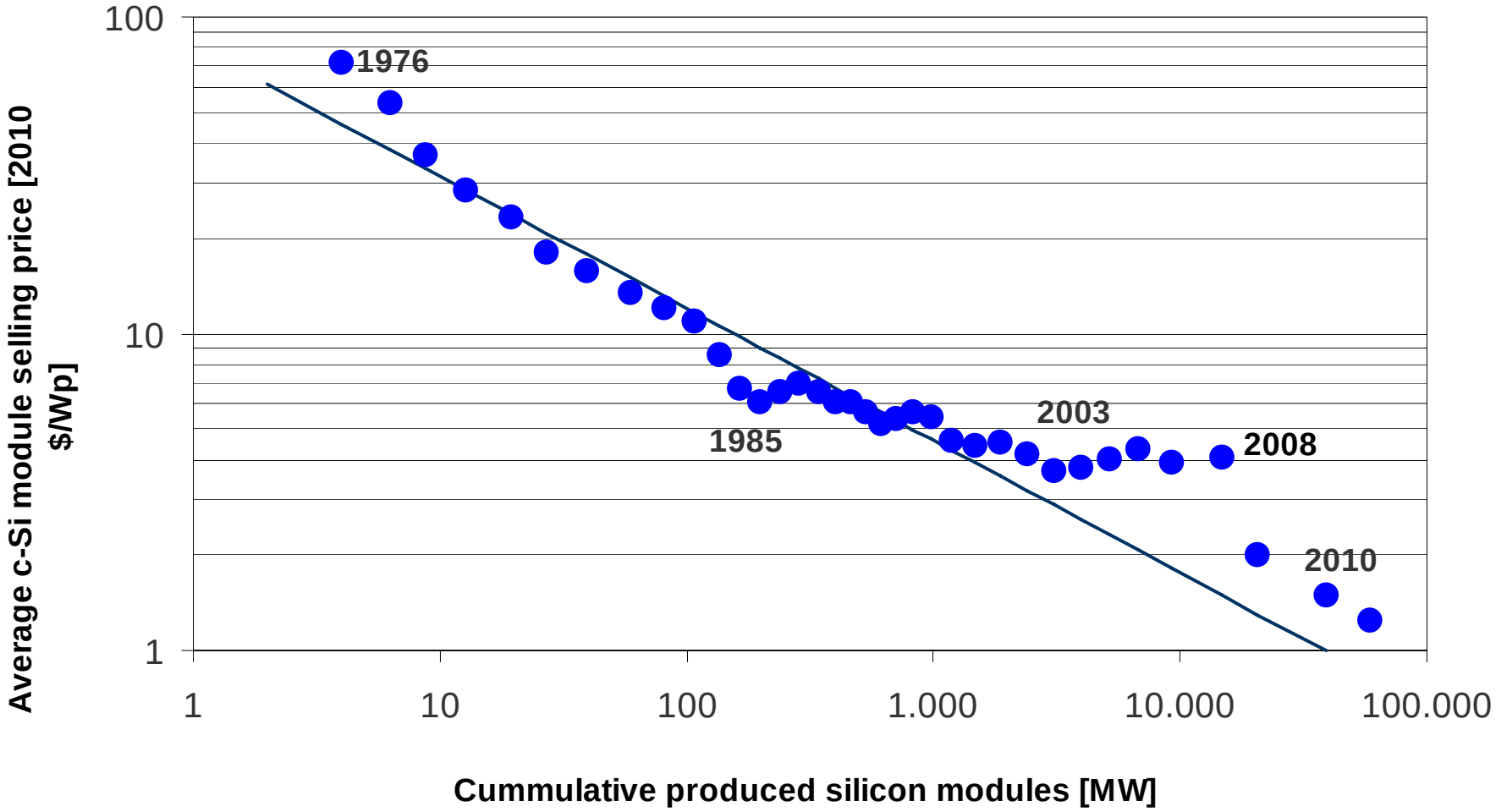
Note: Solar PV system cost includes solar panel, battery, 4 lights, charge controller, installation materials, and installation

Figure SHS prices (US$/Wp) in selected African countries *M. Moner-Girona, R. Ghanadan, A. Jacobson, D. M. Kammen, Decreasing PV costs in Africa: Opportunities for Rural Electrification using Solar PV in Sub-Saharan Africa, Refocus, Volume 7, Issue 1, January-February 2006*

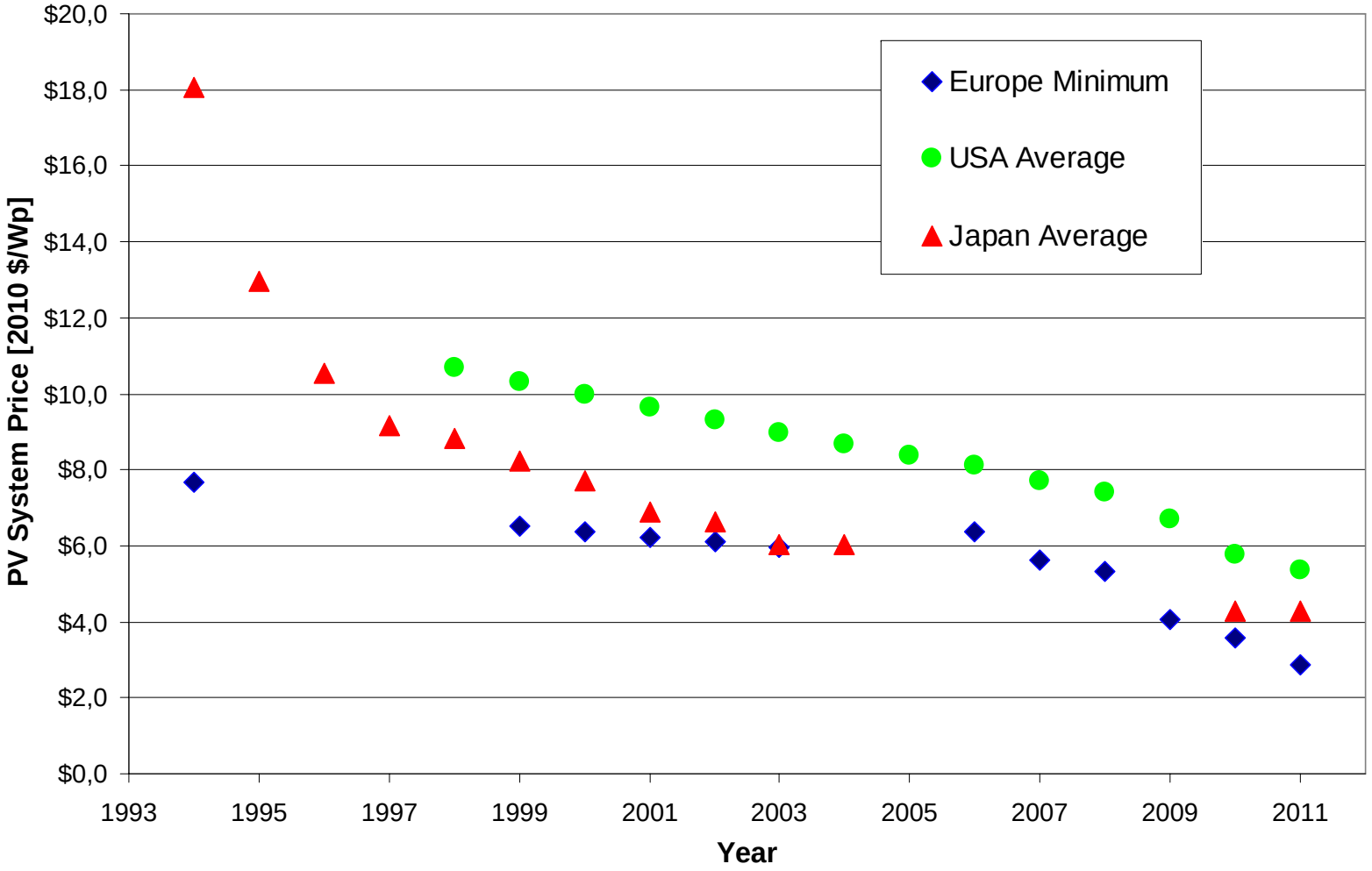
Positive developments

- Positive trends in the technology costs and in the policies
  - Learning curve
  - More diverse set of technologies
  - New financing policies
    - Performance finance
    - Microfinance

c-Si module prices



PV system prices



Energy performance financing

- Payment for results: Donors only pay on delivery
- Getting assets on the ground: allowing private sector first movers to prove out a new regulatory environment whilst provide ongoing feedback to government and donors.
- Modular standardized roll out: 4 to 5 small scale (1-15MW) plants per country.
- Public private risk sharing: private sector assumes construction and operating risks while donor supports local government to firm up the investment environment.
- Lower cost of capital: reducing commercial return on capital (equity, debt) and pulling in private sector professional actors at a very early stage
- Open architecture: All platforms will have open architecture, but starting with a small number of players in each, starting in one sector in one or two countries.