Copper Contribution to Renewables and Energy Efficiency

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ICREPQ
March 2010
Granada, Spain

The European Copper Institute (ECI)

Non profit organisation

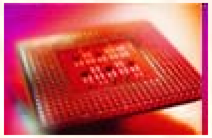
Representing the world's mining companies and the European copper industry

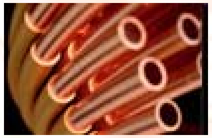
Network of Associations

Brussels based headquarters with a network of 11 Copper Development Associations

Mission

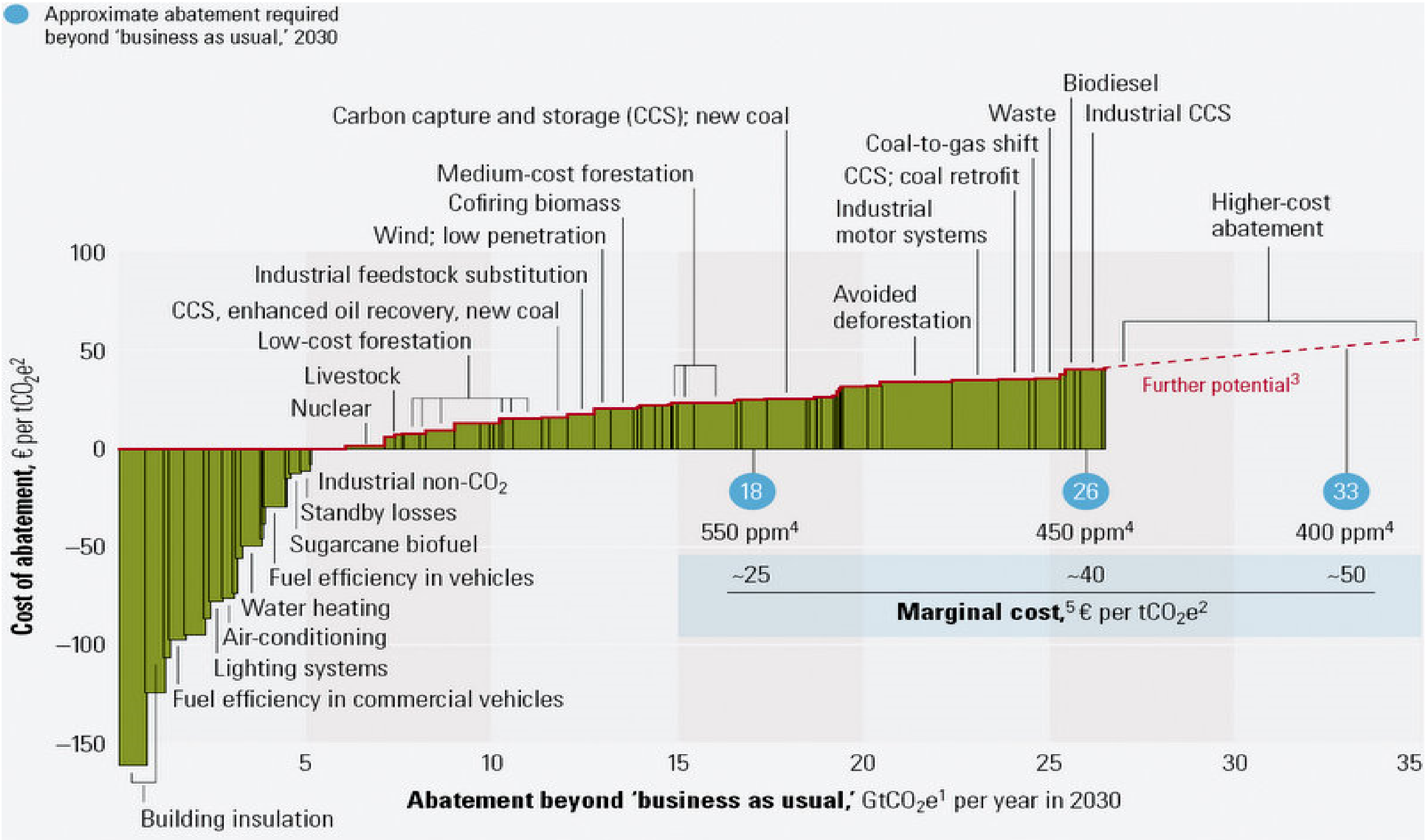
Communicate copper's essentiality for health, technology and quality of life.







Energy Efficiency and Renewables vs CO2 abatement cost



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http://lightbucket.files.wordpress.com/2008/05/carbonabatement800.jpg

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- Transformers
- Renewables
- PV case study

ELECTRIC MOTORS

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Electric motors : key figures

65% of EU industrial electricity use

202 TWh / year savings potential

by switching to energy efficient motor driven systems

http://www.leonardo-energy.org/high-efficiency-motor-systems-0

Electric motors : electricity savings potential

202 TWh annual savings potential
by switching to energy efficient motor driven systems

7% of total electricity consumption of EU

Electricity System impact

Total amount of EU network electricity losses

35 nuclear power plants (1000 MW)
70% load factor

130 fossil fuel power plants (350 MW)
50% load factor

1.5 times the EU's total 2008 wind capacity (142 TWh generated in 2008)

Electric motors : GHG savings potential

202 TWh annual savings potential
by switching to energy efficient motor driven systems

100 Million Tonnes annually
CO_2 saved

GHG impact

About 20 % of the GHG emission reduction in EU between 1990 and 2010 (400 - 500 MT)*

Significant reductions in NOx, SO_2, heavy metal, and dust emissions

*Source : Report of the review of the initial report of the European Community, FCCC/IRR/2007/EC. UNFCCC, 15 February 2008.
2008 GHG inventories 1990-2006 (submissions to UNFCCC)

Electric motors : economic savings potential

202 TWh annual savings potential
by switching to energy efficient motor driven systems

€ 10 Billion annual operating costs saved

Economic impact

€ 50 Billion investment saved for new generation capacity

Lower Life Cycle Cost — a typical reduction of 35 %

6 % reduction on fossil fuel imports

Electric motors : barriers to be removed

High efficiency motors (Eff1) represent only 12 % of the market in the EU. If energy efficient motor systems have in the large majority of the cases the lowest Life Cycle Cost (LCC), why is the adoption rate so slow?

Split Budgets : purchase department and operating costs managers need to make a common approach on Life Cycle Cost basis

Existing stocks : back-up spares of the same type and efficiency in the warehouses, even if LCC is higher

Lack of Information : education is needed in terms of definitions and Life Cycle Cost

Long Life Cycle : 20 years. A poorly-reasoned purchasing decision will have a negative impact lasting for 20 years.

How Copper saves CO2 emissions in motors

22 kW

+1 kg Cu -> - 3 Tons CO2

Eco-design analysis

- Manufacturing
- Utilisation
- End of Life

		Type 1	Type 2	Type 3
Materials				
Aluminium	Kg	3,5	3,5	4
Copper	Kg	8,8	12,9	13,9
Electrical steel	Kg	108	108	108
Parameters				
Rating	Kw	22	22	22
Efficiency	%	89.5	91.8	92.6
Lifetime	Years	20	20	20
Load	%	50	50	50
Annual operation	Hours	4380	4380	4380
Environmental balance				
Primary Energy	GJ	1233	940	841
CO2	Tons	56	43	38

Increasing Copper

Increasing Efficiency

Decreasing CO2

Given that one kg of copper takes 3 kg of *CO2e* emissions in production the environmental payback is more than a factor 1000, while at the end of life, the kg copper can be recycled for the next application.

http://www.leonardo-energy.org/webfm_send/359

The European Copper Institute : a long tradition in promoting efficient motor systems

European Motor Challenge Program

The MOTOR CHALLENGE PROGRAMME
An initiative promoted by the European Commission

- **ECI supports this program launched in 2003**
- **Voluntary program of European Commission focused on improving the efficiency of motor driven systems**

The European Copper Institute : removing barriers through education

Leonardo ENERGY blog

Reports the latest developments in motor efficiency standards, case studies, etc.

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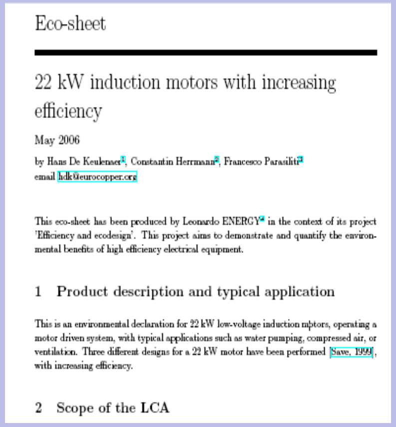
The European Copper Institute : removing barriers through education

Eco-design


Eco-sheet

22 kW induction motors with increasing efficiency

May 2006

by Hans De Keulenaer[1], Constantin Herrmann[2], Francesco Parasiliti[3]
email hdk@eurocopper.org

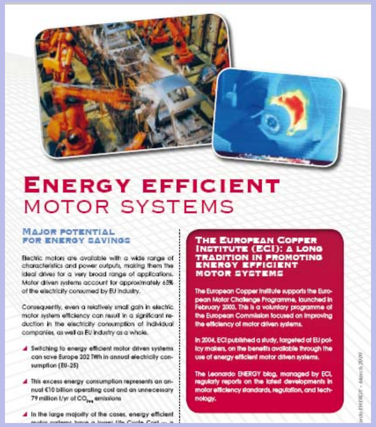
This eco-sheet has been produced by Leonardo ENERGY[4] in the context of its project 'Efficiency and ecodesign'. This project aims to demonstrate and quantify the environmental benefits of high efficiency electrical equipment.

1 Product description and typical application

This is an environmental declaration for 22 kW low-voltage induction motors, operating a motor driven system, with typical applications such as water pumping, compressed air, or ventilation. Three different designs for a 22 kW motor have been performed [Save, 1999], with increasing efficiency.

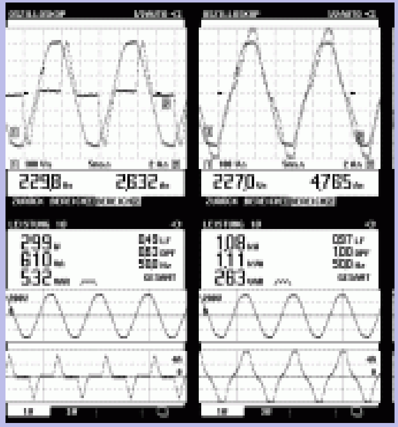
2 Scope of the LCA

Policy Briefings



Seminars on the Web

Technology Diffusion



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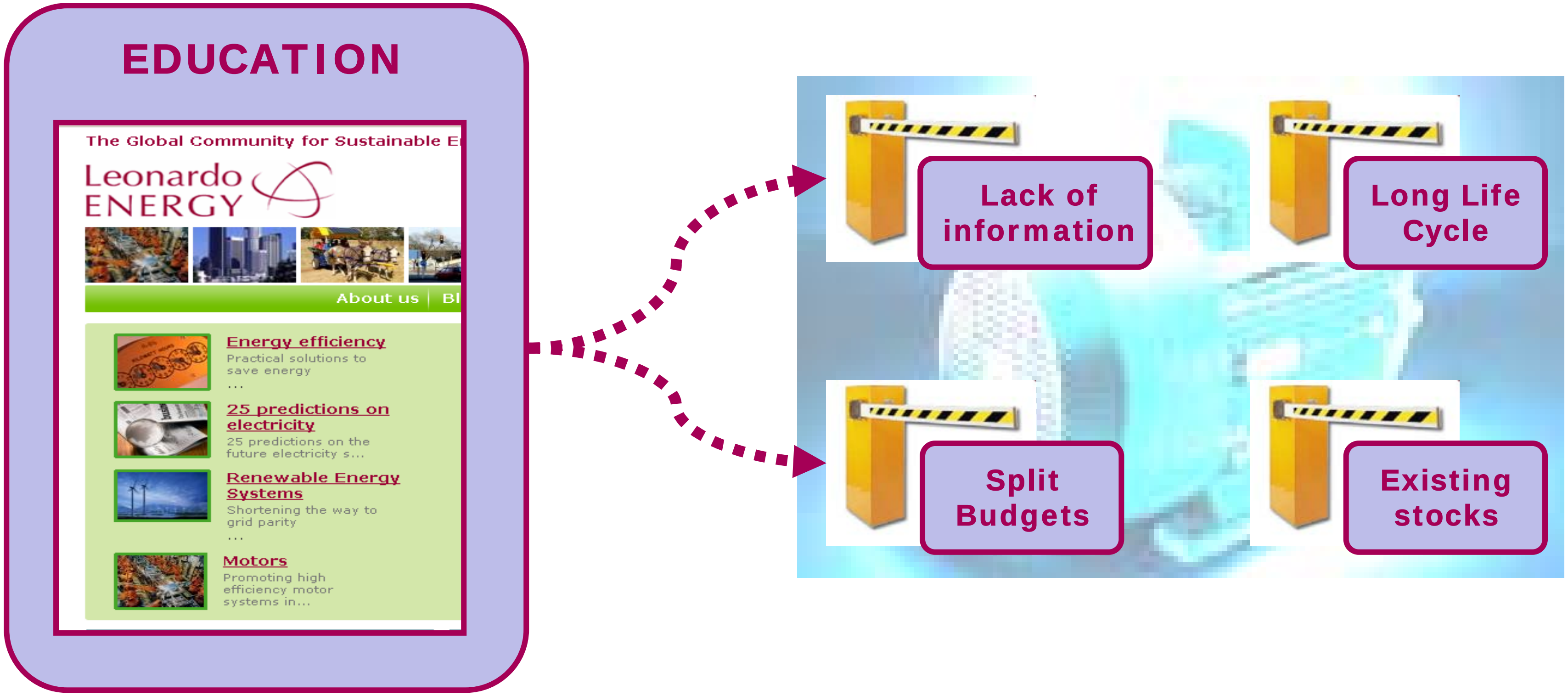
Removing barriers for motors



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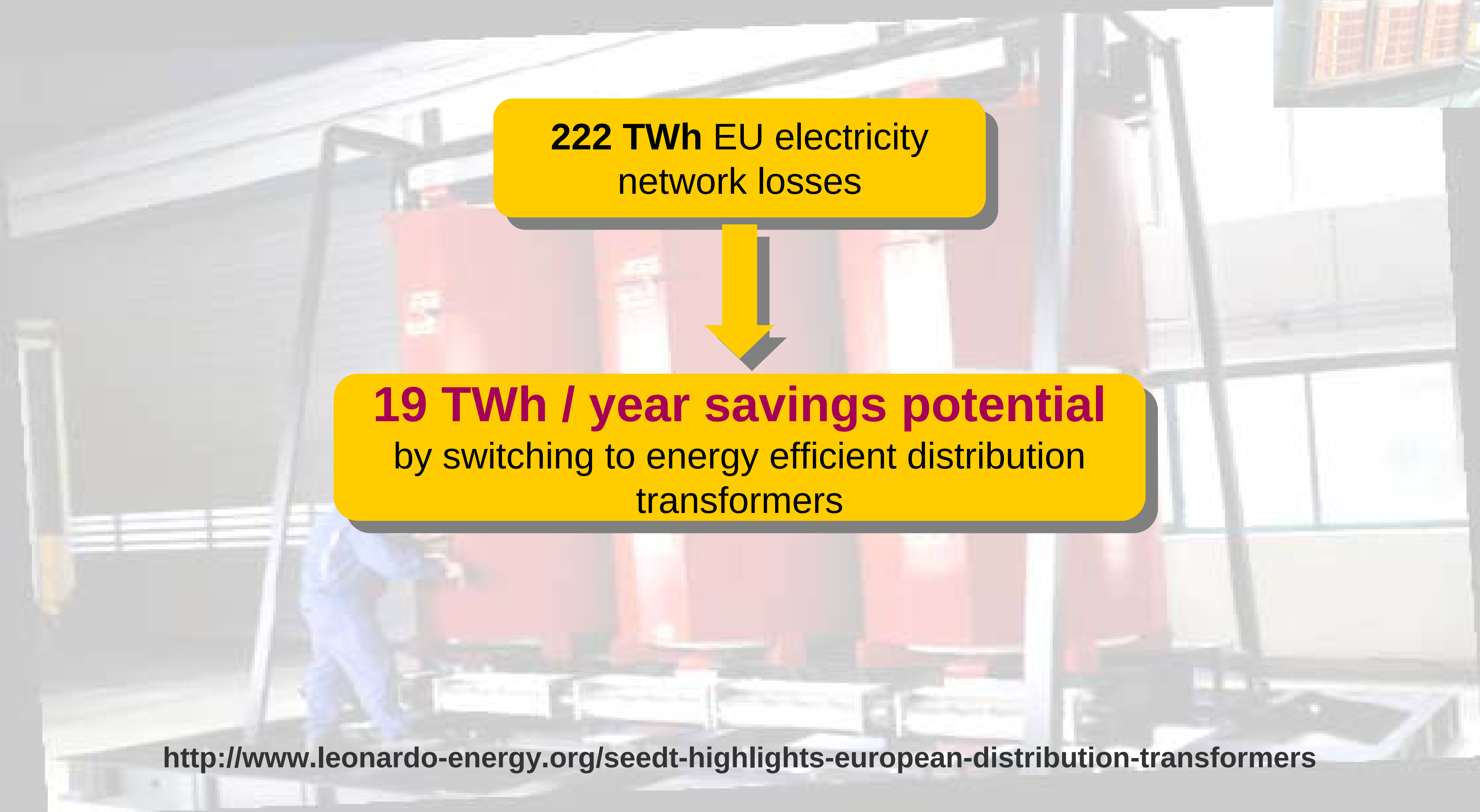
TRANSFORMERS

Distribution transformers : key figures



222 TWh EU electricity network losses

19 TWh / year savings potential

by switching to energy efficient distribution transformers

http://www.leonardo-energy.org/seedt-highlights-european-distribution-transformers

Distribution transformers : electricity savings potential

19 TWh annual savings potential
by switching to energy efficient distribution transformers

Electricity System impact

0,7% of total electricity consumption of EU

9% of total amount of EU network electricity losses

3 nuclear power plants (1000 MW)
70% load factor

13 fossil fuel power plants (350 MW)
50% load factor

13% of EU's total 2008 wind capacity (142 TWh generated in 2008)

Distribution transformers : GHG savings potential

19 TWh annual savings potential
by switching to energy efficient distribution transformers

10 Million Tonnes annually
CO_2 saved

GHG impact

About 2 % of the GHG emission reduction in EU between 1990 and 2010 (400 - 500 MT)*

Significant reductions in NOx, SO_2, heavy metal, and dust emissions

*Source : Report of the review of the initial report of the European Community, FCCC/IRR/2007/EC. UNFCCC, 15 February 2008.
2008 GHG inventories 1990-2006 (submissions to UNFCCC)

Distribution transformers : economic savings potential

19 TWh annual savings potential
by switching to energy efficient distribution transformers

Economic impact

€ 1 Billion annual operating costs saved

€ 5 Billion investment saved for new generation capacity

Lower Life Cycle Cost — IRR from 10% to 70%

A reduced dependency on fossil fuel imports

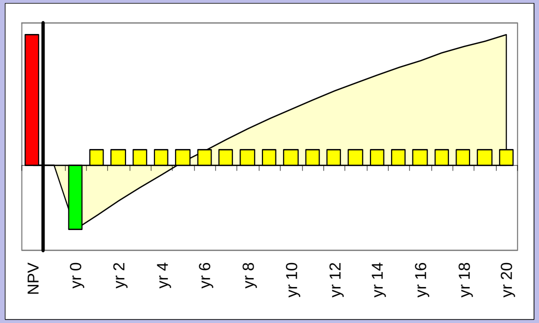
Transformers : barriers to be removed

Regulatory Models to integrate Life Cycle Cost analysis

80% of EU distribution transformers population belong to electricity distribution companies, whose activity is regulated

Life Cycle Cost Analysis

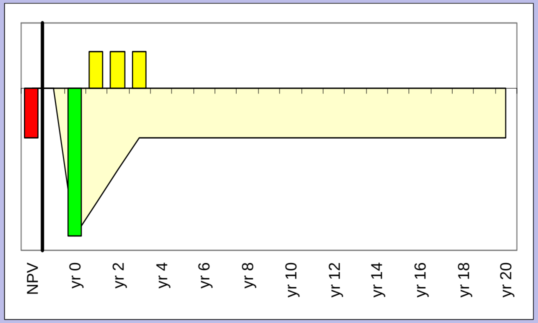
The higher efficiency, the higher benefit



Investment premium is recovered and generates positive NPV

Current Regulatory Practice

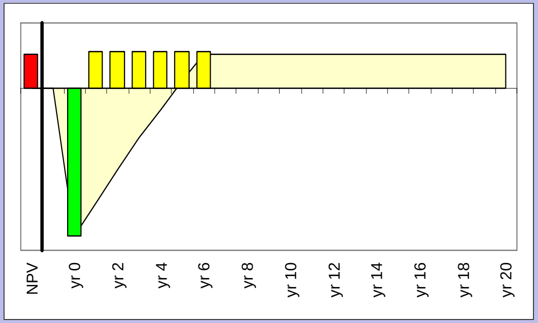
Discourages investments in efficient transformers



Benefits removed at regulatory review avoid positive NPV

Regulatory Model Proposal

Do not remove benefits before a period long enough



2, 3 or more regulatory periods before benefit removal encourages renovation using efficient equipment

Legend: Investment premium (green), energy savings (yellow), net present value (red)

400 kVA C-C' vs. A-A'; 5% discount rate (real); energy valued at 35 €/MWh

Source : Endesa Distribución

How Copper saves CO2 emissions in transformers

1.6 MVA

+1 kg Cu -> - 0.5 Ton CO2

Eco-design analysis

- **Manufacturing**
- **Utilisation**
- **End of Life**

Increasing Copper

Increasing Efficiency

Decreasing CO2

		AA’	CC’	C-Amorphous
Materials				
Mech steel	Kg	850	725	887
Copper	Kg	505	725	1225
Electrical steel	Kg	1100	1200	1550
Parameters				
Rating	MVA	1.6	1.6	1.6
Load Losses	kW	17	14	14
No-Load Losses	kW	2.6	1.7	0.4
Lifetime	Years	30	30	30
Load	%	50	50	50
Annual operation	Hours	8760	8760	8760
Environmental balance				
Primary Energy	GJ	19750	15061	11439
CO2	Tons	897	683	522

One kg of copper takes 3 kg of *CO2e* emissions in production, while at the end of life, the kg copper can be recycled for the next application.

http://www.leonardo-energy.org/webfm_send/361

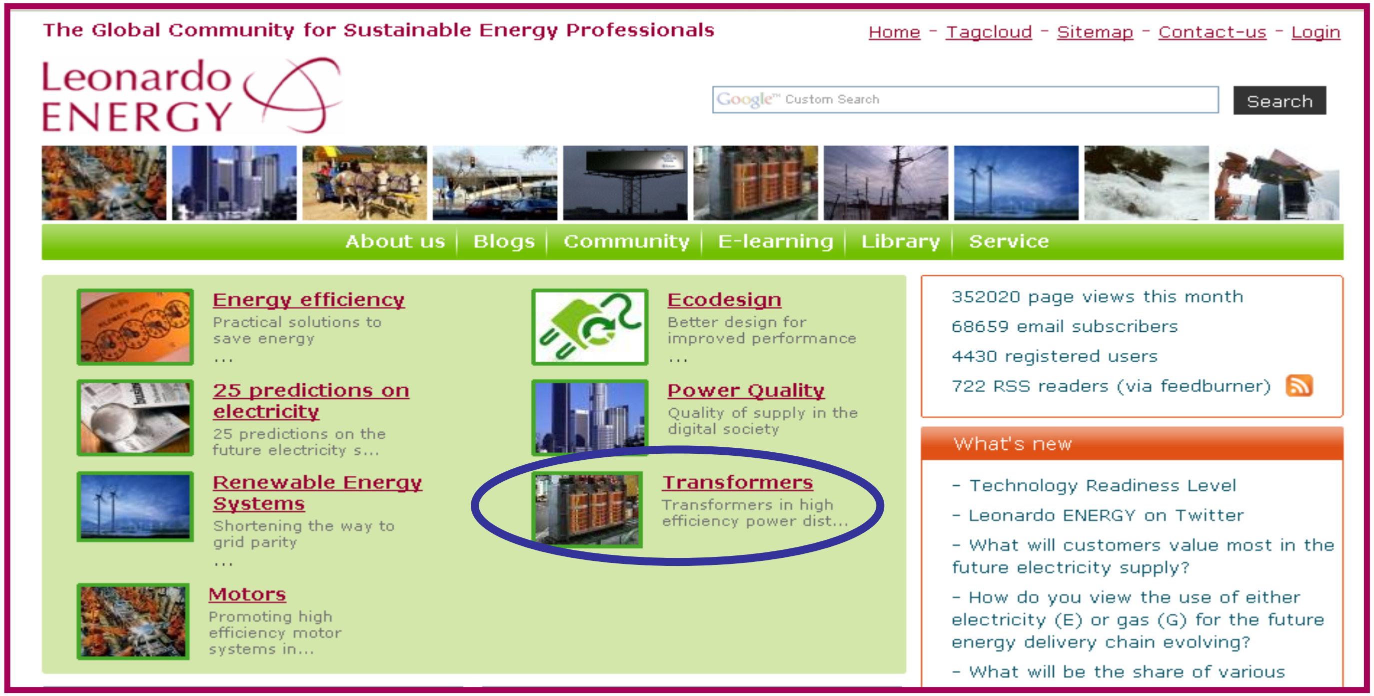
The European Copper Institute : a long tradition in promoting efficient distribution transformers

Strategies for Development and Diffusion of Energy Efficient Distribution Transformers

- **ECI participates in this program.**
- **SEEDT builds the business case for development and diffusion of energy efficient distribution transformers.**
- **A project within the framework of the Intelligent Energy program of the European Union.**
- **For the SEEDT project, ECI works in collaboration with the NTUA (Greece), Wuppertal Institute (Germany), and ENDESA (Spain).**

The European Copper Institute : removing barriers through education

Leonardo ENERGY blog



Reports the latest developments in transformer efficiency standards, regulation, and technology.

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Removing barriers by active regulatory actions

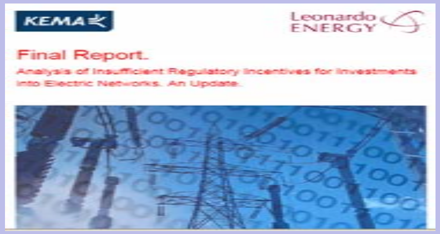
EU Regulators Group-ERGEG

Treatment of Electricity Losses - CONSULTATION

Active contribution to promote regulatory reform

REPORT

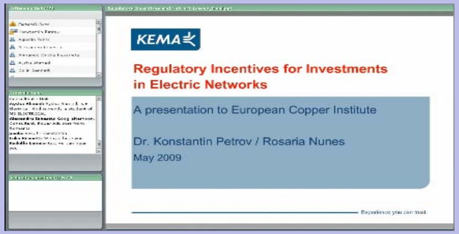
Insuficient Regulatory Incentives for Investments in Electricity Networks



Pointing at the savings potential and the regulatory proposals

WEBINAR

Regulatory Incentives for Energy Efficiency in Networks



Spreading the regulatory proposals to the professionals

REGULATORY MODEL

http://www.leonardo-energy.org/huge-potential-energy-savings-improved-regulatory-models-efficient-investment-and-loss-reduction

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RENEWABLES

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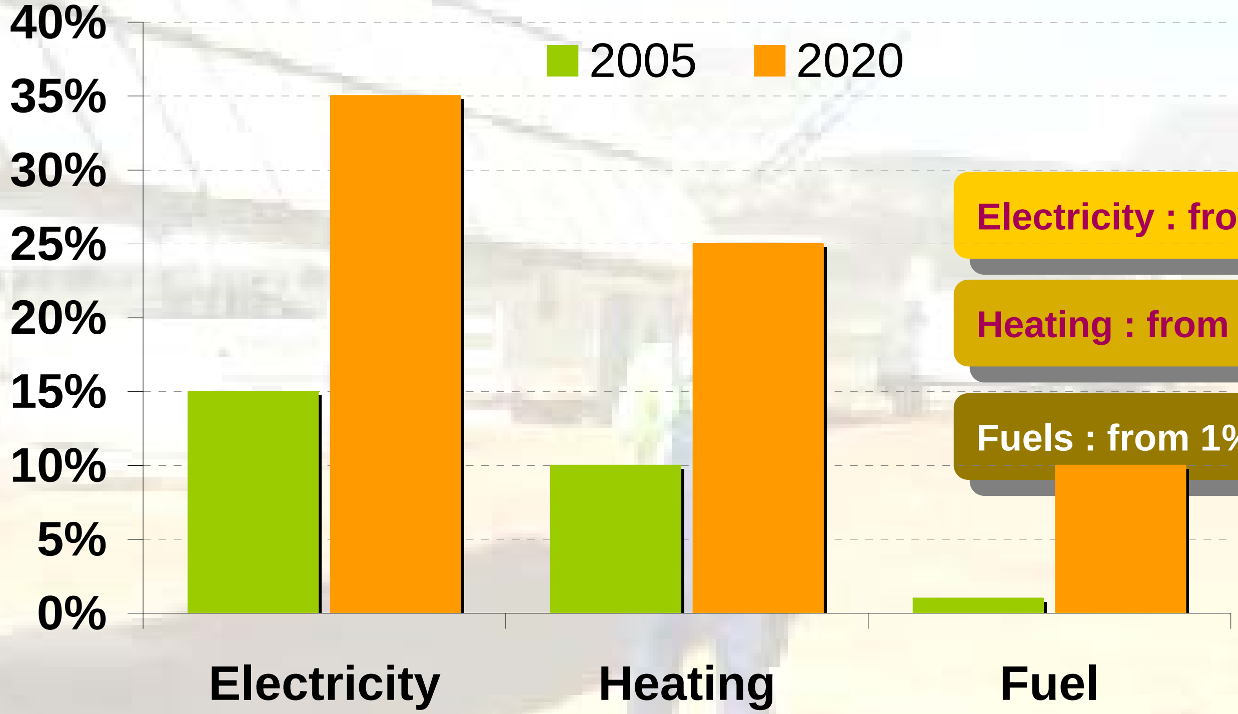
Renewables : key figures

EU to reach 20% renewables in final energy consumption by 2020



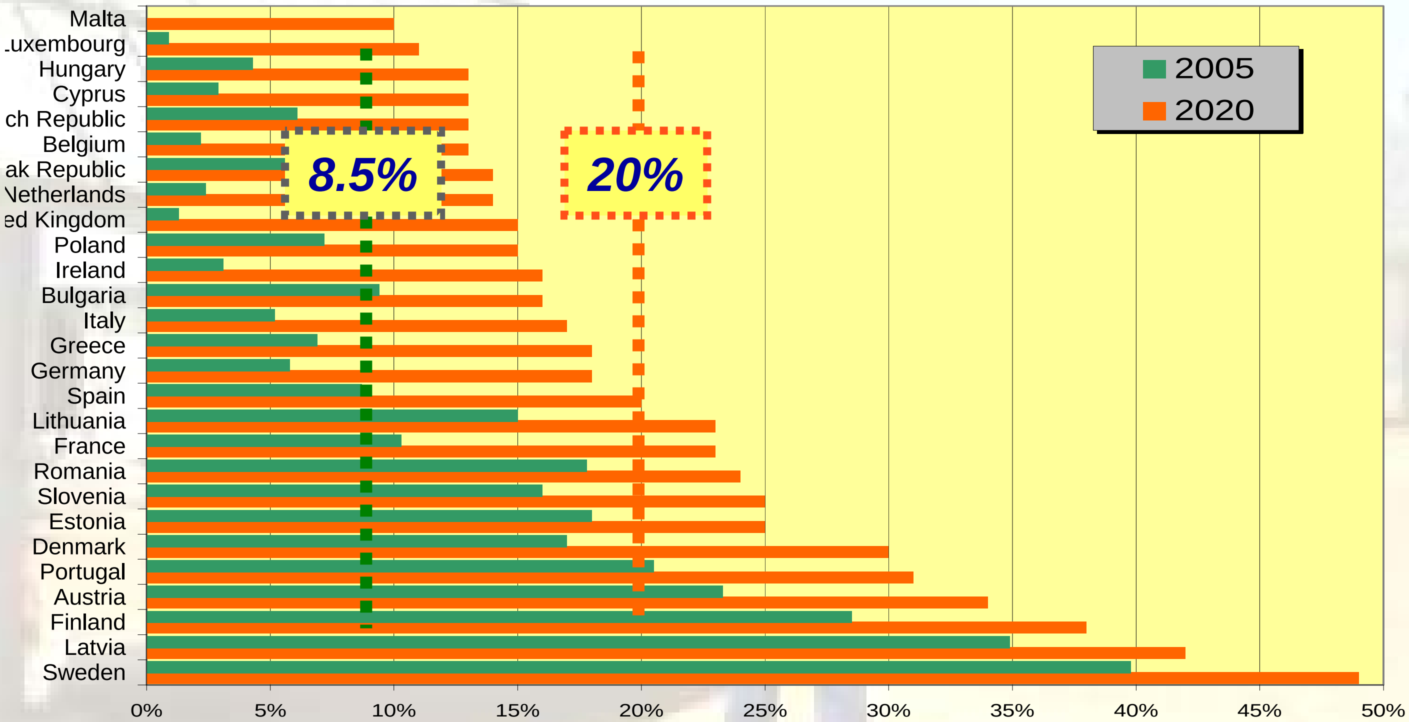
Electricity : from 15% to 35%

Heating : from 10% to 25%

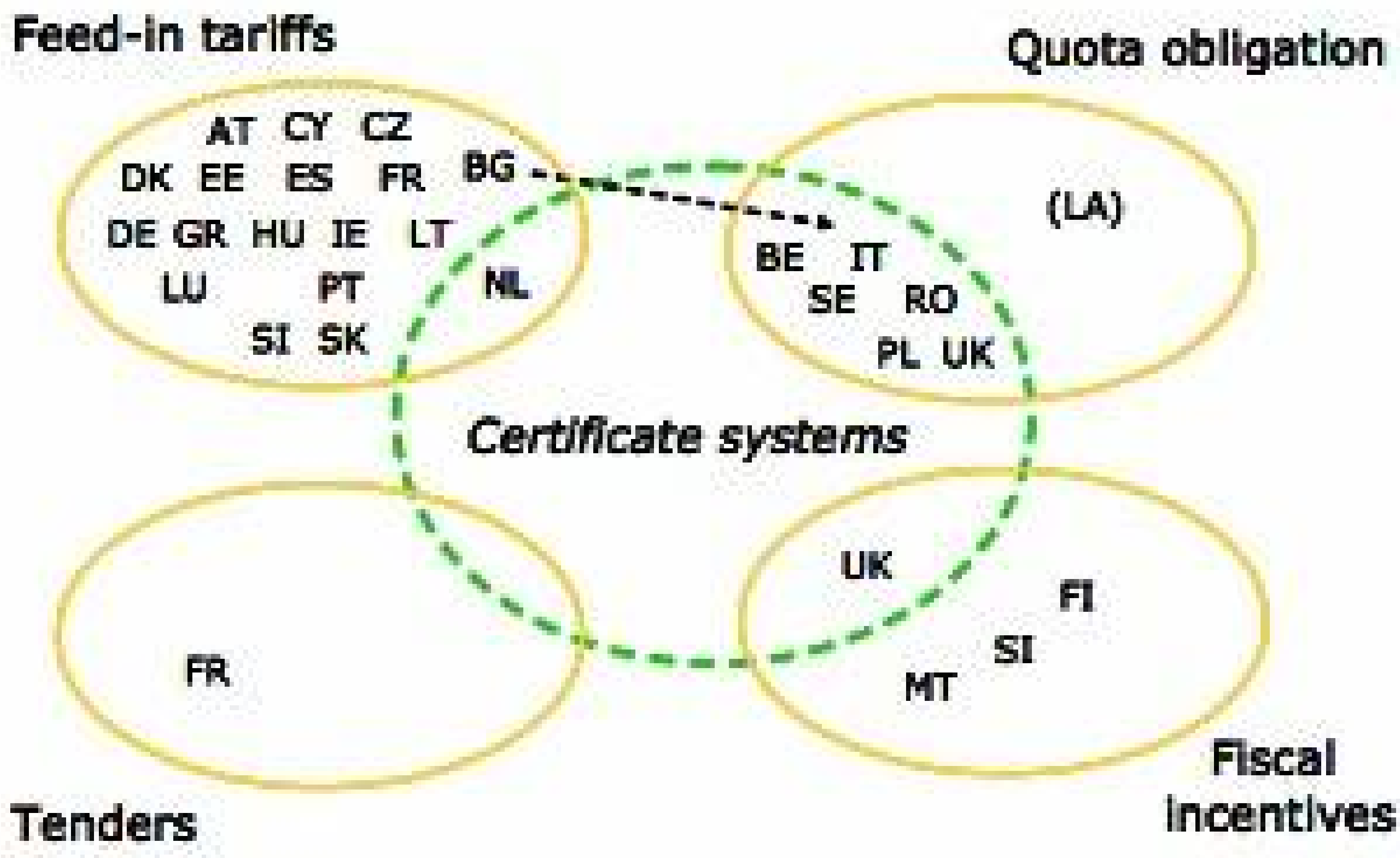
Fuels : from 1% to 10%

Renewables : key figures

EU to reach 20% renewables in final energy consumption by 2020



Support policy as the main driver for renewables



Support policy as the main driver for renewables

	Feed In Tariff	Quota + TGC	Tendering / Bidding	Fiscal / Financial Incentives
Cost allocation	To consumers	To Generators	To Generators	To Generators
Administrative burden	Depends on the form	Depends on the form	YES, complex	YES, complex
Long term confidence for investors	YES	NO	Depends on the form	NO, terms can easily change

http://www.leonardo-energy.org/webfm_send/2757

Support policy as the main driver for renewables

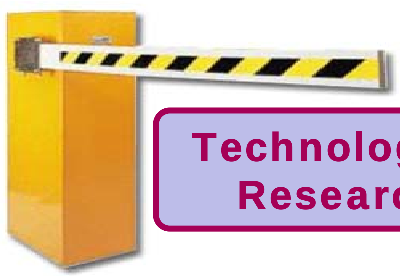
	Feed In Tariff	Quota + TGC	Tendering / Bidding	Fiscal / Financial Incentives
Encourages specific technology	YES, possible	YES, possible	YES, possible	YES, possible
Takes technology learning into account	Depends on the form (Germany degression tariff)	Depends on the form	Depends on the form	Depends on the form
Suitable for immature RE market	YES	NO, as market oriented	NO, as market oriented	YES, stimulates new tech projects

http://www.leonardo-energy.org/webfm_send/2757

Barriers to renewables development

Legal / Administrative

- National, Regional and Local **coordination.** Responsibilities definition and share
- Precise **deadlines** for planning approval
- Lighter process for **smaller projects**
- Administrative **charges** transparent and cost-related



Technology / Research

- Development of **technical specifications**
- **European Standards** (eco-label, energy-label…)
- Needed more **EU Research** interaction and cooperation
- Improve **spreading** the quickly evolving technology of renewables

Grid Integration

- **Grid** infrastructure **development**
- **Interconnections** between countries
- Rules for **bearing and sharing the costs** of grid development and reinforcement
- Provide physical **access to grid**
- **Dispatching** priority
- Dealing with **variability** and **forecast** ability

As indicated in the proposal for Directive by EC :
http://ec.europa.eu/energy/climate_actions/doc/2008_res_directive_en.pdf

Special accent by the European Commission: INFORMATION AND TRAINING

Information on SUPPORT MEASURES

To be made available to the broad public (consumers, builders, installers, architects…)

Information on BENEFITS, COSTS and ENERGY EFFICIENCY

Of equipment and systems for the use of electricity, heating and cooling from renewable sources

CERTIFICATION schemes

For installers of small-scale RE:

- Biomass boilers and stoves
- Solar Photovoltaic and Thermal systems
- Heat pumps

Guidance for PLANNERS and ARCHITECTS

Objective : consider the use of RE and district heating & cooling when planning, designing, building and renovating industrial or residential areas

As indicated in the proposal for Directive by EC :
http://ec.europa.eu/energy/climate_actions/doc/2008_res_directive_en.pdf

The European Copper Institute : removing barriers for renewables

Leonardo ENERGY blog

Technology introduction, project assessment, engineering practice, support mechanisms, addressing barriers, case studies, how to manuals for small scale…

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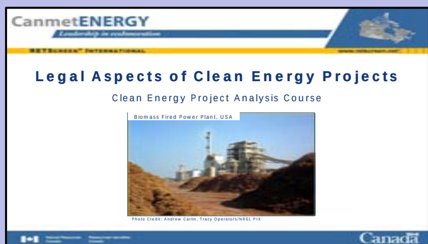
Removing barriers for renewables:
Leonardo Energy PARTNERSHIP Program

Partnership with RETSCreen

Addressing LEGAL issues and PROJECT assessment



Clean Energy Project Analysis Tools

Intensive WEBINAR PROGRAM

Partnership with European RENEWABLE ENERGY RESEARCH Centres Agency

EUREC AGENCY

Supporting and spreading 43 PROMINENT RESEARCH GROUPS from all over Europe in strengthening and rationalizing European Research

Partnership with ESTELA / PROTERMOSOLAR

European Solar Thermal Electricity Association

Spreading the technology, congress contributions, relevance of CSP as a dispatchable technology

LEGAL / ADMINISTRATIVE

TECHNOLOGY / RESEARCH

GRID INTEGRATION

Other relevant partners for renewables : REEEP / Reegle, Green Power Labs, CSP Today, Deuman Climate Change Consulting…

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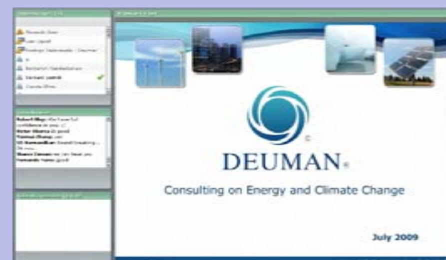
Removing barriers for renewables

IN-DEPTH ANALYSIS

Grid Integration, Support Mechanisms

WEBINAR PROGRAM

Generation of a wide and INTERACTIVE COMMUNITY of PROFESSIONALS



Weekly : Renewables, Clean Development Mechanism…

TECHNOLOGY INTRODUCTION

Concentrating Photovoltaics Concentrated Solar Power

Documentaries, Webinars, Partnership with ISFOC, Estela Solar, 1400+ professionals community

LEGAL / ADMINISTRATIVE

GRID INTEGRATION

TECHNOLOGY / RESEARCH

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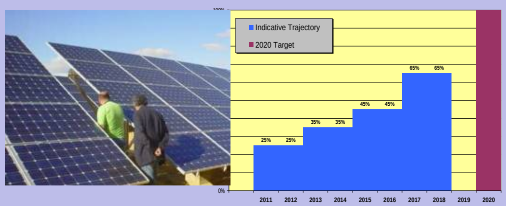
Concrete contribution to European Commission objectives on INFORMATION and TRAINING

Briefing WEBINARS and WEBCASTS introducing the EU Directive and Support Measures



Valuable resource center for project developers

Partnership with REEGLE

Renewables and Energy Efficiency dedicated SEARCH ENGINE

SMALL SCALE RENEWABLES How To Manuals

Photovoltaics, Wind, Heat Pumps

- Information on SUPPORT MEASURES
- Information on BENEFITS, COSTS and ENERGY EFFICIENCY
- CERTIFICATION schemes
- Guidance for PLANNERS and ARCHITECTS

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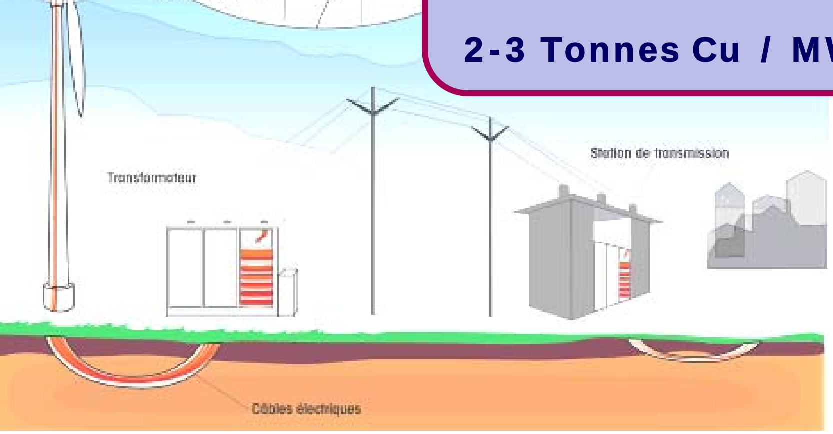
Copper presence in renewables

Copper as a fundamental component of Balance Of Plant / System for Distributed Generation



2-3 Tonnes Cu / MW

4 Tonnes Cu / MW

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- PV case study

Optimization of PV balance of plant : cables and transformer

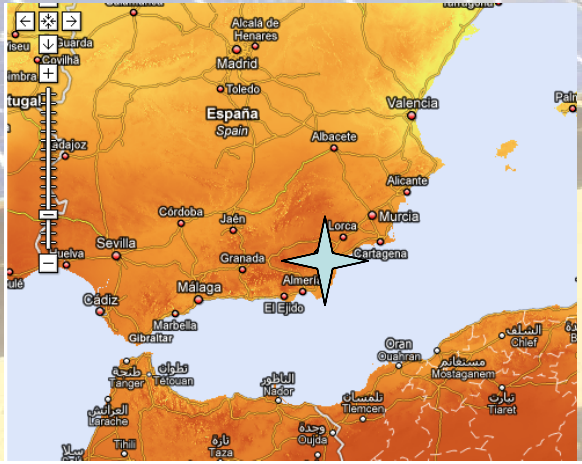
Fix structure

Optimal slope South oriented

Location : South Spain

Slope 33º

Latitude 37,38º



Technical – Economic Model

Inputs

METEO
- Solar Radiation
- Ambient Temperature
- Wind speed

PV MODULES
- Performance
- Sensitivity to radiation and temperature

PLANT LAYOUT
- Length of cables

Computing

PV BEHAVIOUR
- Modules Temp
- Hourly current, voltage, power

CABLE BEHAVIOUR
- Cables Temp
- Hourly current, power loss

BOP BEHAVIOUR
- Trafo
- Earthing

Economic / Financial Results

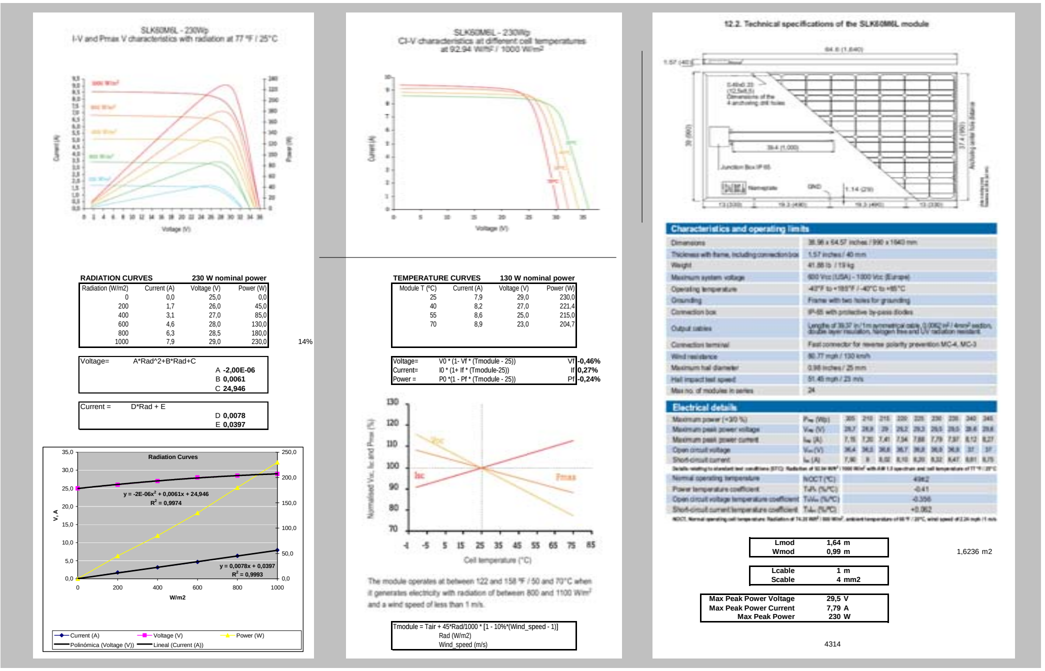
FINANCIAL
- NPV of entire power plant

CABLE SIZING
- Minimizing the Total Cost of Cables

BOP DESIGN
- Optimal Trafo Class and operation mode

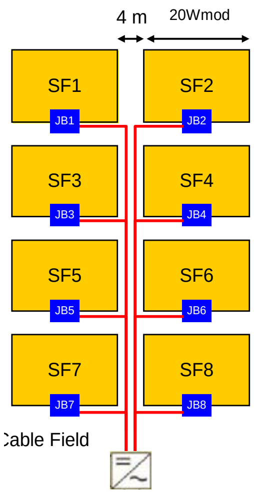
Inputs – PV modules and Plant layout

PV modules

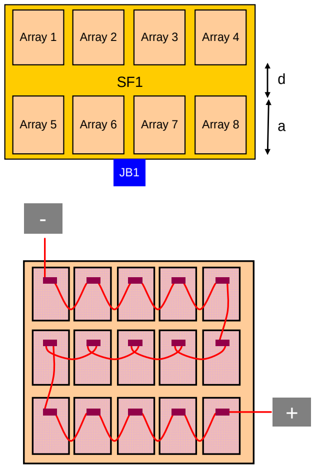


Plant layout

8 Sub-Fields



8 Arrays per Sub-Field



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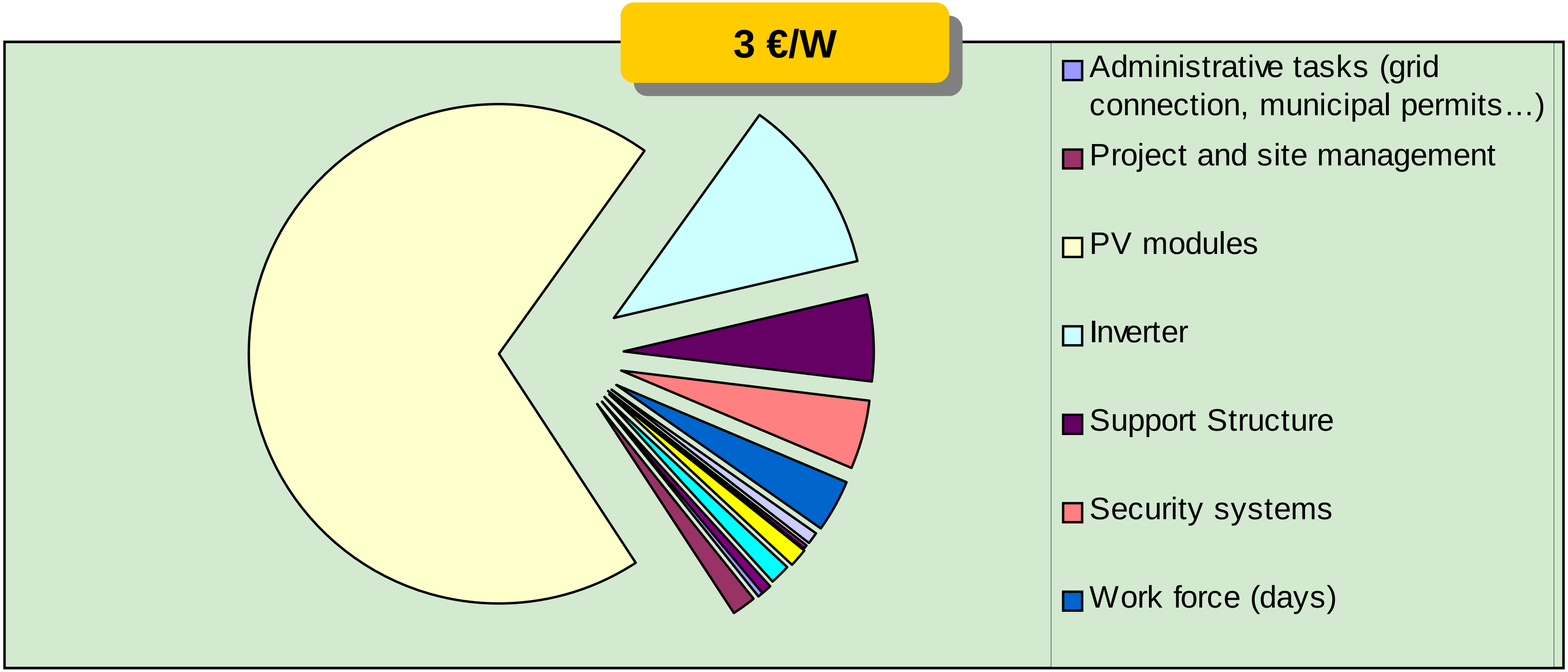
Inputs - Investment



Inputs – Business model along 25 years

Years		0	1	2	3	...	25
Annual generation	MWh		373	370	367	...	308
Feed In Tariff	€/MWh		280	284	288	...	400
Gross Income	k€		104	105	106	...	123
Operation costs	k€		-8	-8	-8	...	-10
EBITDA	k€		96	97	97	...	113
Plant Amortization	years		1	1	1	...	0
Plant Amortization	k€		-58	-58	-58	...	0
EBIT	k€		38	39	39	...	113
Loan Interests	k€		-24	-23	-21	...	0
EBT	k€		14	16	18	...	113
Taxes	k€		-4	-5	-5	...	-34
Net Income	k€		10	11	13	...	79
Cash Flow (Net Income + Amortization)	k€		68	69	71	...	79
Equity	k€	-209				...	
Loan amortization	k€		-31	-32	-34	...	0
Project Cash Flow	k€	-209	37	37	37	...	79
Cumulated Project Cashflow	k€	-209	-172	-135	-98	...	1221

Outputs: maximizing NPV

Nominal Power	220,8	kWpeak
Investment	694	k€
Modules - cable	4	mm2
Arrays - cable	6	mm2
Field - Cable	70	mm2
Voltage drop	1,2%	
IRR	19,46%	
NPV	536,1	k€
Cables : Life Cycle Cost	18,81	k€
Trafo : Total Cost of Ownership	22,6	k€
Trafo Rated Power	240	kVA
Trafo Type	Amorphous	
Trafo Operation	Connected at night	
Total Copper (cable, earthing, trafo)	898	kg
Copper intensity	4,07	Tonnes / MW

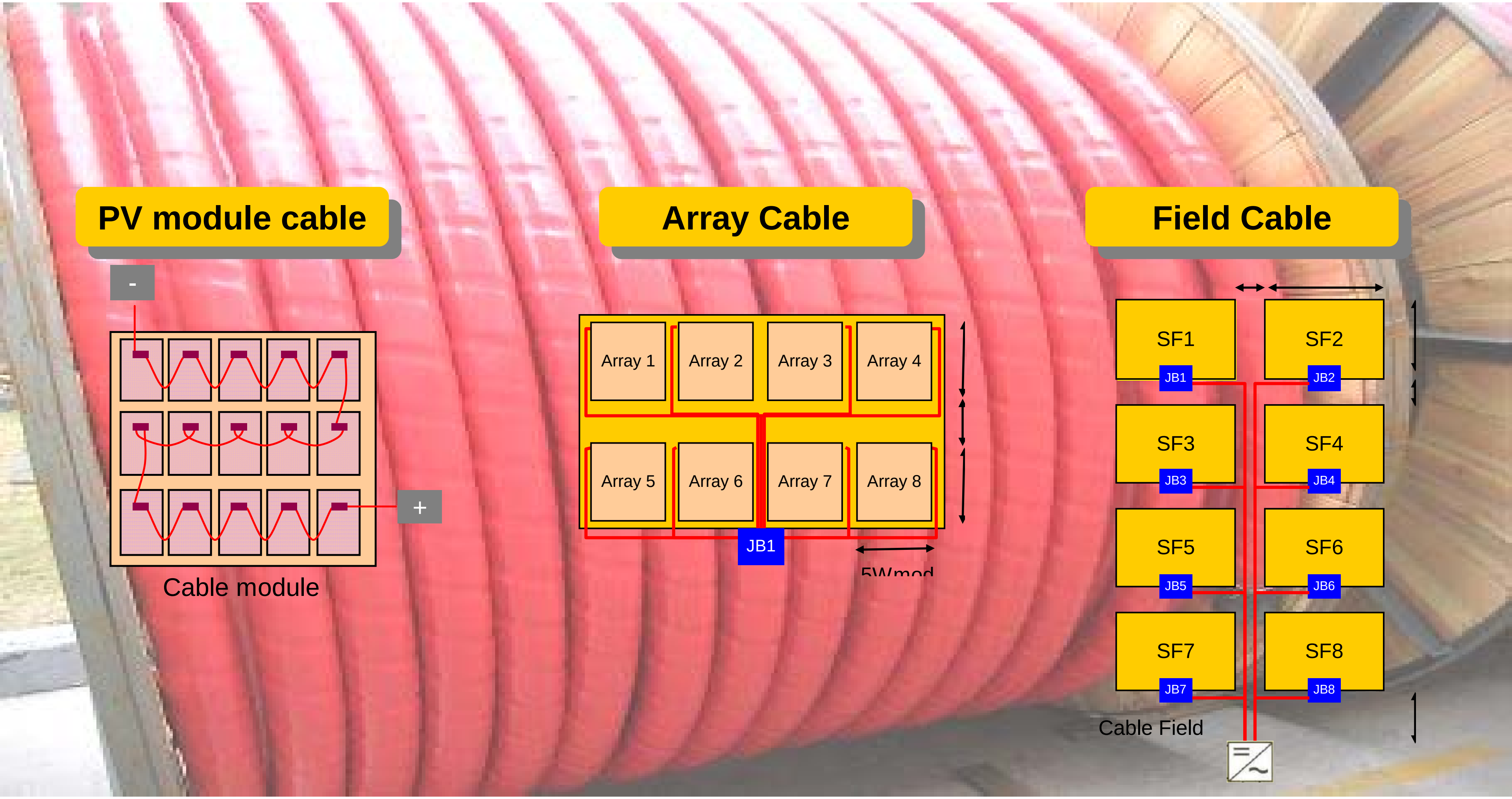
Outputs: minimizing Life Cycle Cost of Cables

Nominal Power	220,8	kWpeak
Investment	694	k€
Modules - cable	4	mm2
Arrays - cable	6	mm2
Field - Cable	70	mm2
Voltage drop	1,2%	
IRR	19,46%	
NPV	536,1	k€
Cables : Life Cycle Cost	18,81	k€
Trafo : Total Cost of Ownership	22,6	k€
Trafo Rated Power	240	kVA
Trafo Type	Amorphous	
Trafo Operation	Connected at night	
Total Copper (cable, earthing, trafo)	898	kg
Copper intensity	4,07	Tonnes / MW

Outputs: minimizing other BOP (Trafo TCO)

Nominal Power	220,8	kWpeak
Investment	694	k€
Modules - cable	4	mm2
Arrays - cable	6	mm2
Field - Cable	70	mm2
Voltage drop	1,2%	
IRR	19,46%	
NPV	536,1	k€
Cables : Life Cycle Cost	18,81	k€
Trafo : Total Cost of Ownership	22,6	k€
Trafo Rated Power	240	kVA
Trafo Type	Amorphous	
Trafo Operation	Connected at night	
Total Copper (cable, earthing, trafo)	898	kg
Copper intensity	4,07	Tonnes / MW

Impact of economic cable sizing



Design codes

Maximum Allowed Current

Maximum Allowed Voltage Drop

Cable position

Cable type

Número de conductores con carga y naturaleza del aislamiento

		2	3	4	5	6	7	8	9	10	11	12	13
[illegible]			PVC3	PVC2		XLPE3	XLPE2						
A2		PVC3	PVC2		XLPE3	XLPE2							
B1					PVC3	PVC2		XLPE3		XLPE2			
B2				PVC3	PVC2		XLPE3	XLPE2					
C						PVC3		PVC2	XLPE3	[illegible]	[illegible]	[illegible]	
D*		VER SIGUIENTE TABLA											
E							PVC3		PVC2	XLPE3		XLPE2	
F								[illegible]		[illegible]	XLPE3		XLPE2

	mm²	2	3	4	5	6	7	8	9	10	11	12	13
Cobre	1,5	11	11,5	13	13,5	15	16	16,5	19	20	21	24	*25*
	2,5	15	16	17,5	18,5	21	22	23	26	26,5	29	33	*34*
	4	20	21	23	24	27	30	31	34	36	38	45	*46*
	6	25	27	30	32	36	37	40	44	46	49	57	*59*
	10	34	37	40	44	50	52	54	60	65	68	76	*82*
	16	45	49	54	59	66	70	73	81	87	91	105	*110*
	25	59	64	70	77	84	88	95	103	110	116	123	140
	[illegible]	72	77	86	96	104	110	119	127	137	144	154	174
	50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	175	188	210
	[illegible]	109	118	130	149	160	171	185	199	214	224	244	269
	95	130	143	156	180	194	207	224	241	[illegible]	271	[illegible]	327
	[illegible]	[illegible]	[illegible]	188	208	225	240	260	280	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	205	236	260	278	299	322	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	233	268	297	317	341	368	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	272	315	350	374	401	435	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	*311*	*360*	*396*	*423*	*481*	*525*	[illegible]	[illegible]	[illegible]	[illegible]

Cable Diameter

Maximum Current

- Maximum Voltage Drop between PV generator and grid connection : 1,5%
- Total Voltage Drop : modules + arrays + field

$$\Delta V = \frac{L \cdot I}{\gamma \cdot S}$$

Standard UNE 20460-5-523 (2004)

Low Voltage Code - REBT (2002) - ITC-BT 40 (Low Voltage Generators)

Design codes

Maximum Allowed Current

MODULES

Maximum current	7,79 A
Correction factor for LV generators	25%
Correction factor for Temperature	0,9
Correction factor for direct exposure to sunrays	1
Corrected current	10,82 A
Table1 (air tray) - XLPE2 & "F" configuration	**1,5** mm2

ARRAYS

Maximum current	7,79 A
Correction factor for LV generators	25%
Correction factor for Temperature	0,9
Correction factor for direct exposure to sunrays	0,9
Corrected current	12,02 A
Table1 (air tray) - XLPE2 & "F" configuration	**1,5** mm2

FIELD

Maximum current	62,32 A
Correction factor for LV generators	25%
Corrected current	77,90 A
Table 2 (underground) XLPE2	**16** mm2

Maximum Allowed Voltage Drop

MODULES

Maximum current	7,79 A
Cable Section	4,00 mm2
Lenght	30 m
Voltage Drop	**1,25 V**

ARRAYS

Maximum current	7,79 A
Cable Section	6,00 mm2
Lenght	47 m
Voltage Drop	**1,31 V**

FIELD

Maximum current	62,32 A
Cable Section	50,00 mm2
Lenght	138 m
Voltage Drop	**3,66 V**

System Voltage	**443**	**V**
Total Voltage Drop	**6,2**	**V**
Relative Voltage Drop	**1,4%**	**< 1,5 %**

Design codes – Results

Section (mm^2)	Current	Voltage Drop
Modules	1.5	**4**
Arrays	1.5	**6**
Field	16	**50**

Nominal Power	**kWpeak**	**220,8**
Investment	**k€**	**694**
Modules - cable	**mm2**	**4**
Arrays - cable	**mm2**	**6**
Field - Cable	**mm2**	**50**
Voltage drop		**1,4%**
NPV	**k€**	**535,4**
Cables : Life Cycle Cost	**k€**	**22,00**
Total Copper (cable, earthing, trafo)	**kg**	**769**
Copper intensity	**Tonnes / MW**	**3,48**

Going beyond design codes: economic sizing

Investment → 7796 € | 11500 € | +3704 € (+48%)

Section (mm²)	Current	Voltage Drop	Economic Sizing
Modules	1.5	4	10
Arrays	1.5	6	10
Field	16	50	70

Nominal Power	kWpeak	220,8	220,8
Investment	k€	694	697
Modules - cable	mm2	4	10
Arrays - cable	mm2	6	10
Field - Cable	mm2	50	70
Voltage drop		1,4%	0,9%
NPV	k€	535,4	535,8
Cables : Life Cycle Cost	k€	22,00	20,11
Total Copper (cable, earthing, trafo)	kg	769	1060
Copper intensity	Tonnes / MW	3,48	4,80

+ 0,4 k€ (0,08%)

- 1,8 k€ (8,2%)

Thank you!

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