Preparatory study for solar photovoltaic modules, inverters and systems

3rd Stakeholders meeting

10th July

The European Commission’s science and knowledge service

Joint Research Centre

European Commission

Introduction to the meeting

09:30	Welcome and introduction
	Tour de table
	Update on the study (tasks, timing..)
10:00	Task 6 – Design options identification and overview
11:30	Coffee break
11:45	Task 6 – Environmental impact and LCC results
	Task 7 – Policy analysis
13:00	Lunch
14:00	Draft transitional methods
15:00	Task 7 – Scenarios overview and analysis
16:30	Next steps
16:45	AOB and closing words

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Study progress and outlook

2nd stakeholder meeting, Brussels (19/12/2018)

- Techno-economic /environmental analysis: technological alternatives evaluation, hotspots analysis

Webinar on EU Ecolabel and GPP (30/04/2019)

- Initial presentation of LCA hot spot analysis and provisional evaluation findings

3rd stakeholder meeting (10-11/07/2019)

- Identification and evaluation of potential policy options (Ecodesign, Energy Labelling, Ecolabel, GPP) for each of the 3 product groups (PV modules, inverters and systems)

Outline

General introduction to the preparatory study

- Previous work from Tasks 1,2,3,4,5
- Important concepts underpinning the study

Task 6

- LCA and LCC modelling for module, inverter and system design options
- Identification of BAT and LLCC technologies

Task 7

- Identification of stakeholders and basis for policy instruments
- Policy options identification and definition
- Modelling of policy scenarios

Study progress

1st stakeholder meeting, Brussels (29/06/2018)

- Scope and definitions, existing standards and legislation, market figures, user behaviour

PV experts, standards meeting in Ispra (31/10/2018)

- Development of transition methods

2nd stakeholder meeting, Brussels (19/12/2018)

- Techno-economic /environmental analysis: technological alternatives evaluation, hotspots analysis

Webinar on EU Ecolabel and GPP (29/04/2019)

- Findings from the evaluation of feasibility using criteria from DG ENV. First draft criteria areas presented for discussion

Previous work

Task 1 (Product scope)

- Scope and components definitions
- Measurements and test standards in place
- Functional unit, lifetime and assumptions for the study, same as PEF

Task 2 (Market data and trends)

- Global market share dominated by crystalline Si types, China dominating the whole value chain
- Quality and durability is a major focus
- Hazardous substances substitution: Lead-free soldering, Fluoride-free back sheet

Task 3 (User Behaviour and System Aspects)

- Consumer requirements
- Direct and indirect impacts
- Understanding factors affecting product lifetime and EoL

Previous work

Task 4 (Technical analysis including end-of-life)

- Description of processes involved in the functional performance of the products
- Base cases, Best Available and Best Not yet Available candidates
- Data sources to model production for lifecycle analysis

Task 5 (Environmental and economic assessment of base cases)

- LCA of Base Cases and BATs and BNATs
- LCA literature review and hazardous substances analysis

Important concepts

BASE CASE (BC)

- Refers to the representative products in 2016
- In response to comments the evolution of this product is represented (BC-optimised)
- BC is the baseline for comparison of improvement options (BAU)

PERFORMANCE RATIO (PR)

- Base case PR is informed by monitoring data
- Modelled PR for improvement options is calculated according to defined derate factors

FUNCTIONAL UNIT (FU)

- Used for the calculation of environmental impacts and levelized cost of energy is ‘1 kWh of electricity generated’
- Benefits of electricity generated is reflected in the FU but can also be fully reflected by reporting on yield and EROI or EPBT (relating the two)

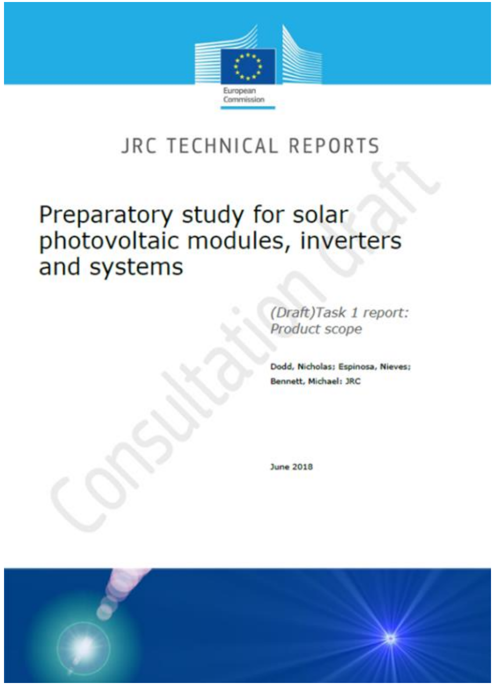
Important concepts

Policy Instrument	Stringency	Scope	Life cycle stage	Verification
Ecodesign	Mandatory	Products, packages of products	Requirements can be set on tested use stage product performance, Information on material efficiency aspects can be requested	Market surveillance is carried out at member state level.
Energy label	Mandatory	Products, packages of products	Energy Efficiency Index (EEI) shall address performance in the use stage.	Market surveillance is carried out at member state level.
EU Ecolabel	Voluntary	Can be products or services	Criteria can be set on any life cycle stage and can include manufacturing sites as well as tested product performance.	Member State Competent Bodies verify compliance evidence and award the label.
GPP	Voluntary	Can be products or services	Criteria can be set on any life cycle stage and can include manufacturing sites as well as tested product performance. The criteria must always link to the subject matter.	Verification is through evidence from tenderers provided during the procurement process.

MEErP

LCA

One policy development process:
DGs GROW, ENER, ENV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JRC TECHNICAL REPORTS

Preparatory study for solar photovoltaic modules, inverters and systems

(Draft)Task 1 report: Product scope

Dodd, Nicholas; Espinosa, Nieves; Bennett, Michael; JRC

June 2018

Consultation draft

- *Ecodesign minimum requirements*
- *Energy Label classes*
- *Ecolabel criteria*
- *GPP criteria*

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Task 6:
Assessment of BAT, design options and improvement potential

- Identification of BAT and LLCC technologies
- LCA and LCC modelling for module, inverter and system design options

Design options identification

- Not have a significant variation in functionality, quality or in the primary or secondary performance parameters compared to the BC
- Have a significant potential for improvement on one of the following parameters: energy/water/resources consumption, hazardous substances, emissions to air, water or soil, ease for reuse and recycling, lifetime extension, etc.
- Should not entail excessive costs and the impacts on the manufacturers be carefully investigated

EU and MS or third country market contexts should be considered

Reporting against functional unit

Environment

The environmental impacts are expressed per kWh of electricity generated and reflecting 30 years lifespan. E.g. primary energy (MJ/kWh)

Cost

LCOE is the levelised cost over 30 years of generating the FU. It includes: initial investment (incl. module and inverter costs), operations and maintenance, cost of fuel and cost of capital

Product specific inputs
Functional unit

Modules: 1 kWh DC under predefined climatic and installation conditions for a typical year. Service life: 30 years

Inverters: 1 kWh AC from a reference photovoltaic system (excl. the inverter efficiency) under predefined climatic and installation conditions for a typical year. Service life: 30 years

Systems: 1 kWh AC supplied under fixed climatic conditions for a typical year (with reference to IEC 61853 part 4). Service life: 30 years

	BC1	BC2	BC3	unit
System	3	24.4	1875	kWp
Inverter	2.5	20	1500	kW
Inverter:module DC capacity	1:1.20	1:1.20	1:1.25	
Life span system	30	30	30	years
Life span inverter	10	10	30	years
Inverter units in the LC	3	3	1 (replacement of parts)	unit
Electricity output system	81	662	50862	MWh
Inverter units per kWh	3.69E-05	4.53E-06	1.97E-08	inverters per kWh

	Module parameters
Module Size (m^2/module)	1.6
Module conversion efficiency (%)	14.7
Wafer thickness (micrometer)	200
Cell size (mm^2)	156*156
Technology	Average technology mix of front/back cell connection, diffusion and front collection grid
Main data source	De Wild-Scholten (2014)
Rated power (Wp/m^2)	147
Cells area per module (%)	95.39%
System yield - Yf (in year 1) (kWh_{DC}/kWp)	997
Expected life time (years)	30
Module area per kWh energy produced (m^2)	**2.45E-04**

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Bill of materials data
Modelling

- Ecoreport material data
  - Primary data from PEF pilot- treeze model in Simapro
  - Generic data from Ecoinvent 3.4
  - Data from literature, e.g. PERC, SHJ, inverters

Product specific inputs

Life cycle cost and Levelised cost of electricity

- The MEErP methodology is usually based on an analysis of life cycle cost (LCC). Why LCOE instead of LCC
- Levelised Cost of Electricity (LCOE) is widely used in the electricity sector to express the total life cycle cost of delivering electricity to the grid.
- The difference of LCOE with respect of LCC is that it is normalized to the unit of power generated.

$$LCOE = \frac{CAPEX + \sum_{t=1}^{n}[OPEX(t)/(1+WACC_{Nom})^{t}]}{\sum_{t=1}^{n}[Utilisation_{0} \cdot (1-Degradation)^{t}/(1+WACC_{Real})^{t}]}$$

Products and segments

PV products

- Modules
- Inverters
- Systems

Market segments

- Residential
- Commercial
- Utility

Module design options

Design options	Description
Option 1: Optimised multi Si	Optimized BSF modules as of today (2019): - white EVA - more busbars (6) - better glass (AR properties) - factory quality control measures
Option 2: PERC	PERC cells
Option 3: Bifacial + PERC	Bifacial PERC cells and a glass backsheet
Option 4: CdTe	Thin film CdTe
Option 5: CIGS	Thin film CIGS
Option 6: Kerfless old	Epitaxial Si/Ribbon Si
Option 7: SHJ	Silicon heterojunction
Option 8: MSi cleaner cell production	MSi base case module

Module BNAT design options

Option 9: BNAT kerfless new	Kerfless wafer production
Option 10: Back-contact *	Compared to two-sides contacted solar cells, back-contact solar cells have both contact polarities on the rear side which significantly reduces optical losses at the illuminated front side both from cell metallization and cell-to-cell interconnection (task 4 report)
Option 11: Perovskite	Perovskite based thin film PV is not yet in production, but this technology has made remarkable progress in the past few years. Because of its potential of very low-cost production, and its suitable bandgap for tandem formation with crystalline silicon, it could be (or pave the way for) a significant and disruptive technology PV energy generation (task 4 report)
Option 12: Perovskite/Si-tandem	The start-up Oxford PV showed that the tandem configuration has the potential to outperform single junction Si PV with efficiencies over 22%. They have acquired a production facility in Germany targeting tandem pilot production by 2019-2020 (task 4 report)

* Pending manufacturer LCI

Inverter design options

Design options	Description
Residential	
Option 1: more efficient	This design option represents the potential for improvement on the Euro efficiency of the base case
Option 2: longer life time	This design option represents the potential for extension of the design lifetime of the base case
Option 3: repair (repaired)	This design option represents the extent to which a product is designed for repair along its lifetime
Option 4: monitor/smart	This design option represents the potential for monitoring to diagnose and react to faults related to firmware or hardware. It can help additionally the consumer to adjust their demand to increase self-consumption
Option 5: Module Level Converter (MLI)	This design option represents the installation of module level inverters that may increase yield in mismatch conditions
Option 6: Hybrid storage worst performer Option 7: Hybrid storage best performer	These design options represent the installation of inverter with integrated storage to either: - provide peak shaving in feed in (German EEG case). - increase hourly and quarterly self-consumption

System design options

Design options	Description
Residential	
System Options	
System Option 1: Multi Si optimised + best inverter (SO 1)	This option combines the best module with the best inverter
System Option 2: Multi Si optimised + best inverter + better design (SO 2)	This system combines the best module with the best inverter and includes a better design by installer
System Option 3: Multi Si optimised + best inverter + optimised O&M (SO 3)	This system combines the best module with the best inverter and includes optimized operation and maintenance routine.
Package option 1 (PO 1)	Multi Si module and reference inverter
Package option 2 (PO 2)	Multi Si optimised module and reference inverter
Package option 3 (PO 3)	PERC module and reference inverter
Package option 4 (PO 4)	CIGS module and reference inverter

Base case evolution

Production step	Selected improvement measures	
	Optimised BSF 2020	**Optimised BSF 2025**
Wafer production	Multi-crystalline with diamond wire sawing with larger wafer size than>156x156 mm^2 170 um wafer thickness and 80 µm of kerfless	Epitaxial wafer production with larger wafer size than>156x156 mm^2 and wafer thickness of 120 µm and no kerfless
Semi-conductor preparation e.g. passivation	Bifacial PERC cell without passivation	SHJ on n-type mono wafer
Cell metallisation	Reduced Ag to 50 mg/cell and Al to < 200 mg/cell	Reduced Ag and Pb-free cell metallization paste with 90 mg/ml and Al< 200 mg/cell
Cell stringing	Full-cells and 5BB interconnection	Half-cell, busbarless cells with copper interconnection with Pb-free soldering
Cell encapsulation	Glass-glass with 3.2 mm glass	Glass-glass with AR and anti-soiling coating with < 3.2 mm glass thickness
Module power	340 Wp for 72-cell modules	440 Wp for 72-cell modules
Degradation rate	0.7%	0.5%
Performance warranty	25 years	30 years
Factory quality inspection	Infrared+Electroluminescence/Lock in thermography	Infrared+high-resolution Electroluminescence/Lock in thermography Light/Potential Induced Degradation assessment

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Design option parameters

PV Modules	PV Inverters
Module type	Inverter type
Performance degradation rate (% per year)	Rated power (kVA)
Failure rate modules (%/year)	Euro Efficiency η_{conv}[%]
Cells per module	Failure rate inverters (% / year] = 1/(average life time)
Module power density (Wp/m²)	Cost (EUR/VA)
Wafer thickness/Active layer thickness (µm)	
Kerf thickness (µm)	
Total silicon use in kg per m^2	
Economic life time for the FU (years)	
Cost (EUR/Wp)	

Failure assumptions in inverters

	BC 1 residential	BC 2 Commercial	BC 3
EOL (years)	30	30	30
proxy replacement rate for EoL (%/y)	3,33%	3,33%	3,33%
MTBF BAU (years)	15	15	15
constant failure rate BAU (%/y)	6,67%	6,67%	6,67%
MTBF BAT LL (years)	191	50	30
constant failure rate BAU (%/y)	0,52%	2,00%	3,33%
BAU total failure rate (%/y)	10,00%	10,00%	10,00%
BAT total failure rate (%/y)	3,86%	5,33%	6,67%
BAU inverter needed over 30 y life	3,00	3,00	3,00
BAT inverter needed over 30 y life	1,16	1,60	2,00

Notes:

wear out failures = wear out + economic life time of installation

premature failures = warranty replacements (assumed in BOM)

random failures = constant failure rate phase

Discussion

- Selection of design options for modules, inverters and systems
- Design option parameters used for modelling
- Sources for bill of material data
- Inverter failure assumptions

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- Identification of BAT and LLCC technologies
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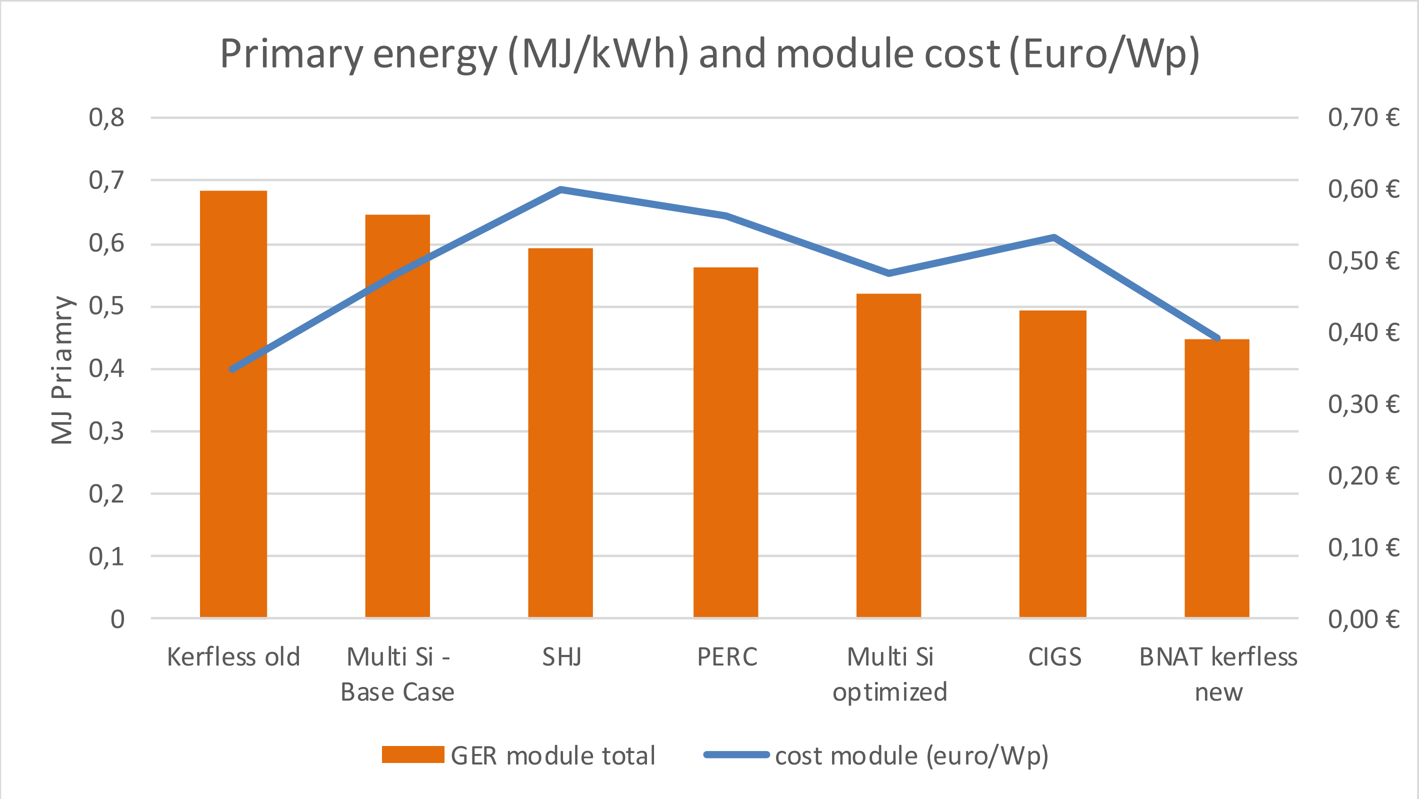
Lead impact category and supplementary parameters

- Lead indicator: Primary energy

  Excludes regionalised effects related to electricity production

- Possible secondary indicators:
  - ✓ *Modules:*
    - Polycyclic aromatic hydrocarbons
    - Volatile organic compounds
    - Heavy metals
  - ✓ *Inverters*
    - Photochemical ozone formation
    - Polycyclic aromatic hydrocarbons
    - Heavy metals

Analysis of BAT and LLCC – Modules residential



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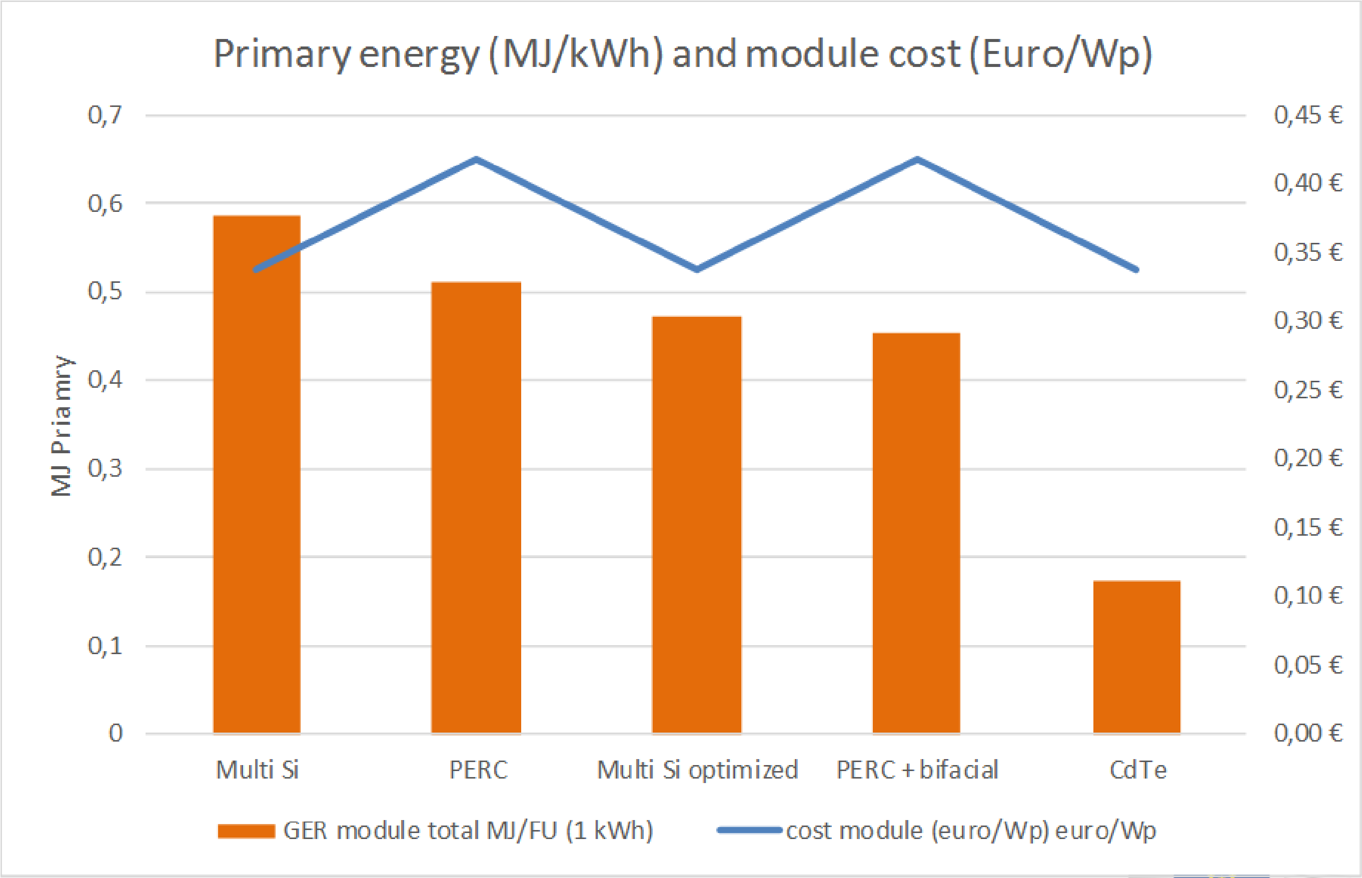
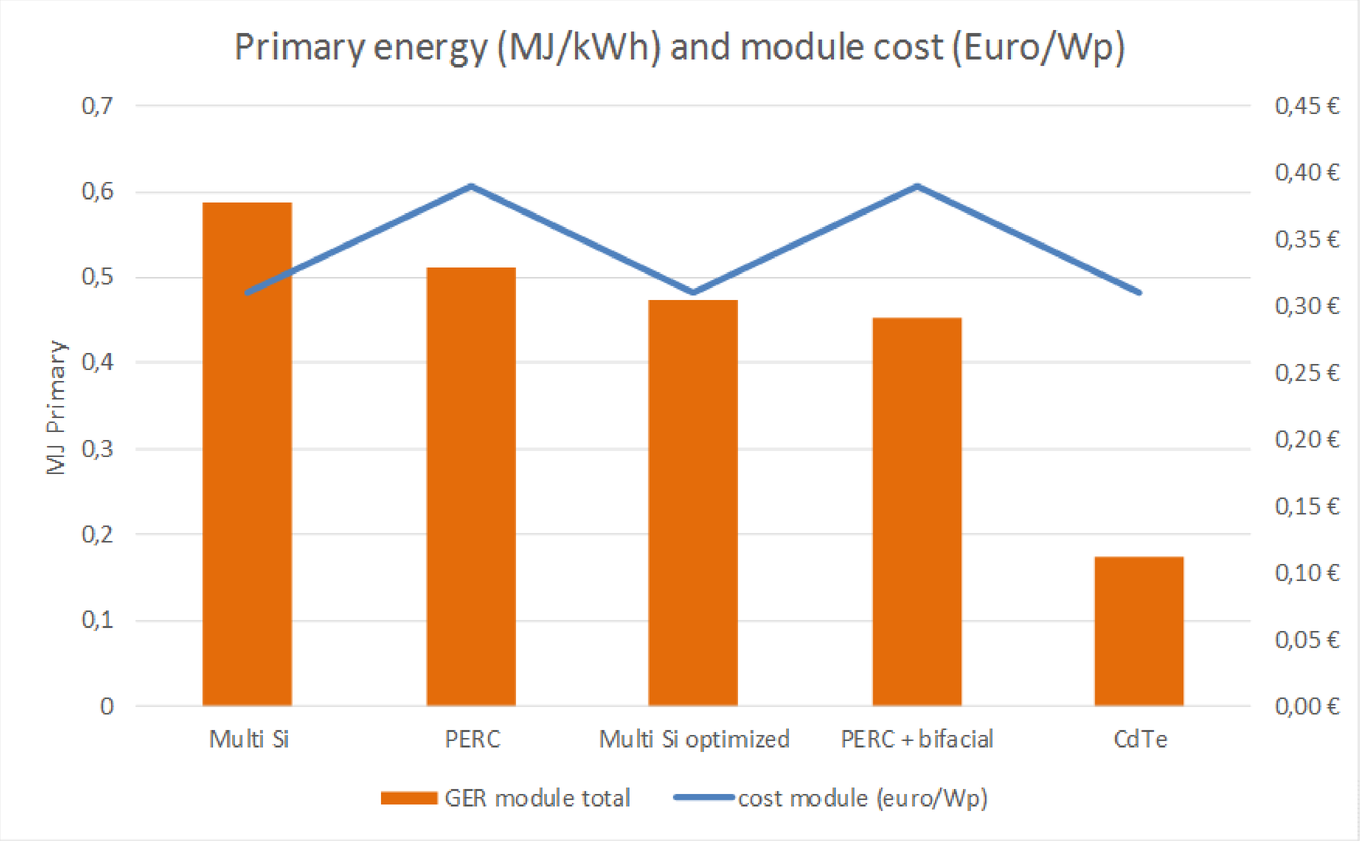
Analysis of BAT and LLCC – Modules commercial



Analysis of BAT and LLCC – Modules utility



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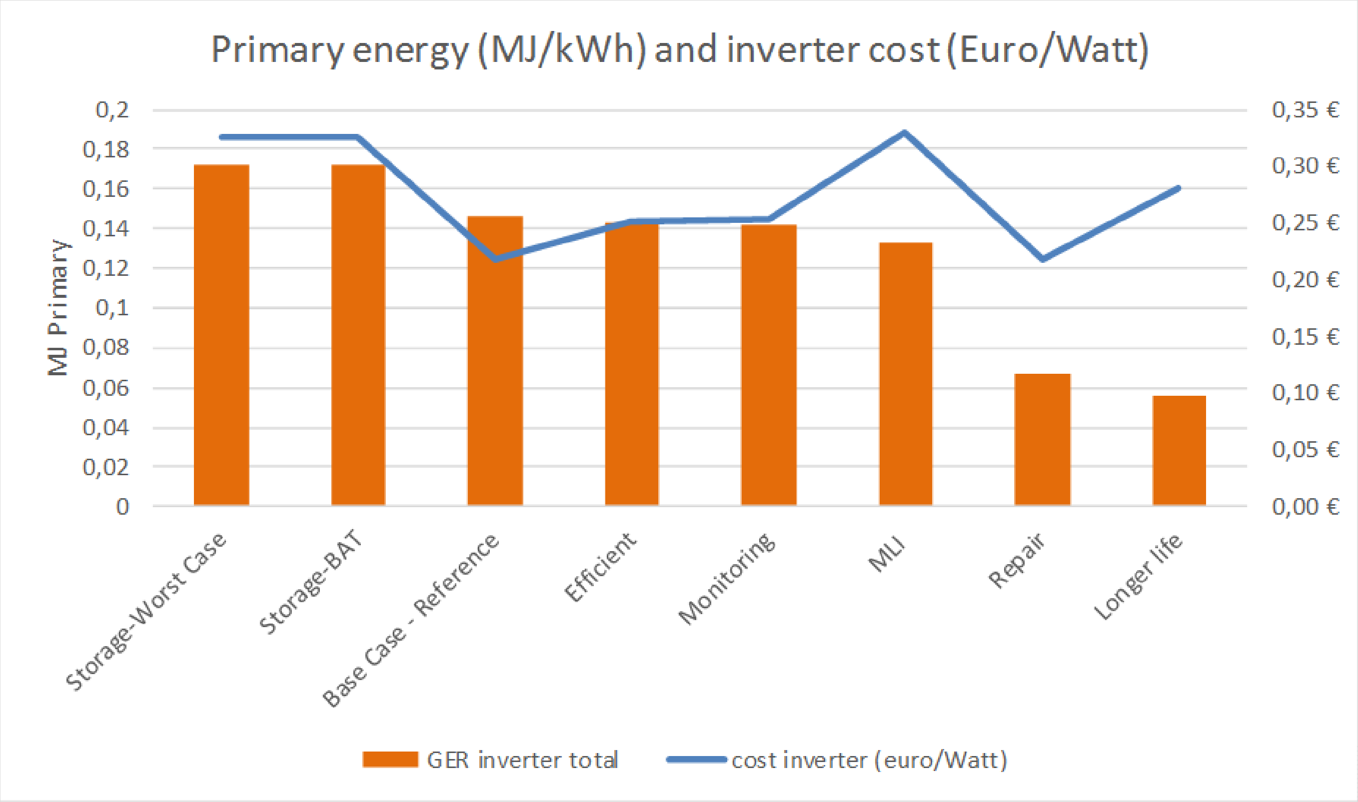
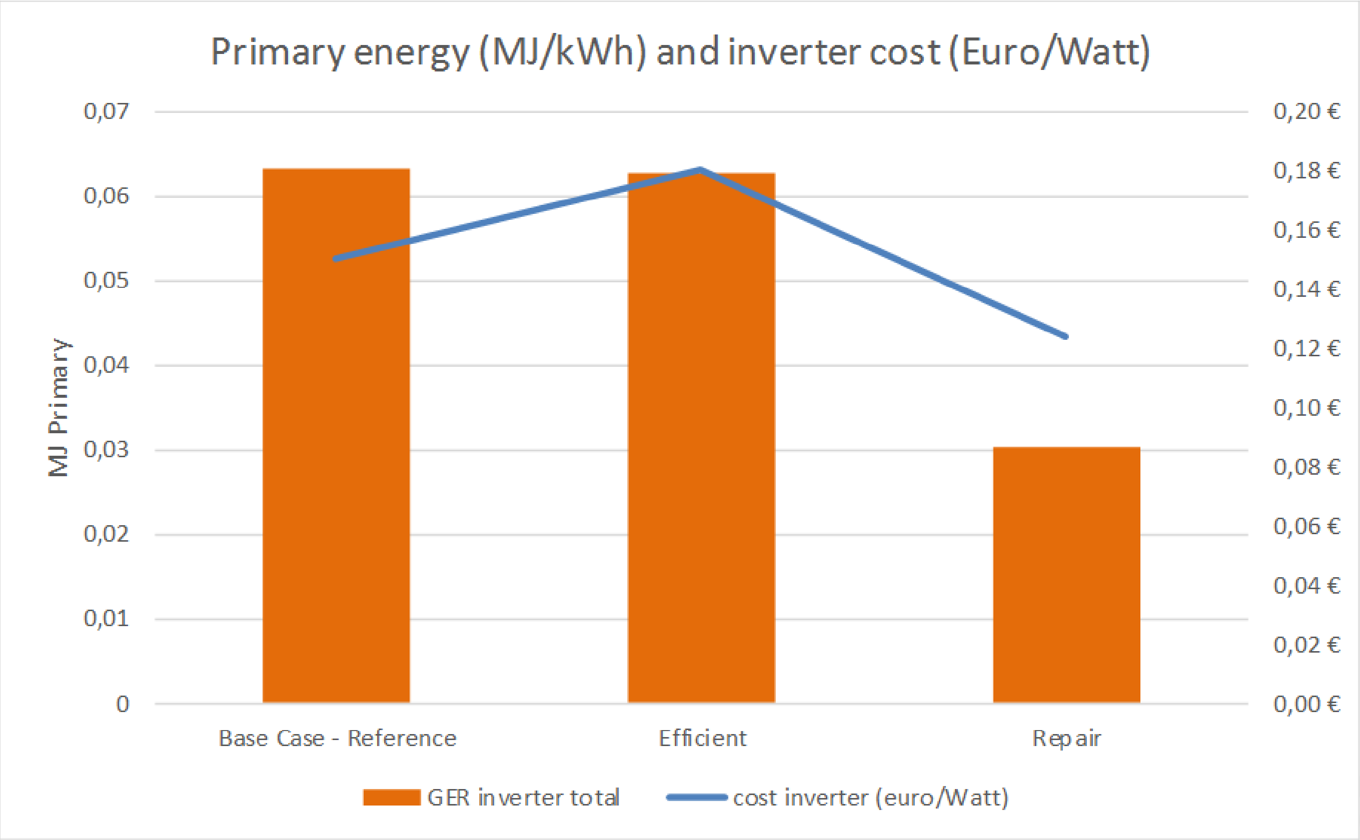
Analysis of BAT and LLCC – Inverters residential



Analysis of BAT and LLCC – Inverters commercial



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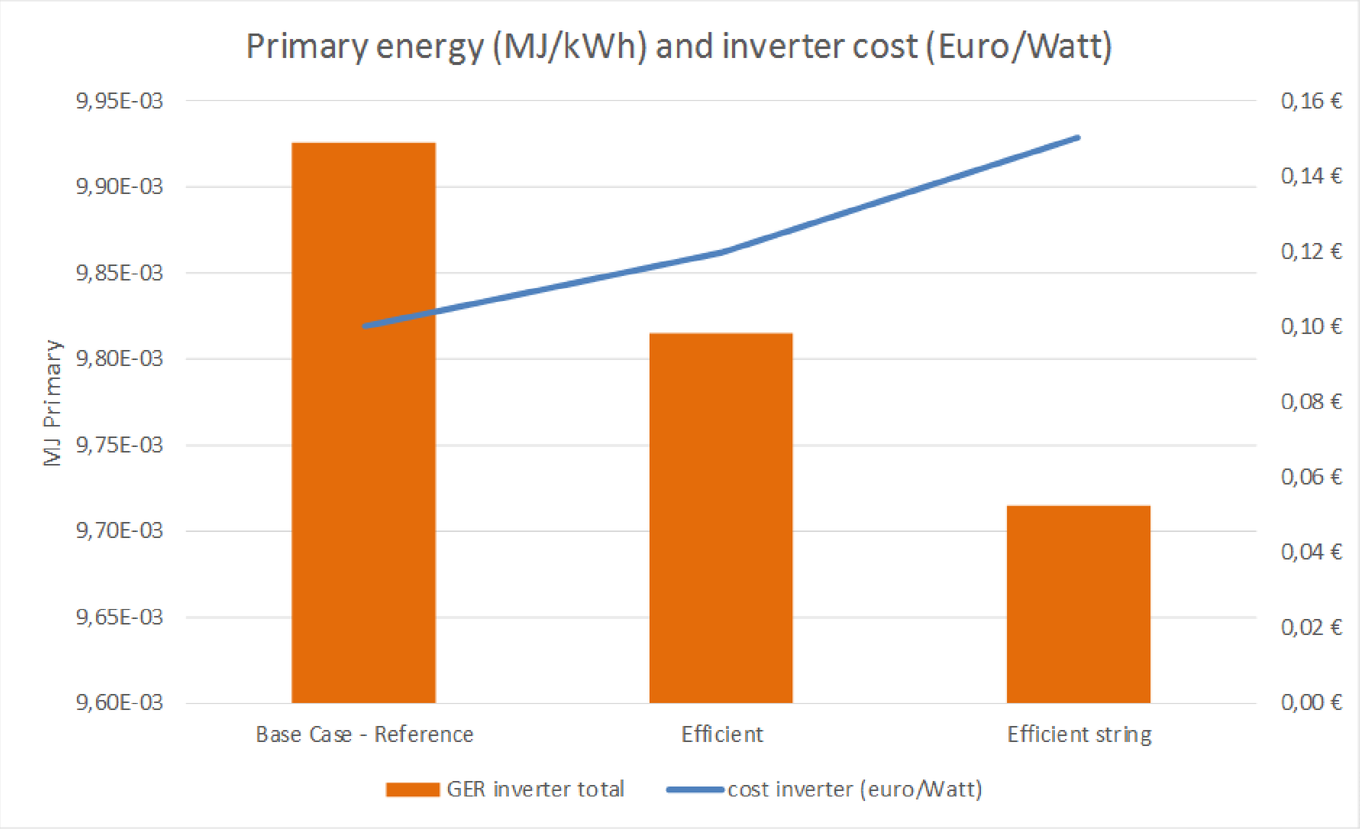
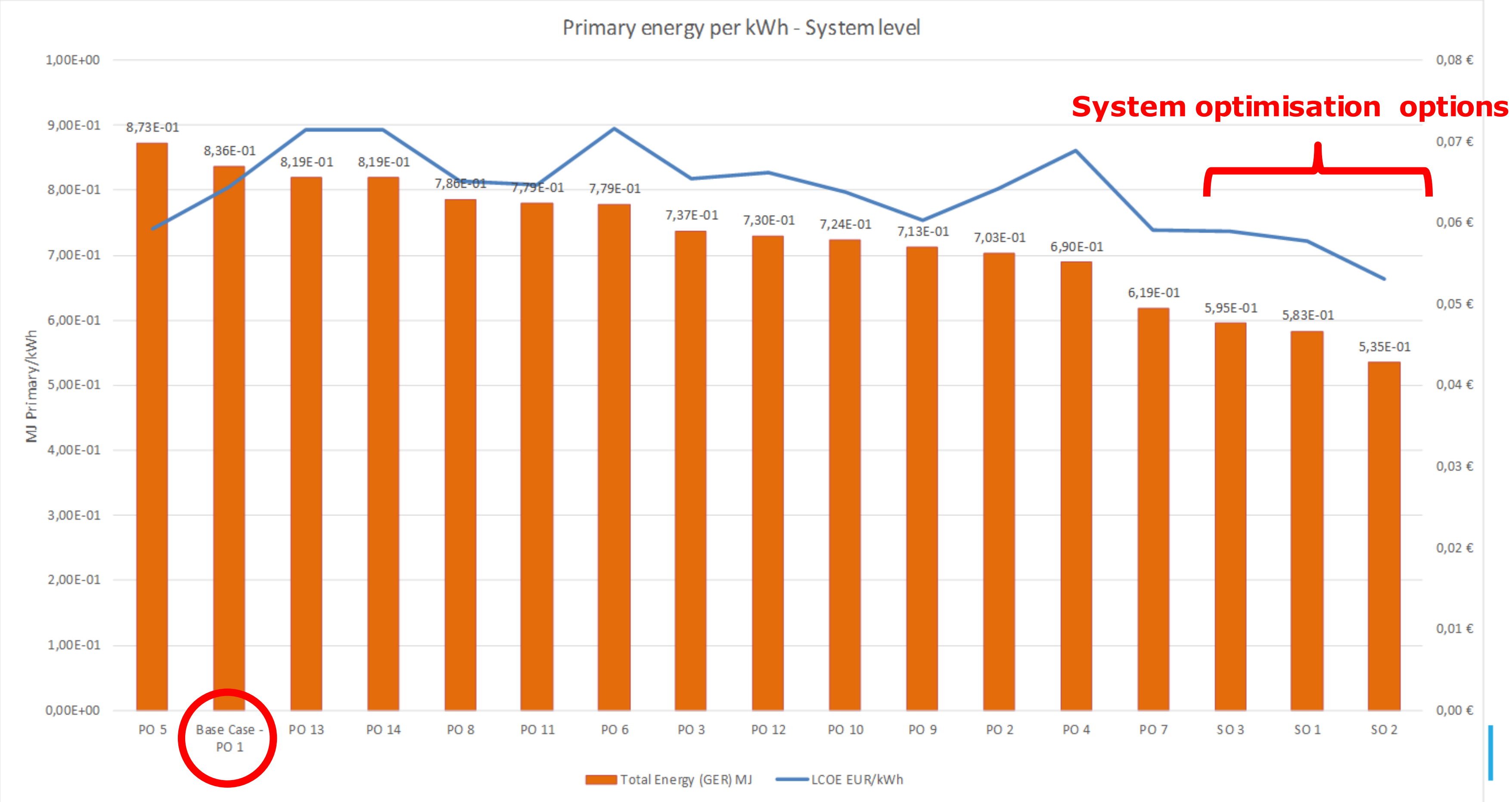
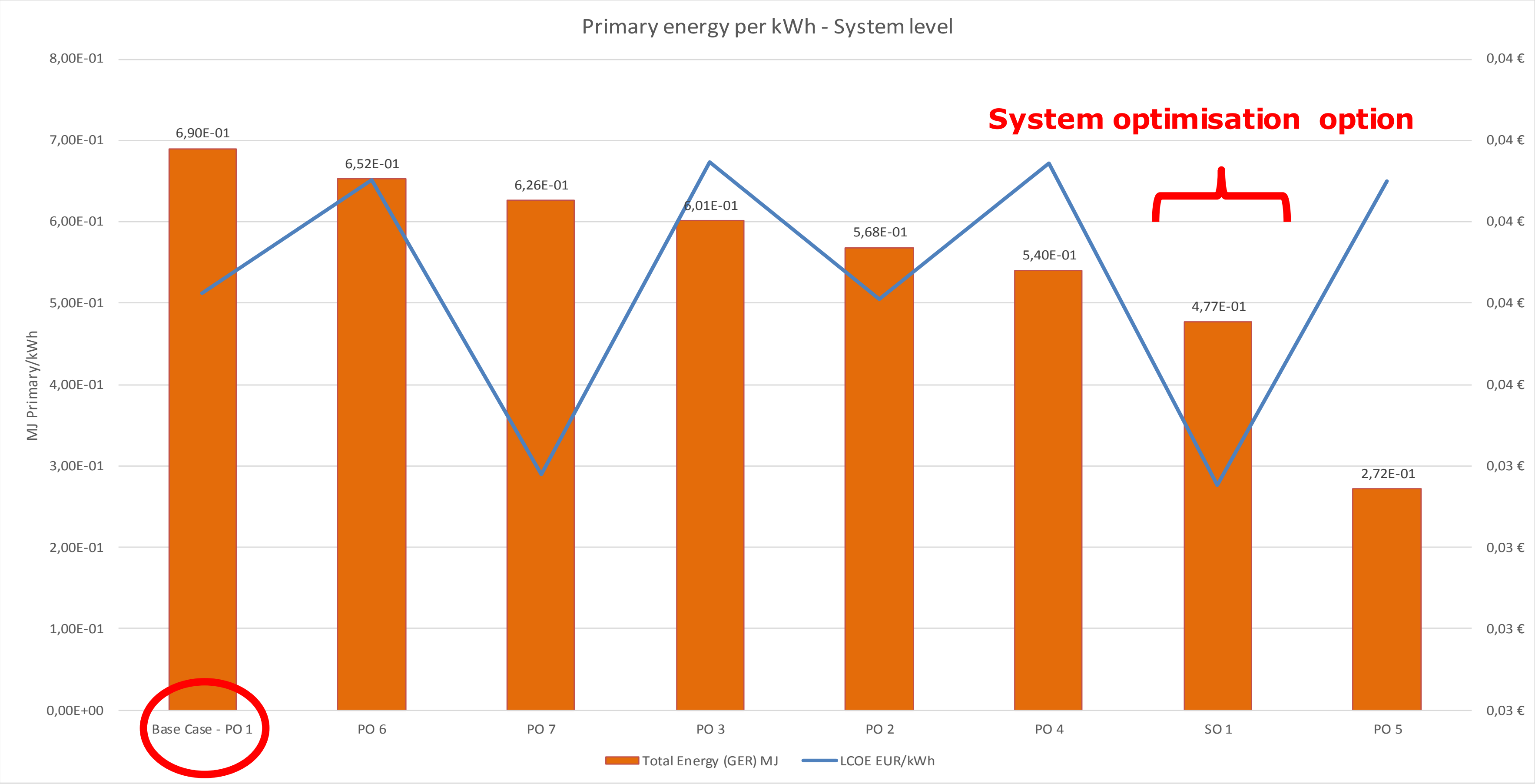
Analysis of BAT and LLCC – Inverters utility



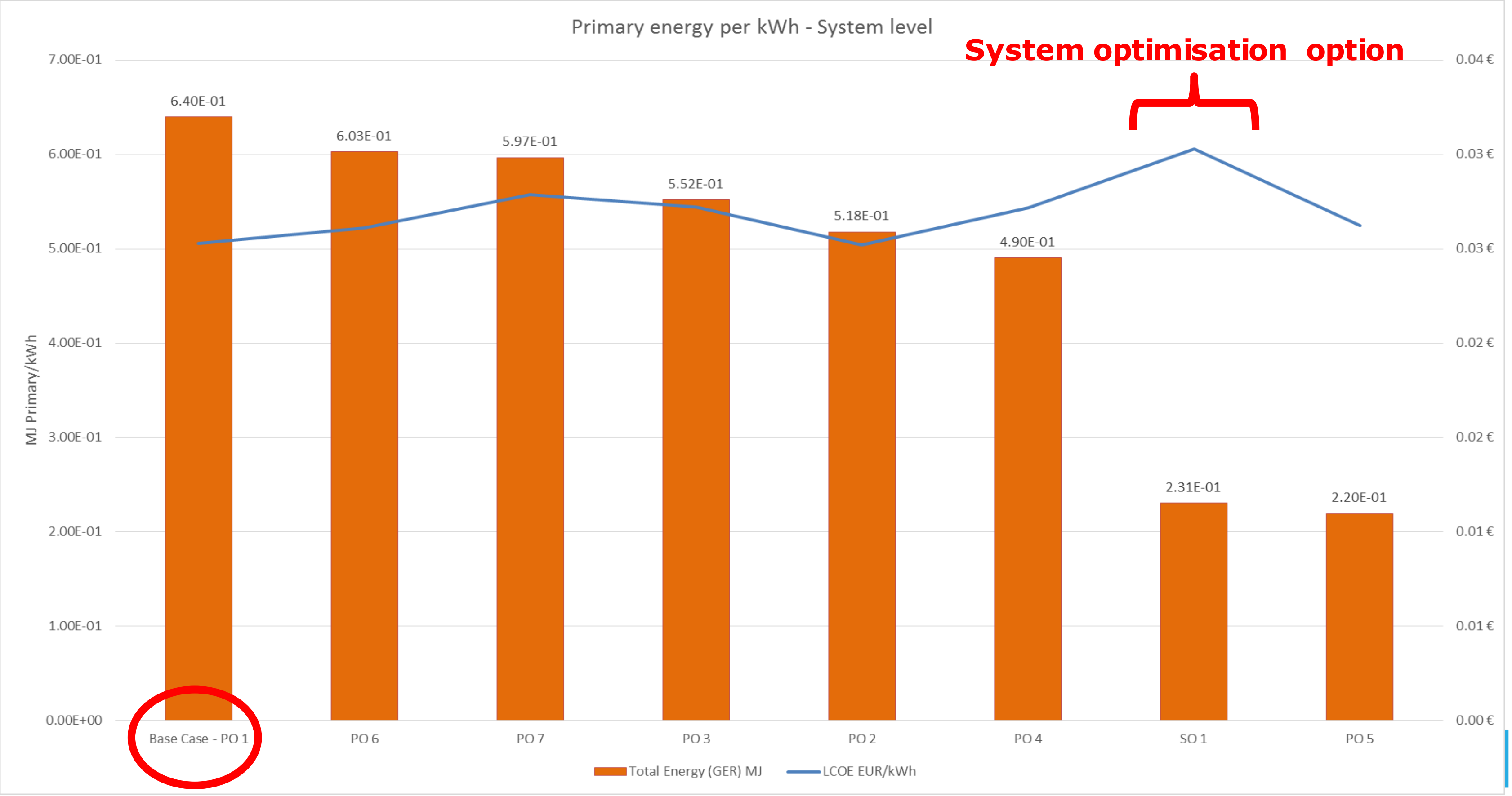
Analysis of BAT and LLCC – Systems residential



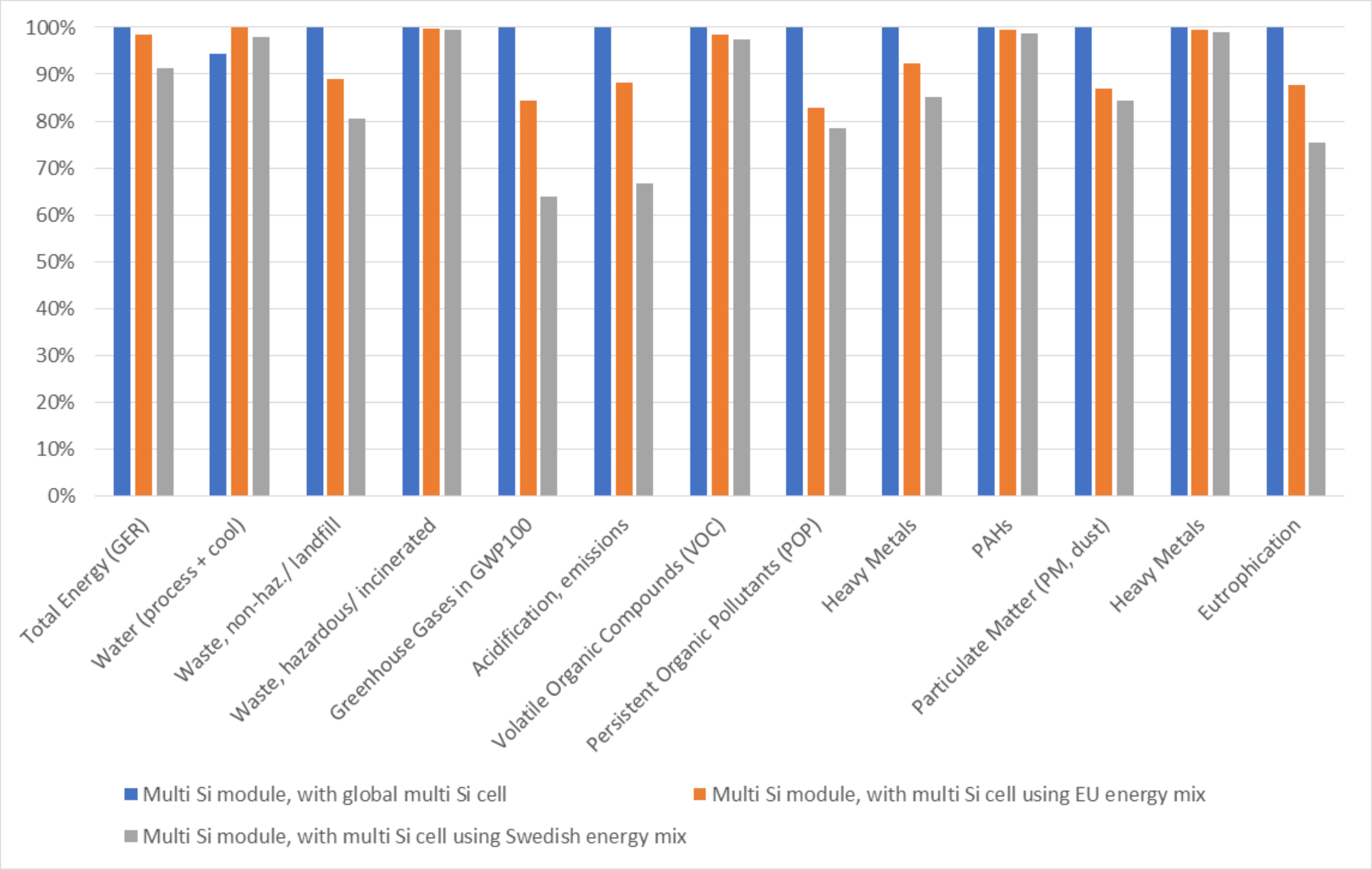
Analysis of BAT and LLCC – Systems commercial



Analysis of BAT and LLCC – Systems utility



Influence of the electricity mix on the results



pean
mission

BNAT & systems analysis

MODULES

- Crystalline silicon wafers created by lift-off or epitaxial growth with in-situ growth of the pn junction– thereby reducing silicon waste.
  - It would not require a substantial change in downstream production technology and relevant for the residential sector where the BAT has a low penetration rate
- Tandem formation of a crystalline silicon cell is with perovskite or other thin films

INVERTERS

- Designs based on wider band gap semi-conductors (MOSFET)

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Task 7: Policy scenario analysis

- **Policy analysis**
- Scenario overview and analysis

Stakeholders positions

- Impact on achievement of EU climate and renewable energy targets
- Importance of product quality and durability
- Address Critical Raw Materials (CRM) and hazardous substances
- Transfer of best practices form utility to the residential market segment
- NSF 457 leadership standard and the PEFCR as the basis for the EU Ecolabel
- Opportunity to stimulate EU industry

Opportunities and barriers

- High upfront-cost for PV systems, access to and the cost of capital
- Uncertainties in support policies
- Uncertainties in future energy prices
- Market access and metering schemes for small producers
- Lack of knowledge or skilled subcontractors
- Repair frameworks may not be supported particularly in residential segment
- Opportunities to increase self-consumption
- Opportunities for public authorities to support residential installations
- Opportunities to use auctions to drive quality systems and components

The potential for self-regulation

MODULE PERFORMANCE

- Existing schemes or initiatives for addressing quality and /reliability
  - The PV QAT International Photovoltaic Quality Assurance Task Force (PVQAT) initiative.
  - The DNV reliability module reliability scorecard,
  - The Photon module and inverter performance test programme.
- Labelling of front runners:
  - The NSF/ANSI 457 (shortly to be extended to inverters)
  - The 'Ecolabel consortium'
- Development of EPD category rules
  - Next steps for PEF CR?

The potential for self-regulation

SYSTEM PERFORMANCE

A number of project standards and certifications have been developed, primarily driven by the needs of investors for due diligence and to ensure the ‘bankability’ of proposals:

- DNV system ‘Project certification of photovoltaic power plants’ including system and component quality and performance requirements
- VDE ‘Quality Tested mark for Photovoltaic Power Plants’ - information to investors.
- IECRE qualification standard and rating system for PV systems is currently under development.

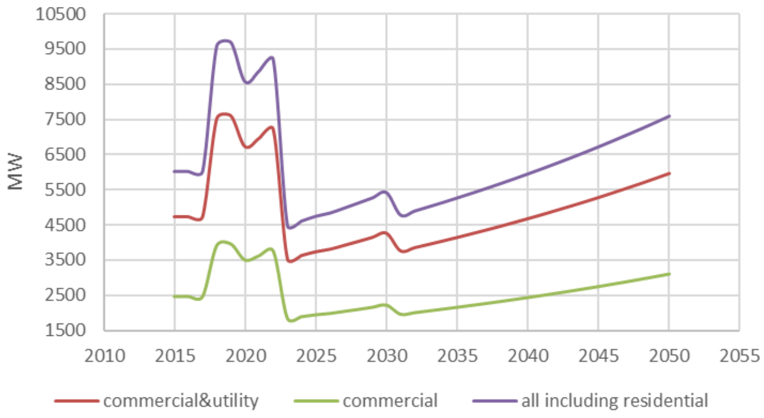
No proposals of voluntary agreements have been tabled by any (industrial) stakeholder.

Scenario overview: Business as usual (BAU)

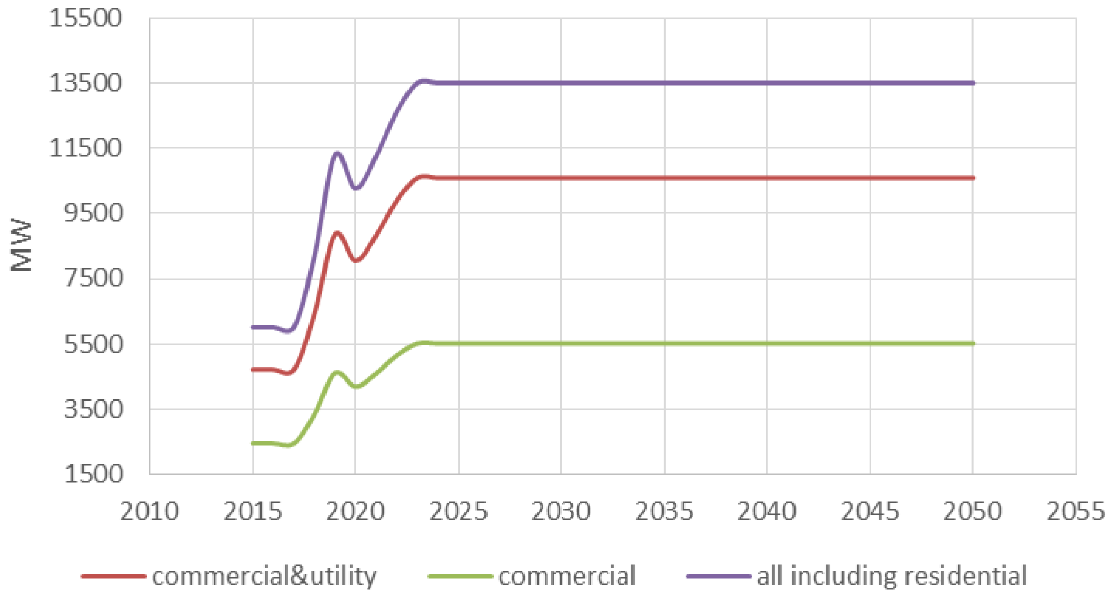
Business as Usual (BAU) scenario:

- Products with the same level of performance as the BCs
- Scenarios linked to module technologies and application field (R, C, U)
- EU reference scenario for evolution of PV deployment through to 2050
- Evolution of the market segments and technologies based on market intelligence (task 2)

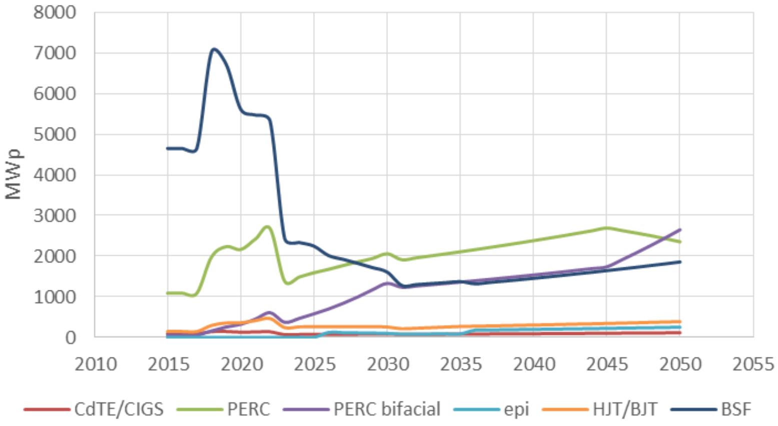
Scenario overview: Business as usual (BAU)



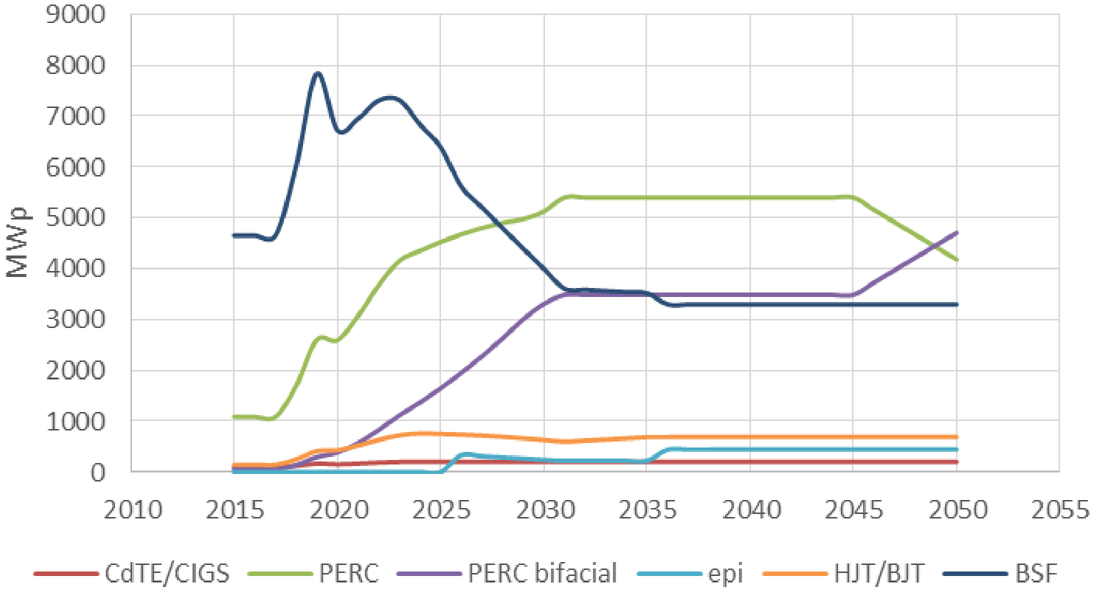
REVISED STOCK DATA



Scenario overview: Business as usual (BAU)



REVISED STOCK DATA

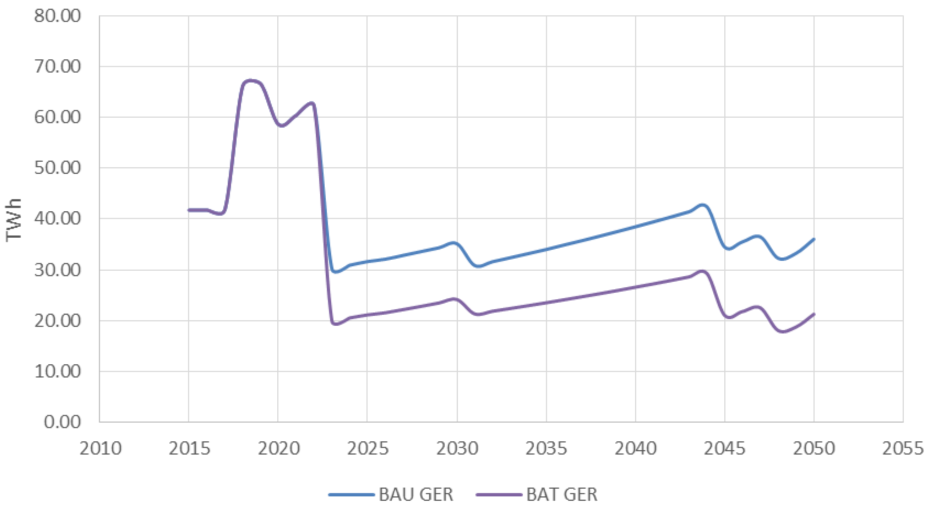


Scenario overview: BAT

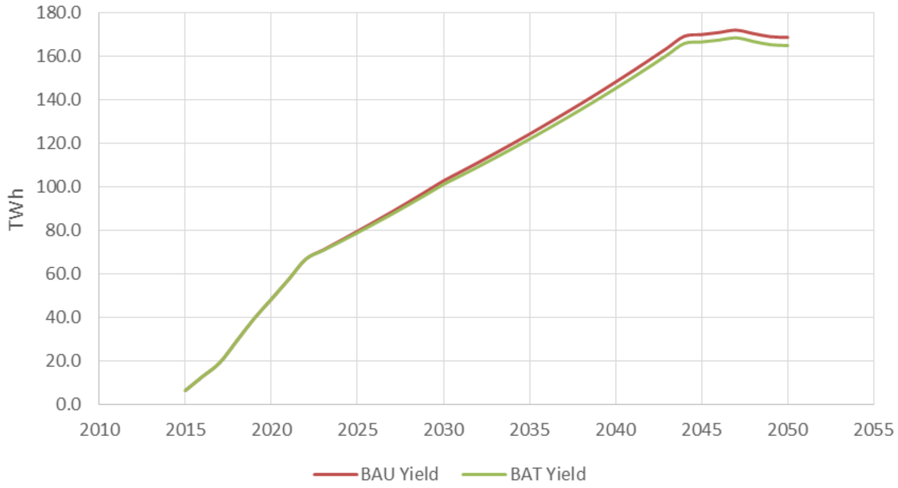
BAT scenario:

- Combines greater deployment of
  - BAT module technologies (CIGS for residential and CdTe for commercial/large scale),
  - BAT inverter technology (longer life products)
  - BAT systems (design optimisation with improved operation & maintenance)

Scenario overview: BAT



GER for the FU complemented by yield improvement



Scenario assumptions: increased yield?

3.6 kW Residential system

Yield improvement
Area maintained with higher performance modules
(3.6 -> 4.4 kW)

Yield maintained
Reduced area same kW rating (3.6 kW)

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Scenario overview: Mandatory instruments

Ecodesign scenarios:

- Two tier introduction in 2022 and 2024 for modules and inverters:
  - Efficiency and life time yield scenarios
  - Quality and durability scenarios

Energy Label scenarios

- Residential energy ‘package’ label: modules + inverter efficiency
- Residential system energy label: system design energy yield

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Scenario overview: Voluntary instruments

EU Ecolabel scenarios:

- Residential label combining criteria on package and service:
  - Module and inverter BAT environmental performance
  - PV system BAT service offer (*not* final system design)

Green Public Procurement scenarios

- Environmentally improved PV systems – system life cycle performance
- Facilitating residential reverse auctions: package + installation service

Consideration of combined effects of mandatory and voluntary instruments

Policy option 6: modules/inverters aspects

	Ecodesign	Energy Label	EU Ecolabel	EU GPP
Efficiency	✓	✓		
Energy yield		✓	As input data	As input data
Energy Payback Time			✓	
Durability	✓		✓	✓
Long-term degradation	✓		✓	✓
Smart readiness	✓		✓	✓
Hazardous substances			✓	
Material content	✓		✓	

Policy option 6: system aspects

	Ecodesign	Energy Label	EU Ecolabel	EU GPP
Energy yield		✓		As input data
Energy Payback Time				✓
Performance Ratio		✓		✓
Design optimisation		As input data	✓	✓
Operation/maintenance		As input data	✓	✓
Transport/handling			✓	✓
End of life				✓

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Task 7: Policy scenario analysis

- Policy analysis
- **Scenario overview and analysis**

Policy option 1: Business as usual (BAU)

The assumptions forming the basis for the Business As Usual (BAU) stock model:

- Market intelligence (Task 2). Data sourced from the Becquerel Institute, the IEA PVPS programme, PV Market Alliance, Solar Power Europe, GTM and VDMA.
- The stock model is based on capacity installed – assumptions had to be made about the size of modules and inverters in different market segments:
    - 1 string inverter (residential segment), 3 string inverter (commercial segment) and central inverter (utility scale segment).
    - The system base cases proposed are representative for the market segments of residential (3 kW), commercial (20 kW) and utility scale (1.5 MW), see Task 5.
    - Module technologies modelled in Task 2: Back Surface Field multicrystalline silicon(BSF), PERC silicon, PERC silicon bifacial, thin film modules (CIGS/CdTe), epitaxial modules, Hetero-junction(HJT/BJT).
    - Repowering assumed, end markets for degraded old modules in the future are unclear

Policy option 2: Ecodesign requirements on modules and inverters

- Module option 2.1: Performance requirements on efficiency and life time electricity yield - This initial Ecodesign option would introduce a cut-off based on the potential of module products to generate electricity.
- Module option 2.2: Performance requirements on quality and durability: This further Ecodesign option would introduce a more stringent set of quality and durability tests for module products.
- Inverter option 2.3: Performance requirements on efficiency and life time electricity yield - This initial Ecodesign option would introduce a cut-off based on the Euro Efficiency of the inverter product.
- Inverter option 2.4: Performance requirements on quality and durability - This further Ecodesign option would introduce a more stringent set of quality and durability tests for inverter products.

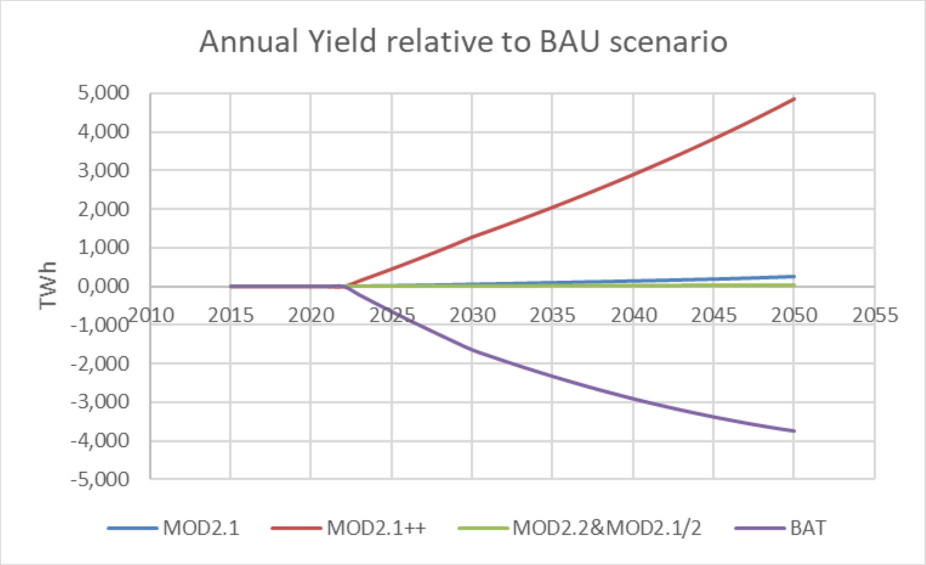
Module option 2.1: Efficiency requirements

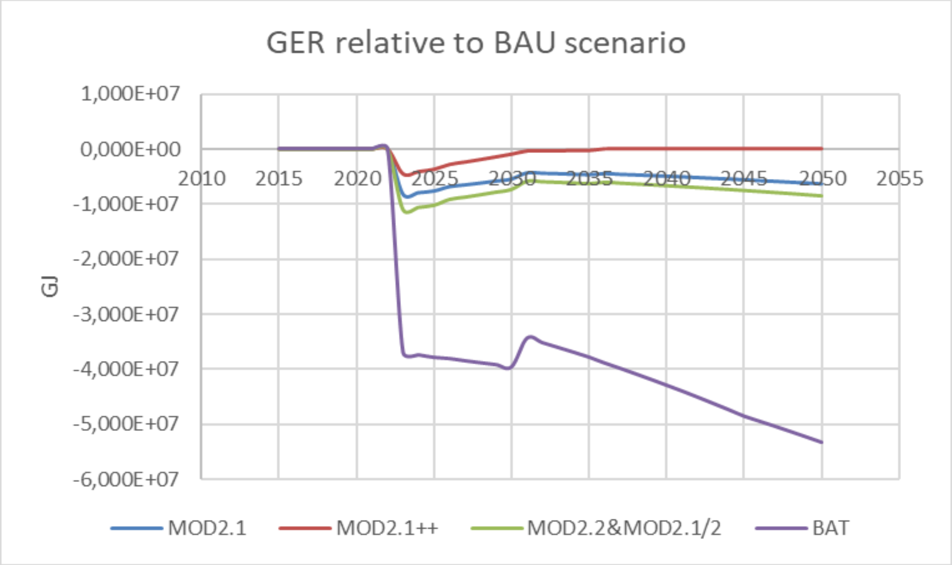
- A threshold of 14% is proposed for 2.1 tier 1 based on the performance of the LLCC option (the optimised BSF module) and the best performing models available in the market for the BAT (the CIGS module). 16% in second tier
- Main assumption: BC and low performing modules would be removed progressively form the market, moving largely towards modules with a higher power output.

TWO TIERS

- Tier 1 policy in place in 2021 and will be assumed effect in the scenario calculations from 2022 onwards
- Tier 2 policy in place in 2024 and will be assumed effect in the scenario calculations from 2022 onwards

Requirements on modules (MOD 2.1/2.2)





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Module policy option 2.2: Quality and durability requirements

- Optimised BC (LLCC option). Factory quality tests and material specifications:
  - reduce failures at the infant, mid-life phases of a module product
  - minimise performance degradation along its lifetime
- Priority focus on:
  - Cell micro-cracks, PERx cell LeTID and module PID issues
  - Unvalidated v. validated long-term performance degradation claims
  - Material selection in order to minimise degradation mechanisms

Starting point for basic reliability requirements: IEC/EN standards + Ispra TS rules on degradation reporting

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Module policy option 2.2: Quality and durability requirements

IEA Task 13 proposal
- covered by IEC 61730
- browning may not result in power loss?

PERx cell LeTID minimisation
- Recovery of loss occurs over time
- New LeTID test to be inserted in IEC 61215?.
- Would it only result in relabelling nameplate power?

IEA Task 13 proposal
Extended duration (>1000 hrs) not expected to further simulate field conditions

Factory cell defects
- Not standardised: definition of inactive area required.
- Should be complemented by EN 62941?

Performance aspect	Detailed proposed requirements
Performance requirements	
2.2.1 Component degradation	- *UV pre-conditioning:* MQT10 of IEC 61215 over four cycles of 15 kWh/m^2 in the two stipulated UV wavelength ranges, followed by visual inspection and a pass/fail based on no detectable browning of the encapsulant/laminate. - *Potential Induced Degradation:* Testing according to IEC 62804 shall result in no more than a 5% power loss after 192 hours at 1000V. - *Light Induced Degradation:* Testing according to IEC 63202-1 shall result in an efficiency loss of no more than 2.5% .
2.2.2 Water ingress	*Damp heat:* MQT 13 of IEC 61215 extended to 2500 hours of exposure divided into four separate cycles followed by application of the pass criteria..
	Junction box: Achievement of an Ingress Protection rating of at least IP67, category 1 according to EN 60529.
Information requirements	
2.2.3 Cell integrity	The inactive cell area shall be no more than 8% upon optical inspection using electroluminescence imaging[8].
2.2.4 Lifetime performance degradation	The manufacturer shall declare the average linear degradation rate expected over a notional service lifetime of 30 years. The declaration shall be clearly identified as being either: - *Validated:* Based on minimum number and time series of field observations made according to the Transitional Method. - *Unvalidated:* Based on accelerate life testing methods carried out in a laboratory.

2.2.5 Repairability	The manufacturer shall report on: - the possibility to access and replace the bypass diodes in the junction box [9], - the possibility toreplace the whole junction box of the module
2.2.6 Dismantlability	The manufacturers shall report on the potential to separate and recover the semi-conductor from the frame, glass, encapsulants and backsheet. Design measures to prevent breakage and enable a clean separation of the glass and internal layers during the operations shall be detailed.
2.2.7 Material disclosure	The manufacturer shall declare the content in grams of the following materials in the product: - Lead - Cadmium - Silicon metal - Silver - Indium - Gallium - Tellurium For the encapsulant and backsheet the manufacturer shall also declare the type of polymers used (inlcuding if it is fluorinated or contains fluorinated additives) and content in grams.

Unvalidated degradation claims
Design type approval required in order to make a default claim?

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Inverter policy option 2.3: Efficiency requirements

Performance aspect	Detailed proposed requirements
2.3.1a Euro efficiency for PV inverters without storage	Require a minimum efficiency of 96% measured according to EN 50530. Allowances shall be provided for micro-inverters and hybrid inverters to offset for their other benefits.
2.3.1b Efficiency requirements for PV inverters with possibility to connect storage or with integrated storage	Require a minimum efficiency of 90% at 25% of nominal power and at minimum MPP voltage and battery around 50% state of charge. Measurement according 'Effizienzleitfaden 2.0'.
2.3.2 Smart readiness (monitoring system features)	Manufacturers shall to ensure that the inverter supports class A data monitoring according to IEC 61724-1, including: – Basic system performance assessments; – System loss analyses; – Electricity network interaction assessment; – Fault localisation; – System degradation measurements.

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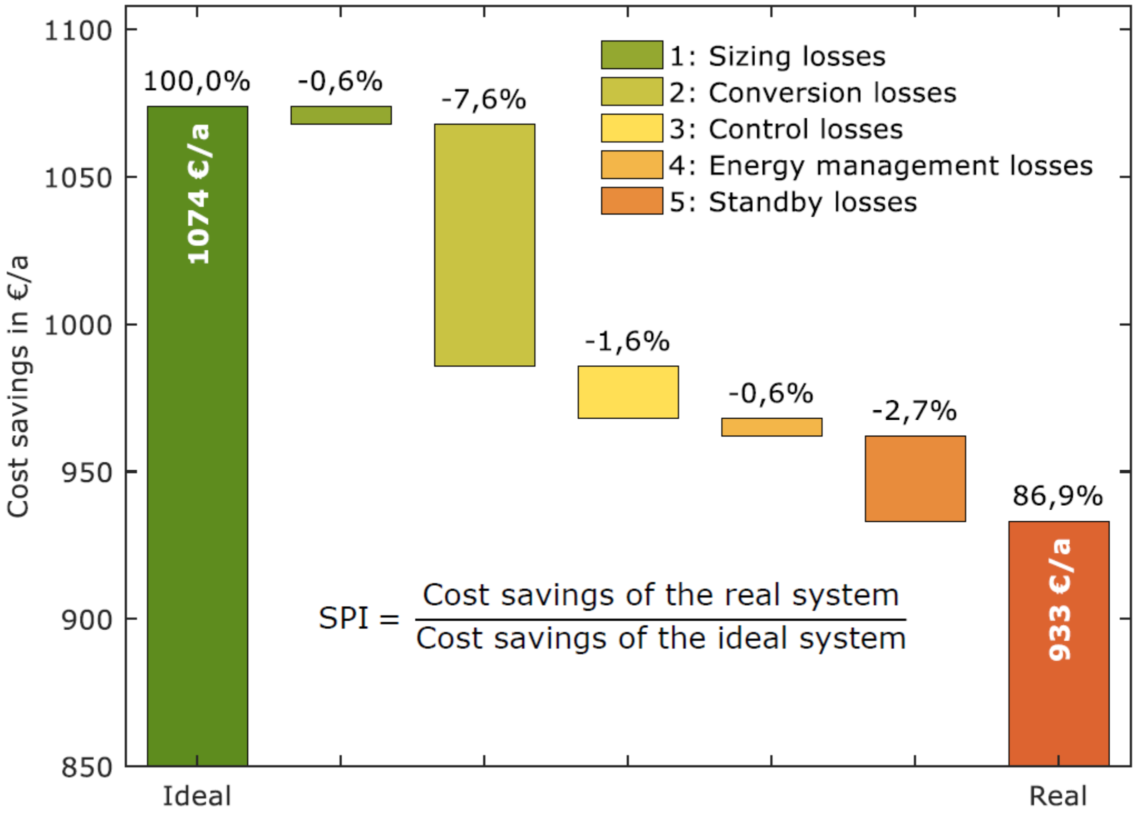
Illustrative storage system losses



Source: HTW Berlin (2018)

PV output 5 kWp, battery capacity 3,7 kWh, load demand 5 MWh/a, feed-in tariff 12 ct/kWh, retail price 28 ct/kWh

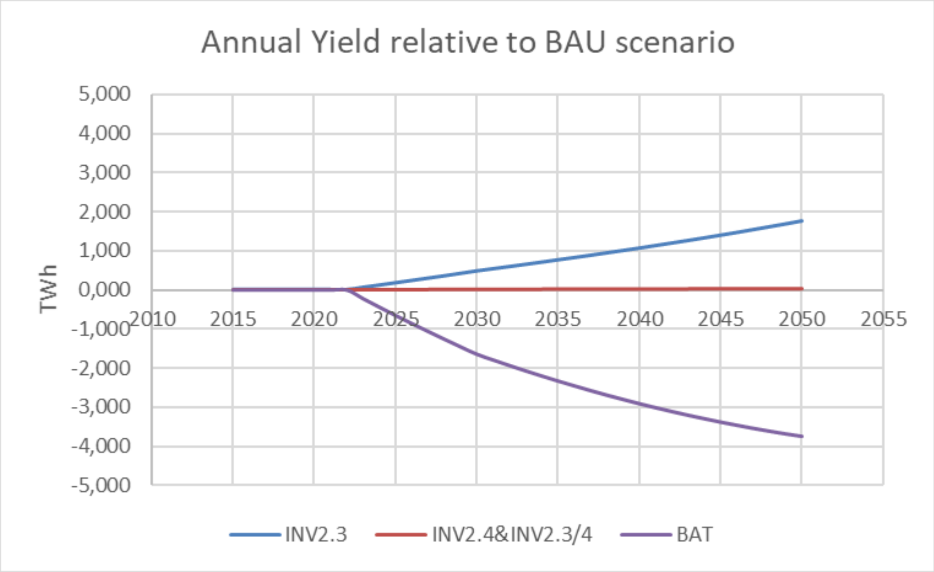
Inverter policy option 2.4: Quality and durability requirements

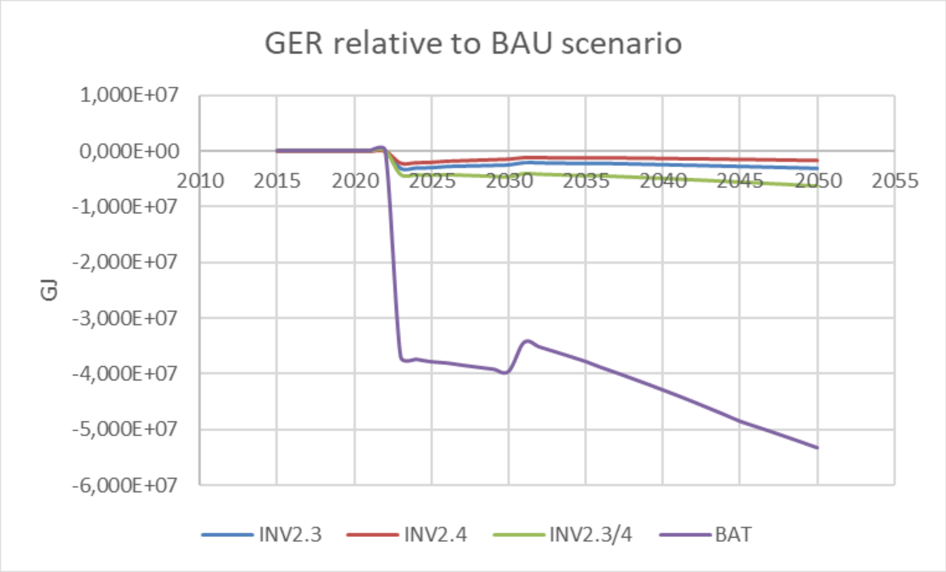
Performance aspect	Detailed proposed requirements
2.4.1 Quality and durability	*Thermal cycling:* For outdoor conditions, the IEC 62093 Test 6.4 subjected to conditions of -40oC to +85oC for 400 cycles followed by the specified functionality test.
	Operating temperature: Capacitors, inductors and transformers used within inverters shall be selected so that under the most severe rated operating conditions, the temperatures do not exceed the temperature limits specified in IEC 62109-1 Table 1 minus 20 °C (10 °C for capacitors)
	Water ingress: Achievement for outdoor conditions an Ingress Protection rating of at least IP67, category 1 according to EN 60529.
Additional information requirements	
2.4.2 Preventative repair cycle	Manufacturers shall provide a preventative maintenance and replacement cycle. This shall include a list of parts recommended to be replaced and the timing of the replacement as a preventative measure to achieve the intended design technical lifetime.
	Manufacturers shall ensure that replacement parts and firmware updates are made available in line with the recommended replacement cycle.
2.4.3 Technical design life declaration	Manufacturers shall declare based on internal design parameters and qualification testing the design technical lifetime of the inverter. This declaration shall include a Mean Time Between Failure (MTBF) calculation.

Applicable to **commercial and utility** market segments

Residential focus proposed on:
- Onsite pick-up/replacement service
- Inverter repair rate in off-site workshop (original manufacturer)

Requirements on inverters (INV 2.3/2.4)





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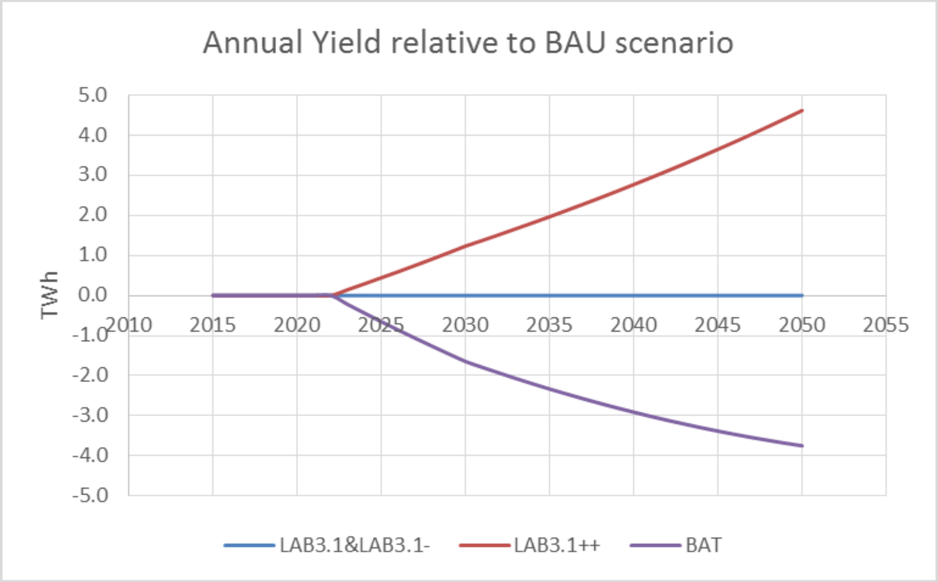
Policy option 3: Energy labelling requirements for residential PV systems

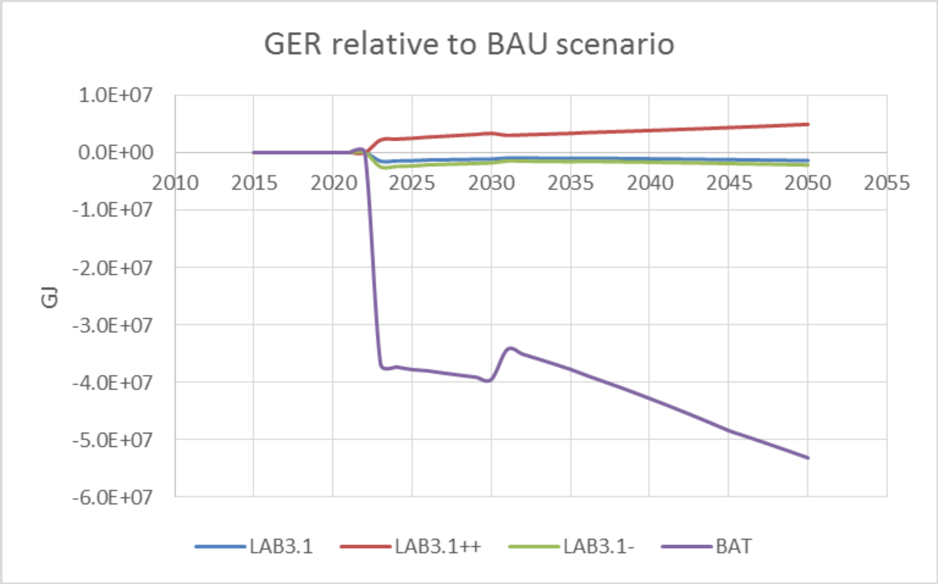
- Residential package energy label option 3.1: Simplified approach based on component efficiency
  - Calculation for module and inverter components reported efficiency.
  - The module efficiency combined with the euro efficiency would be a proxy as the Energy Efficiency Index (EEI) for improved yield.
- Residential system energy label option 3.2: Yield and performance ratio based approach
  - More complex to calculate but will accommodate a wider range of product performance characteristics under conditions in the field

Energy label policy option 3.1: Efficiency-based EEI

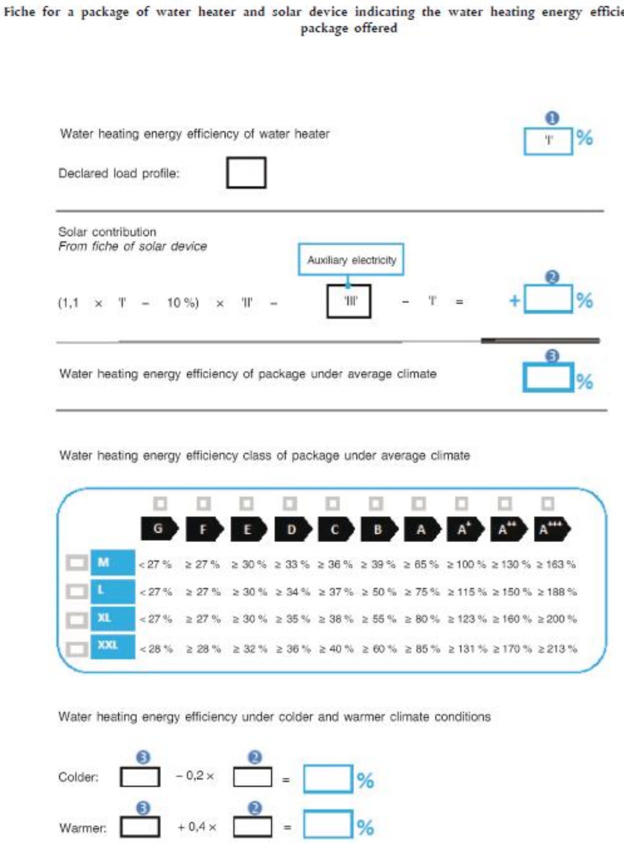
Label class	Combined performance	Indicative module efficiency	% Models	Indicative inverter euro efficiency	% Models	Indicative technology packages
A		*>21.5%*	0%	*Empty*	0%	-
B	>19.6 – 21.6%	>19 – 21.5%	4%	>98%	11.6%	SHJ, bifacial + MOSFET
C	15.3 – 19.6%	>16.5 – 19%	40.6%	>96 – 98%	55.5%	Optimised BSF, PERC/PERT +String Central
D	12.2 - 15.3%	>14 – 16.5%	43.7%	>94 – 96%	16.4%	BSF, CIGS, CdTe +Micro-inverters
E	8.5% - 12.2%	9-14%	10.9%	<94%	16.3%	BSF
F						
G						

Requirements on residential energy package label





Energy label policy option 3.2: System yield


Fiche for a package of water heater and solar device indicating the water heating energy efficiency of the package offered

Water heating energy efficiency of water heater ❶ 'I' %

Declared load profile:

Solar contribution
From fiche of solar device

Auxiliary electricity

(1,1 × 'I' − 10 %) × 'II' − 'III' − 'I' = + ❷ %

Water heating energy efficiency of package under average climate ❸ %

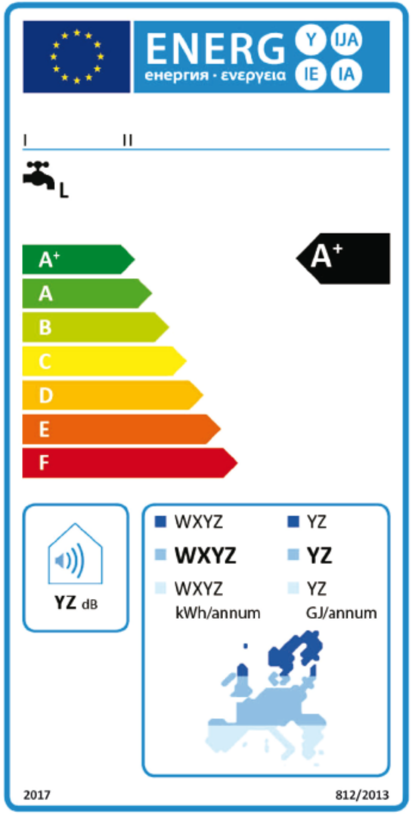
Water heating energy efficiency class of package under average climate

	G	F	E	D	C	B	A	A+	A++	A+++
M	< 27 %	≥ 27 %	≥ 30 %	≥ 33 %	≥ 36 %	≥ 39 %	≥ 65 %	≥ 100 %	≥ 130 %	≥ 163 %
L	< 27 %	≥ 27 %	≥ 30 %	≥ 34 %	≥ 37 %	≥ 50 %	≥ 75 %	≥ 115 %	≥ 150 %	≥ 188 %
XL	< 27 %	≥ 27 %	≥ 30 %	≥ 35 %	≥ 38 %	≥ 55 %	≥ 80 %	≥ 123 %	≥ 160 %	≥ 200 %
XXL	< 28 %	≥ 28 %	≥ 32 %	≥ 36 %	≥ 40 %	≥ 60 %	≥ 85 %	≥ 131 %	≥ 170 %	≥ 213 %

Water heating energy efficiency under colder and warmer climate conditions

Colder: ❸ − 0,2 × ❷ = %

Warmer: ❸ + 0,4 × ❷ = %



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Policy option 4: EU Ecolabel criteria set

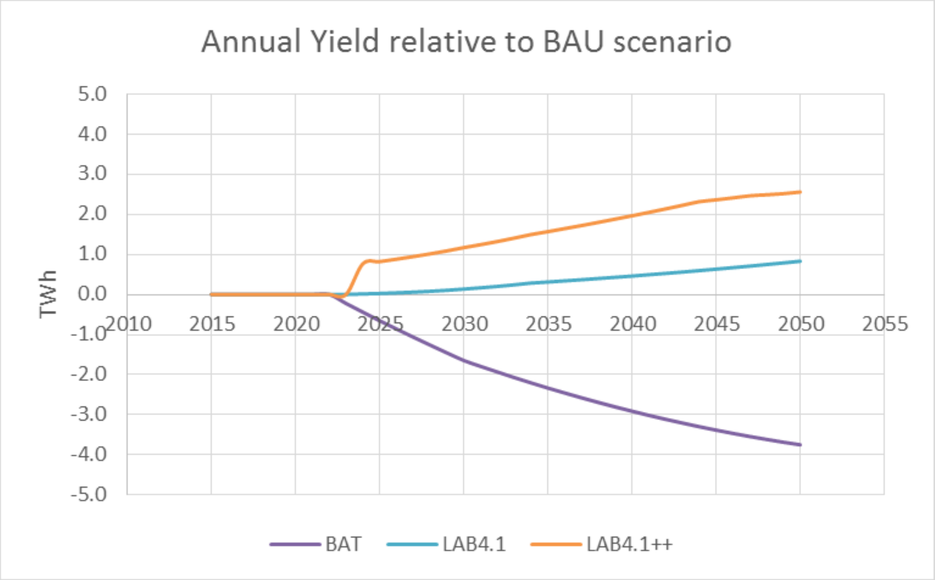
- Targets residential systems of <10 kWp.
  - 1. Package approach: criteria for modules and inverters that would differ from policy options 2 and 3 by focussing more on life cycle hot spots, hazardous substances and circular design (Module and inverter BATs)
  - 2. Service approach: criteria for the main components of a PV system (i.e. modules and inverters) together with criteria covering aspects of the service provided by system installers (system BAT)
    - the system design factors taken into account
    - protocols for the transport/handling of modules
    - the installation of monitoring and
    - provision of maintenance/aftercare services

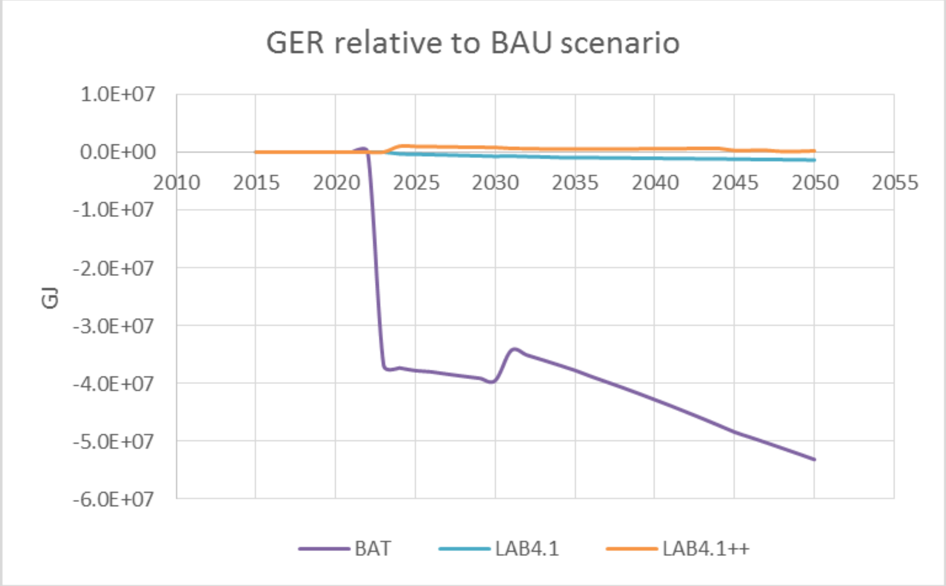
Policy option 4: EU Ecolabel criteria set

Because of the uncertainty related to possible take-up of the EU Ecolabel only one option has been modelled.

- LAB 4.1 assumes a gradual uptake 5% of new systems annually by 2030
- LAB 4.1++ is a more optimistic LAB 4.1 scenario that assumes both a gradual uptake of 5% in 2024 rising to 20% by 2030 and also the installation of more generation capacity on roofs

EU Ecolabel criteria for packages and services





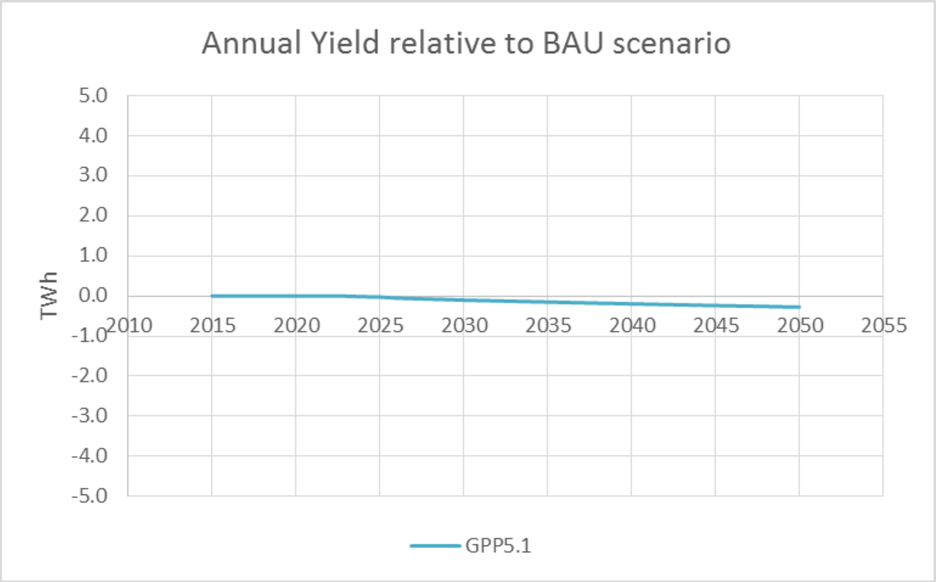
Policy option 5: Green Public Procurement (GPP) criteria

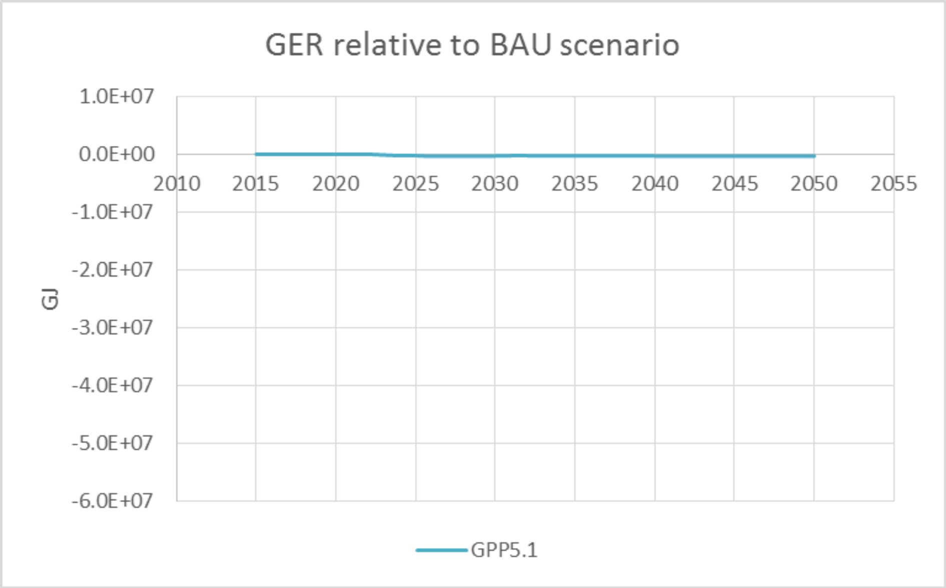
- GPP criteria option 5.1: Improved PV system life cycle performance
  - An overall focus on minimising the life cycle environmental impact of a solar PV system,
  - Additional focus on the project management of a PV system installation, extending from contractor selection through to decommissioning.
- GPP criteria option 5.2: Facilitating increased residential system installations
  - the criteria set could also be used to boost residential deployment by promoting and providing a framework and criteria for 'reverse auctions'
  - The public tender for the service may include quality specifications for the systems offered to households, including monitoring systems and an extended guarantee for each system.

Policy option 5: modelling assumptions

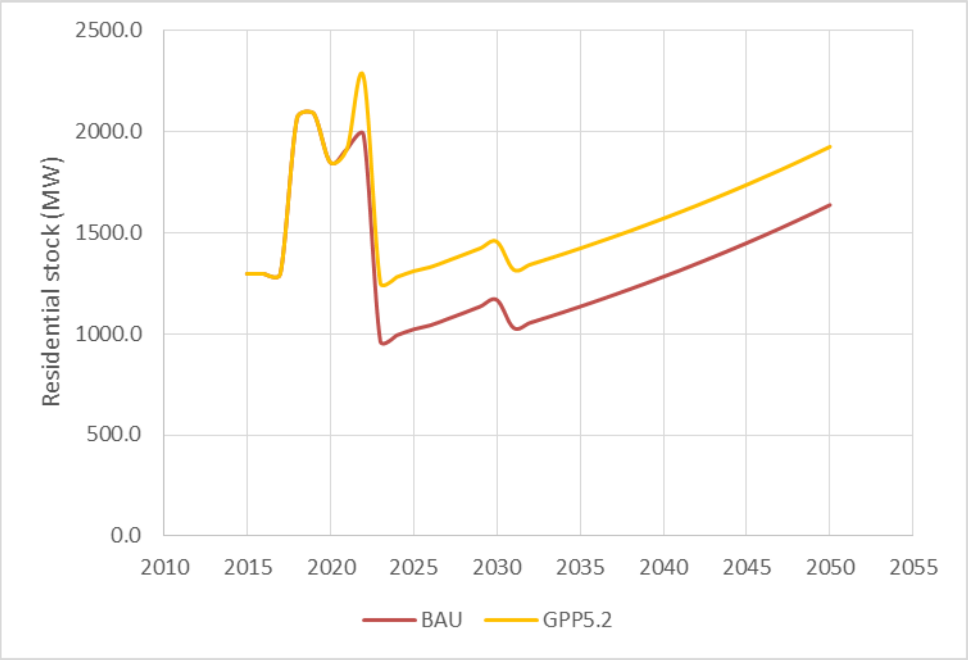
- Option 5.1. Take up based on the public sector installation rate for solar PV systems.
  - No distinction is made at this stage between core/comprehensive GPP criteria.
  - estimated that 4% of annual system capacity is accounted for by public buildings to which 20% could have criteria applied to it by 2022, 40% by 2024 and 80% by 2026 onwards.
- Option 5.2. Increased residential take-up based on use of this process by cities taking part in the Covenant of Mayors for climate and energy initiative.
  - If extrapolated to 400 of the 800 cities above 50,000 inhabitants
  - Initial take-up in first round of 30 homes then assumed to increase to 60 and then to 120 in 6 monthly procurement rounds
  - This would approximate to 288 MW of new capacity per annum from 2022 onwards.

GPP criteria on systems (GPP 5.1)





GPP criteria on reverse auctions (GPP 5.2)



Policy option 6: combined instruments

Policy combination	Advantages	Disadvantages
GPP (voluntary) + Energy Label (mandatory)	• Enables procurers to follow the recommendations in the Energy Efficiency directive to use labelled products • Enables procurers to relate the yield of a PV system to the energy payback time • The label rating can provide a benchmark for a criterion within the GPP	• May result in conflicting information if a high performing system has components that cannot meet the GPP module/inverter criteria
EU Ecolabel (voluntary) + Ecodesign (mandatory)	• The EU Ecolabel criteria could be used to address some aspects of system performance • Complementarity – ecodesign would cut off the worst performing products whilst the other would reward the best performers. • The Ecodesign requirements can provide a performance metrics and test methods for criteria within the EU Ecolabel	-
EU Ecolabel (voluntary) + GPP (voluntary)	• EU Ecolabel criteria usually provides the basis for comprehensive GPP criteria • Both criteria sets can address the full life cycle performance of the products including any trade-off between yield and GER • GPP might enhance the take-up of the EU Ecolabel products	• A low take-up of the EU Ecolabel may limit the number of pre-verified meeting ambitious environmental criteria • Both have a degree of uncertainty as to the take-up

Additional policy options using other EU policy instruments (to be checked by DG ENER/ENV)

- Policy option 7.1: Renewables Directive member state capacity auction requirements - performance requirements for any EU public PV capacity auction process that takes place in member states.

e.g. Top runner initiative (China) and CRE auction criteria (France)

- Policy option 7.2: Energy Performance of Buildings technical systems requirements - explore use of provisions within the EPBD that require MS to establish minimum performance requirements for major building renovations and technical building systems.

Next steps

- Comments on the Task 6 and 7 documents can be made through BATIS until 13th September 2019

Please use BATIS to submit your comments
http://eippcb.jrc.ec.europa.eu/batis/login.jsp

BATIS Helpdesk
JRC-B5-PRODUCT-BUREAU@ec.europa.eu

Discussion with Q&A

Preparatory study for Solar PV modules, inverters and systems

Options and feasibility for EU Ecolabel and Green Public Procurement (GPP) criteria

11th July 2019

The European Commission's science and knowledge service

Joint Research Centre

European Commission

Introduction to the meeting

09:00 Welcome and introduction
Update on the study (tasks, timing..)
09:45 Summary of background study including scope, market and technical analysis

11:00 Coffee break

11:15 Assessment of the evidence for EU Ecolabel: criteria areas and need for the label
12:45 Assessment of the evidence for Green Public procurement: criteria areas and need for the label
13:45 Next steps
14:00 AOB and close

European Commission

Options and feasibility for EU Ecolabel and Green Public Procurement (GPP) criteria

Summary of the background study

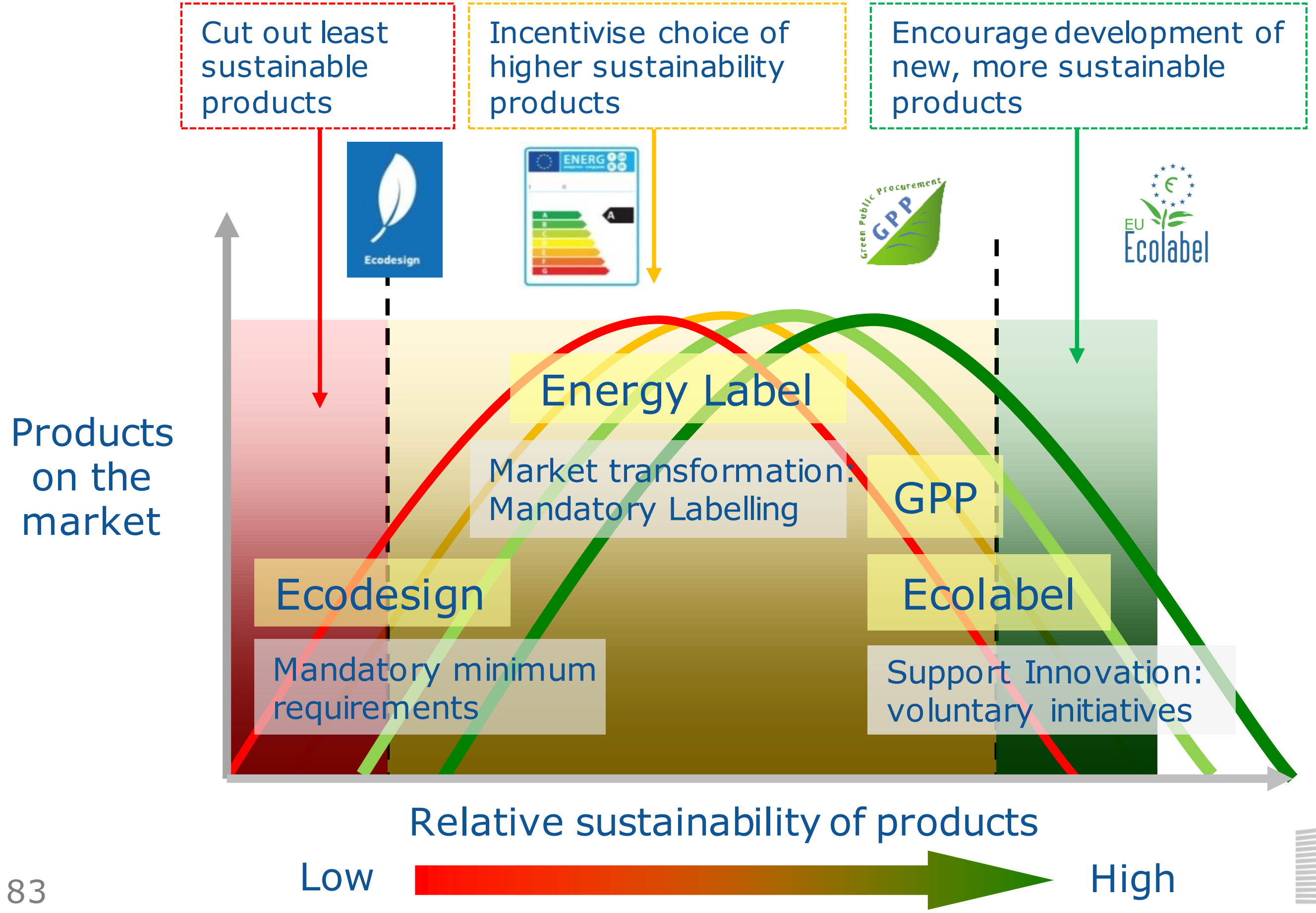
11th July 2019

The European Commission's science and knowledge service

Joint Research Centre

European Commission

EU product policy instruments



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Task 6 Scenario overview: BAT

BAT scenario:

- Combines greater deployment of
  - BAT module technologies (CIGS for residential and CdTe for commercial/large scale),
  - BAT inverter technology (longer life products)
  - BAT systems (design optimisation with improved operation & maintenance)

Task 7 Scenario overview: Mandatory

Ecodesign scenarios:

- Two tiers introduction in 2022 and 2024 for modules and inverters:
  - Efficiency and life time yield scenarios
  - Quality and durability scenarios

Energy Label scenarios

- Residential energy package label –modules + inverter efficiency
- System residential energy label – yield

Task 7 Scenario overview: Voluntary

EU Ecolabel scenarios:

- Residential package label combining BAT criteria:
  - Module and inverter environmental performance
  - System service

Green Public Procurement scenarios

- Environmental improved systems – life cycle performance
- Facilitating residential reverse auctions

Consideration of combined effects of mandatory and voluntary instruments

Study completed to date

Preliminary evaluation of the options and feasibility

Focus of attention:

- Whether there is a need for EU Ecolabel and/or GPP criteria* and what contribution they could make to EU policy objectives,
- Whether the scope/focus should be different from the Ecodesign scope,
- Possible criteria areas and the feasibility of addressing identified LCA hot spots and applying the hazardous substance criterion,
- The scope of the public procurement routes and project stages that could be addressed.

*the justification for the need of EU Ecolabel and/or GPP criteria is linked, inter alia, to the study conclusions on the need of Ecodesign/Energy labelling measures (tbd on June 2019)

Ecolabel: market 'pull'

'….promote products with a reduced environmental impact during their entire life cycle…. avoid the proliferation of environmental labelling schemes and to encourage higher environmental performance in all sectors for which environmental impact is a factor in consumer choice.'

- Regulation (EC) No 66/2010 on the EU Ecolabel
- Multi-criteria sets informed by LCA
  - ✓ Shall indicatively reflect best 10-20% products on market
  - ✓ Aspects may include energy, chemicals, circularity, CSR
- Identification of **front runner** product specifications
- Must include a focus (for products) on hazardous substances

Should the scope be different for EU Ecolabel?

Possible considerations:

- Potential to label DIY (Do It Yourself) kits or system packages
  - Modules and inverters are largely B2B products
  - Labelling of set packages offered to retail customers?
  - Communication of changes in composition over time?
- Potential to focus on the sub-5-10kW residential scale?
  - the scale that retail consumers would look to purchase PV systems
  - Preparatory Study highlights potential to transfer best practices in design, O&M of large scale PV systems to smaller residential systems

Stakeholder feedback
EU Ecolabel product scope

- Modules and inverters are B2B, they cannot be distinguished as B2C products or as 'dual-use equipment'
- DIY kits have limited market relevance, but criteria could encourage distributors/retailers
- Aspects of the service provided to retail customers should be addressed
- Sub-5kW is an artificial cut-off
- Care should be taken to ensure that system components are not included which may require criteria – batteries as specific case
- Clarity is needed on products such as PV in street furniture is required

Consumer perspective (1)

Important factor at the design stage:
estimation of a systems annual AC energy yield

- Entails an understanding of
  - a system's Performance Ratio, as defined in IEC 61724-1,
  - the annual solar irradiation for the location
  - Use of automated simulation tools and pre-defined packages of modules and inverters.
- Forms part of the quotation process for installers and retailers.

Other considerations?
Aesthetics, longer term maintenance, access for cleaning and repair/replacement

Consumer perspective (2)

EU consumer organisations provide advice on the installation of PV systems, as well the purchase of modules and inverters.

- Own in-house performance testing and auditing of products
- Varying and sometimes non-standard methods and metrics
- Supporting checklists for contracting installers

Test Achats (Belgium), Which? (UK)

✓ Audit PV manufacturers factory quality procedures and check production samples

OCU (Spain)

✓ Field tests and rates PV module and inverter kits in comparison to manufacturers claims.

Subsidy schemes: system and product tests

Qualification requirements impose requirements on all equipment, suppliers and contractors used.

- Belgium & UK: Compliance with EN 61215 and EN 61464, plus IEC 61730 where incorporated onto a building
- Italy: Performance Ratio (PR) of systems field tested in accordance with EN 61724.
  - PR >0.78 where inverter ratings <20kW
  - >0.80 where inverter ratings >20 kW
- France: Durability of mounting system, waterproofing of main components and halogen content of cables

Existing voluntary labelling schemes

- ✓ Blue Angel ecolabel criteria set for inverters (2012)
  - Challenges faced establishing module and system criteria
- ✓ NSF/ANSI 457 leadership standard for modules (2017)
  - Three manufacturers in process of certifying
  - Scope will be extended in 2019 to include inverters
- ✓ Cradle to Cradle certification awarded to module products (2016)

Only Cradle to Cradle currently awarded to PV products

- No specific PV product criteria
- General applicability to products
  - hazardous substances (safety to human health and environment)
  - production site energy use/GWP emissions
  - circular product design
  - social fairness

Technical analysis

	Base case - 2016	Best Available Technology (BAT):	Best Not Yet Available Tech. (BNAT)
Modules	Multi Si module based on back contact (BSF)	CIGS & CdTe	Lift-off or epitaxial growth Tandem crystalline perovskite
Inverters	R: 1 string inverter C: 3 string inverter U: central inverter	Long lifetime and repairable inverters (20 y+)	MOSFET based inverters
Systems	R: BSF + 1 string C: BSF + 3 string U: BSF + central	Transfer optimised performance practices from utility scale to residential and commercial	-

LCA literature and hot spot analysis

4 broad categories of potential identified:

- Those that have a metric and standardised method(s) but for which establishing a benchmark will be difficult e.g. production energy use (GER), life cycle GWP emissions (supply chain)
- Those that have a metric but no standardised method(s) e.g. silver content of a module, the semi-conductor recovery rate
- Those that don't have a clear metric nor the basis for performance benchmarks, e.g. glass thickness for an specific grade
- Those for which an initial benchmark can be identified but no standardised method exists, e.g. degradation rate

LCA hot spot analysis

MODULES

- For Si-based: ingot manufacturing and wafer production
- For thin-film, metal deposition together with flat glass production

INVERTERS

- Integrated circuit of the printed circuit board

SYSTEMS

- The electricity demand in the supply chain of aluminium and copper production for the mounting structure and cabling
- Balance of system (BOS) components in thin-film installations

LCA hot spot analysis – criteria potential

MODULES

1) Use of less energy intensive manufacturing processes,
2) Silicon ingot slicing, e.g. change of laser cutting, lift-off, kerfless (epitaxial), diamond wire sawing for multicrystalline

- Verification: Primary energy and GHG emissions reporting, e.g. ISO 14064, 50001 Energy Management System, EN 15804 (EPDs)
- Precedents: NSF 457 (7.1.1 required criteria)

INVERTERS

1) Avoiding toxic elements, eg. Cd, Hg, Be, As, Pb, Cr
2) Lead-free soldering techniques

- Verification: Declaration of content of substances from a list of targeted substances, or of no Pb content, or of protocols for the disassembly and recycling

Hot spot analysis

INVERTERS

- Precedents: Ecodesign regulations for WMs/DWs/fridges/TVs/servers and WEEE directive (PCBs > 10 cm2)

SYSTEMS

Use of lighter structures or more sustainable materials, by e.g. having dual junction box design

- Verification: hardly feasible to capture in criteria. Integrated modules? how to credit the integration?

1) Declaration of cabling material
2) GHG emissions reporting standard production specific , e.g. 14064

- Precedents: None

Stakeholder feedback
life cycle criteria

- Criteria with thresholds should be set for ingot/wafer production, with more precise verification of energy use and GHG emissions
- French CRE GWP tender requirements could form the basis for EU criteria
- Benefits of renewable electricity need to be/should always be reflected
- No standard method exists for calculating Energy Payback Time

Residential PV system: simplified EROI

European Commission

Sensitivities to take into account

- Factory quality
  e.g. procedures to minimise micro-cracks in modules
- Product lifetime
  e.g. estimated technical lifetime and repairability of inverters
- Product efficiency and yield
  e.g. kWh yield/kWp under different climatic conditions (IEC 61853-3)

Implications?

Hot spot derived criteria can be combined with criteria on quality, lifetime and yield in order to maximise improvement potential whilst avoiding trade-offs e.g. production PE + lifetime yield PE

Stakeholder feedback
Circular economy criteria

- Stronger criteria are needed on design for recycling/dismantling
- Inverter durability and repairability should be addressed - disassemblability, spare parts, warranty period (up to 15-20 yr), firmware updates, fast on-site response
- Time taken to replace inverters that cannot be repaired on site is a key factor

Other environmental impacts

Hazardous substances in solar photovoltaic products

Ecolabel Regulation (EC) 66/2010 contains in Article 6(6) and 6(7) require that ecolabelled products do not contain hazardous substances

- REACH Candidate List substances (0.10% screening)
  - Five phthalates, cadmium sulphide, lead, diarsenic trioxide,
- CLP hazard classification (0.10% screening)
  - Plasticizers, flame retardants and dirt repellents, antimony
- RoHS Regulation
  - Specific exclusion for modules
  - Manufacturer claims: absence/compliance for Cd, Pb, phthalates

Non LCA environmental impacts

Hazardous substances in solar photovoltaic products

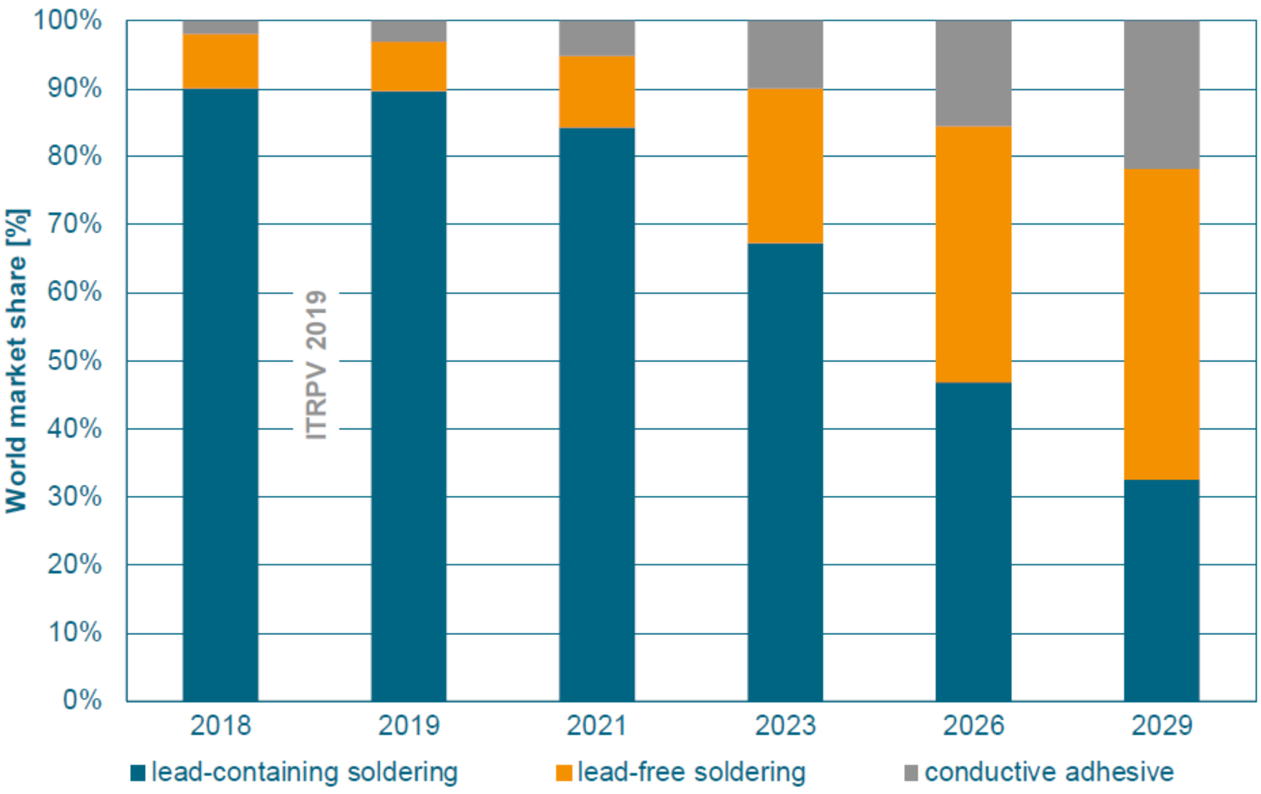
- **Substances meeting criteria for CLP classification**

Substance	Use	Alternatives	Information gaps
Plastizicers	• Cable sheathing • Module encapsulation	• Phtalate free plastizisers e.g. TOM, DOTP) • Cable sheating materials (e.g. TPE, EVA)	• Extent of use of the Alternatives?
Flame retardants	• Polymer back sheet material for fire protection • Cable sheathing	• Fluoropolymers • Thicker materials, e.g. PET • Metal phosphinates with TPEs	• Use in junction boxes and electronic components in inverters? • Suitability of inorganic alternatives?
Dirt repellents	• Module glass	• Morphological texturing of glass	• Alternatives? • Migration of existing coatings ?

Stakeholder feedback
Hazardous substance criteria

- A major addition to the REACH Candidate List is lead, the use of which in solder would require derogating
- The potential for lead and phthalate free modules exists in the market, so this should be promoted
- Specific environmental hazards such as antimony in front glass require addressing
- The REACH Candidate List criterion 'article' scope should be clearly defined – i.e. which sub-assemblies?
- The potential need for derogations for modules and inverters shall be more clearly stated
- Alignment with RoHS thresholds could contradict policy aims to increase renewables deployment

Market penetration of 'lead-free' modules



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The need for derogations

Derogation will be needed according to Article 6(7) of the Ecolabel Regulation (EC) 66/2010

- REACH Candidate List substances (0.10% screening)
  - Cadmium sulphide (semi-conductor), lead (solder/metallisation), diarsenic trioxide (module glass)
- CLP hazard classification (0.10% screening)
  - Subsitute plasticisers (cables)
  - Flame retardants (inverter PCB)
  - Diantimony trioxide (crystalline module glass)
  - Titanium dioxide, zinc dioxide (antisoiling)

Non LCA environmental impacts

Hazardous substances in manufacturing processes

- High GWP (Global Warming Potential) gas emissions not significant

  - Use of CF_4, C_2F_6, SF_6 and or NF_3 for edge isolation and reactor cleaning

  - NSF 457 requirement on avoidance or reduction of high global warming potential gas emissions

- Exposure to silicon tetrachloride by-product

  - Production of silane and trichlorosilane

  - Economic impetus now strong to recover as by-product, e.g. polysilicon and fibre optics

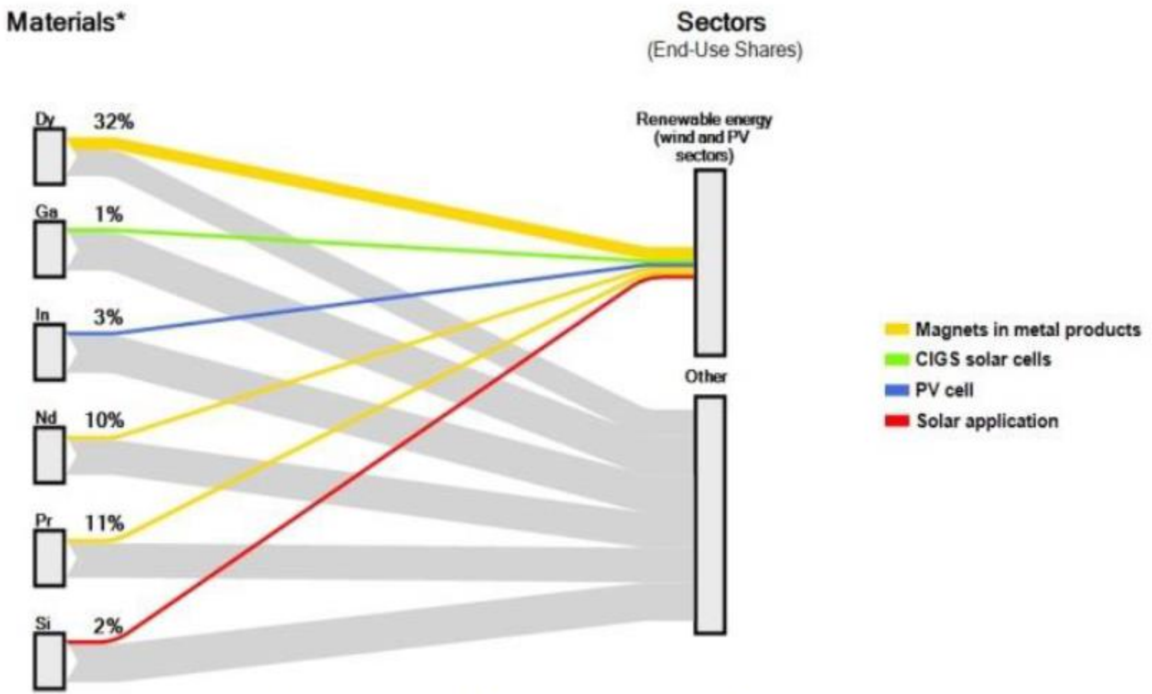
Stakeholder feedback
Non-LCA impacts

- The scoping of potential pollution sources from PV production site processes should be more exhaustive
- High GWP gas abatement systems should be addressed regardless of their low LCA contribution
- Silicon tetrachloride abatement systems should be addressed regardless of a reduction in the risk

Non LCA environmental impacts

Use of Critical Raw Materials

- **Indium (CIGS)**
- **Gallium (CIGS, tandem)**
- **Silicon metal**
- Antimony (glass)
- Cobalt (batteries)
- Tantalum (inverters and MLPE)



* Only a subset of all CRMs used in renewable energy sector is included.

Green Public Procurement: market 'pull'

'... a process whereby public authorities seek to procure goods, services and works with a reduced environmental impact throughout their life cycle when compared to goods, services and works with the same primary function that would otherwise be procured.'

- COM(2008) 400 Public procurement for a better environment

  Multi-criteria sets informed by LCA and LCC evidence

  - ✓ Core: minimum additional verification or cost increases
  - ✓ Comprehensive: additional verification or slight cost increase (EU Ecolabel)
  - ✓ Criteria: Selection, Technical Specification, Award and Contract Performance
- Accordance with the Procurement Directive 2014/24/EU

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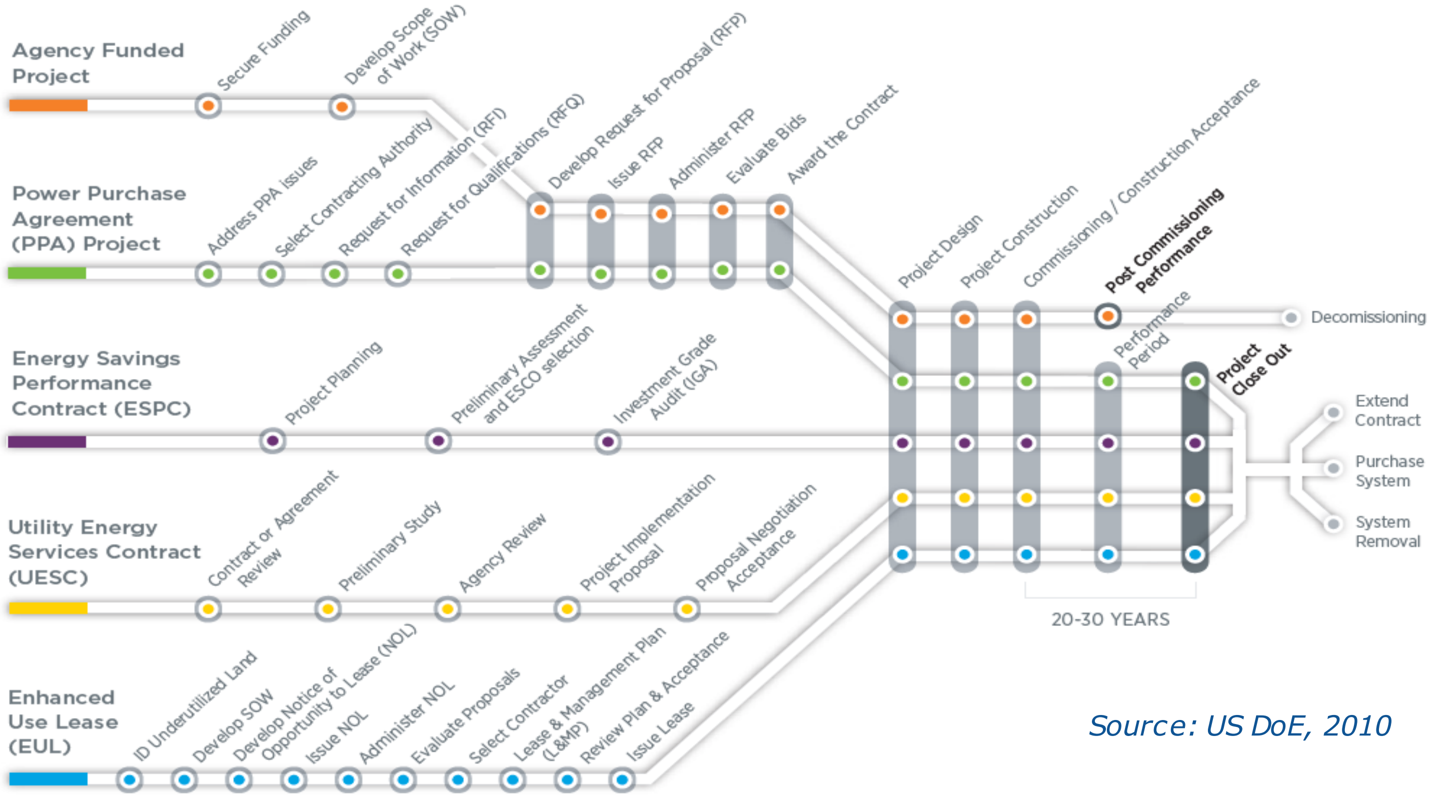
Existing public procurement practices

Initial evidence from a search of tenders published in OJEU and example calls for tender and contracts.

- Award of points and establishment of performance clauses on the basis of:
  - AC output power,
  - warranty length,
  - failure response services and
  - availability of spare parts.
- Monitoring of performance upon grid connection had also been specified.
- Some evidence of PV services on the basis of Power Purchase Agreements (PPAs), energy service agreements and community investment funds.

Novel procurement routes (1)



Source: US DoE, 2010

Novel procurement routes (2)

Public authorities use procurement to attract private investment and facilitate greater residential deployment

- PV services based on Power Purchase Agreements (PPAs), energy service agreements, roof/land agreements and community investment funds
- Reverse auction managed by the public authority
  - Step 1 registration of interested households
  - Step 2 supplier shortlisting and tender process to procure installation service for registered households.
    - ✓ monitoring systems
    - ✓ extended guarantee for each system
    - ✓ price reduction of 35% on market rates (4.000 installs)

Risk mitigation and reduction in LCC/LCOE

Project life cycle cost analysis: IEA PVPS programme, the European Photovoltaic Technology Platform, Solar Bankability and PV Finance

- Optimisation of the potential to generate solar power,
- Minimisation of the risks to loss of income from and,
- Minimisation of the LCOE* along the life cycle of a project.

$$LCOE = \frac{CAPEX + \sum_{t=1}^{n}[OPEX(t)/(1+WACC_{Nom})^{t}]}{\sum_{t=1}^{n}[Utilisation_0 \cdot (1-Degradation)^{t}/(1+WACC_{Real})^{t}]}$$

* LCOE: Levelised Cost of Electricity (€/kWh)

Stakeholder feedback
GPP criteria

- Existing EU GPP electricity criteria (2012) lessons and potential to reward solar electricity should be reviewed *
- The IECRE system conformity rating system (currently under development) proposed as basis for performance criterion – minimum rating of is AA- proposed

* 2017 study in support of revision of EU GPP criteria for electricity showed that purchasing on basis of GOC results in minimal market additionality

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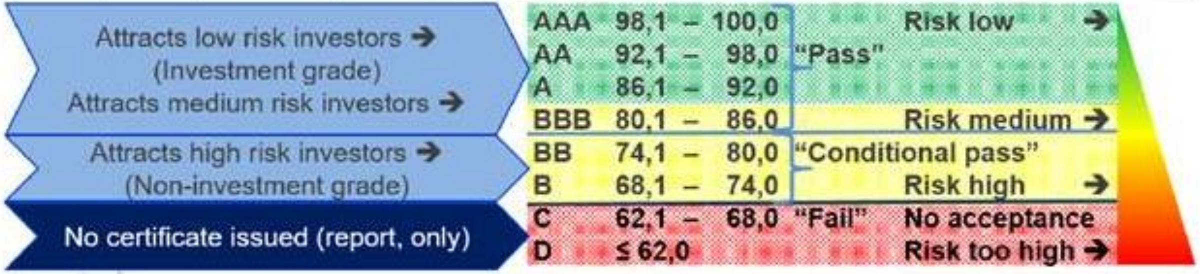
Under development: IECRE conformity rating

Rating		Point range		Short description (proposal)
		From	To	
AAA		981	1000	Benchmark standard
AA	AA+ AA AA-	921	980	Meets high quality standards
A	A+ A A-	861	920	Meets essential quality standards
BBB	BBB+ BBB BBB-	801	860	Meets standards to an acceptable level
BB	BB+ BB BB-	741	800	Meets standards to a moderate level
B	B+ B B-	681	740	Meet standards to a minimum pass level
C		621	680	Fails to meet standards to a major extent
D		≤	620	Completely fails to meet standards

FICTIVE EXAMPLE



Results of Solar Bankability project

Eight priority mitigation measures identified based on their Cost Priority Number (CPN) and potential impact on LCOE:

Preventative

1. Quality testing of modules and inverters
2. Design review + construction monitoring
3. Engineering Procurement Contractor (EPC) qualification

Corrective

4. Basic monitoring of system alarms and notifications
5. Advance monitoring systems for early fault detection/diagnosis
6. Advanced inspection to detect defects
7. Visual inspection to detect visible changes
8. Spare part management

Options and feasibility for EU Ecolabel and Green Public Procurement (GPP) criteria

Assessment of the evidence for EU Ecolabel: criteria areas and need for the label

The European Commission's science and knowledge service

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Evaluation for new EU Ecolabel product groups

- Feasibility of definition and scope: Is it possible to clearly define and classify the product/sub-products as the basis for a criteria scope?
- Existence of other ecolabels and schemes: Is there an existing basis in the EU or internationally for product group criteria?
- Market significance: Could the Ecolabel criteria be effectively targeted at mainstream products identified from market data?
- Visibility: Would the product group provide a high level of consumer visibility for the ecolabel?
- Potential uptake: What existing indications are there of the potential?
- Alignment with legislation and standards: Could the Ecolabel make a positive contribution to specific EU environmental policy objectives?
- Environmental impacts analysis; Can practical, verifiable criteria be identified that address LCA hot spots and issues of significance?

Possible contribution to EU policy objectives

Policy measure	Evaluation
Energy Union Framework Strategy and accompanying new Electricity market rules	**Moderate** for all products, or outside of the scope of this policy instrument
Renewable Energy Directive 2009/28/EC and the revised provisions	**Limited to moderate** role for all products – additional information and visibility for high performance products
Recast Energy Performance of Buildings Directive 2010/31/EU (EPBD) and 2018 update	**Limited to moderate** role in respect of building renovation and smart readiness
Construction Products Regulation (EU) No 305/2011	**Moderate**, in the case that module and inverter criteria on dismantling and durability are defined
Directive 2011/65/EU on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS)	**Moderate to strong**, in the case that module criteria are aligned with RoHS thresholds
Directive 2012/19/EU on Waste Electrical and Electronic Equipment (WEEE),	**Limited to moderate**, in the case of criteria on better design for recycling/depollution or a level of performance from take back/recovery
EU action plan for the Circular Economy	**Moderate to strong,** as an instrument to stimulate innovative design for repairability, recyclability and durability

Possible criteria areas (1) Package components

- Life cycle primary energy/GWP
  1) Reporting the life cycle primary energy, ISO 14064 (*or* EN 15804)
  2) Module energy yield estimated threshold (30 years)
  3) Energy payback time threshold
- Material efficiency
  1) Ease of dismantling flat glass
  2) Reduction of semiconductor materials content
  3) Recycled content of materials of concern, e.g. Cd, In, Ga, Te
- Circular economy
  1) Validated modules degradation rate
  2) Module and inverter durability tests
  3) Module and inverter repair potential
- Hazardous substances

  Content restriction on lead and cadmium

Possible criteria areas (2) System service

- System service aspects
  1) Optimised design (including system PR and energy yield)
  2) Handling and installation protocols
  3) Monitoring and maintenance (incl. smart readiness)

Possible criteria areas (3) Points system

Package

MANDATORY

- Energy payback time
  - Module energy yield
- Module degradation rate
- Smart inverter
- Hazardous substances
- *Quality/durability tests*

ADDITIONAL POINTS

- Module and inverter repair
- Recycled semiconductor
- *Conflict-free minerals*
- *Ease of dismantling*

System

MANDATORY:

- Optimised design
  - System PR and energy yield
- Handling and installation protocols
- Monitoring and maintenance (incl. smart readiness)

ADDITIONAL POINTS:

- *'Energy cloud' service (to avoid the need for battery storage)*

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Summary findings of the evaluation

Evaluation criteria	Finding	Discussion points
Feasibility of definition and scope	To check	Combined criteria on modules and inverters as B2B products + residential service offer, but point of EU Ecolabel award would need legal clarification
Existence of other ecolabels and schemes	Uncertain	Three standards/labels have criteria that could be reflected in an EU Ecolabel criteria but process-based + only one to date awarded to a PV products
Market significance	Uncertain	No specific products that would achieve all of the identified improvement potential. A points system could allow for flexibility in award.
Visibility	Positive	A high profile green product but in reality the degree of visibility for the EU Ecolabel may depend on the point of sale for the PV system or components
Potential uptake	Uncertain	Industry consortium proposal for PV modules. Standards/labels suggest verifiers and some manufacturers interested/ready to bring products forward.
Alignment with legislation and standards	Positive	Moderate->strong contributing role in implementation of some of the main objectives of energy, construction, electrical equipment and circular economy
Environmental impacts analysis	Variable	Lack of performance metrics, performance benchmarks and/or standardised methods for several of the possible criteria areas

Open issues for discussion

- Proposed focus on residential kits/packages (<5-10 kW)
  - Could modules and inverters be labelled as both B2B and B2C?
  - Include the service offered to customers?
- Existing criteria of relevant ecolabels and schemes
  - Are there enough products in the market able to meet such criteria?
  - Respond by having mandatory minimum + optional points system?
- Setting EU Ecolabel criteria that address environmental hot spots
  - General problem: lack of performance benchmarks and/or standardised methods, process-based criteria
  - Use proxies, interim methods and self-declarations?
  - Hazardous substance criteria derogation framework

Discussion with Q&A

Options and feasibility for EU Ecolabel and Green Public Procurement (GPP) criteria

Assessment of the evidence for GPP: criteria areas and need

The European Commission's science and knowledge service

Joint Research Centre

European Commission

Types of GPP criteria

Selection criteria (SC) assess the suitability of an economic operator to carry out a contract

Technical specifications (TS), the required characteristics of a product or a service including requirements relevant to the product at any stage of the life cycle of the supply or service and conformity assessment procedures;

Award criteria (AC), qualitative criteria with a weighted scoring which are chosen to determine the most economically advantageous tender

Contract performance clauses (CPC), special conditions laid down that relate to the performance of a contract and how it shall be carried out and monitored

Evaluation for new EU GPP product groups

Step 1: Contribution to objectives

Step 2: Determine the added value of GPP to existing policy instruments

Step 3: Determine if GPP is the most effective instrument to achieve the objectives

Step 4: Determine the best form of GPP implementation

Contribution to EU policy objectives

- A more active role on the part of public authorities
  - ✓ Increased deployment of solar energy (Renewable Energy Directive)
  - ✓ Decarbonising of the existing building stock (Energy Performance of Buildings Directive)
  - ✓ Citizen engagement via reverse auctions (the Energy Union Framework Strategy)
- Ensuring that for any given geographical location the energy yield is maximised and the energy payback time and LCOE is minimised
- Reduction in the presence of hazardous substances in electrical equipment (RoHS Directive 2011/65/EU)
- Promotion of more repairable, durable and recyclable products (EU Action Plan for a Circular Economy)

Potential contribution to GPP objectives

Life Cycle Cost (LCOE) perspective

- ✓ Contribute towards achievement of grid parity: promote best practices in design optimisation and component selection.
- ✓ Stimulate innovation in module and inverter design as well as system solutions e.g. smart monitoring.

GPP criteria by project phases and risk mitigation

Project phase		Risk mitigation	Potential type of GPP criteria
1. Preventative	**1.1 Selection/testing**	Module and inverter **factory quality and performance testing**	• **Selection Criteria** for factory quality (e.g. IEC 62941, EN 62788) • **Technical Specifications** for modules and inverters (e.g. EN 61215, EN 62093) • **Award criteria** based on declared module degradation rate
	1.2 Design and yield estimation	Quality of **design yield estimate** and associated modelling data and assumptions Quality of **electrical engineering design** to mismatch and other losses	• **Selection Criteria** for the field experience of the design team/EPC contractor • **Award criteria** based on an estimate of the Performance Ratio (with reference to IEC 61724) • **Award criteria** based on energy payback time (dependent on climate/location)

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GPP criteria by project phases and risk mitigation

Project phase		Risk mitigation	Potential type of GPP criteria
1. Preventative	**1.3 Transportation to site**	**Protocols to minimise damage** of modules through mishandling	• **Selection Criteria** evidencing the use of such protocols • **Technical Specification** requiring specific actions within a protocol
	1.4 Installation/construction	**EPC qualification** for competencies of field workers **Advanced monitoring systems** for early detection and diagnosis of faults **Procedures to minimise damage** of modules through mishandling	• **Selection Criteria** for the field experience of the design team/EPC contractor • **Technical Specification** for the monitoring systems • **Technical Specification** requiring specific actions within a protocol

GPP criteria by project phases and risk mitigation

Project phase		Risk mitigation	Potential type of GPP criteria
2. Corrective	**2.1 Operation & maintenance**	**Basic monitoring routines** to detect failures and deviations **Advanced monitoring routines** including visual inspection and IR/electroluminescence sensing **Spare part management** to minimise costs of downtime and increase likelihood of fulfilling design life.	• **Technical Specification/Award Criteria** for the granularity of monitoring system (e.g. IEC 61724-1) • **Technical Specification** based on planning to respond to inverter manufacturers recommended repair cycle
	2.2 Decommissioning	Definition of **dismantling procedures** and **end of life routes**	• **Technical Specification/Award Criteria** requiring specific actions within a protocol and/or provision of specific EoL services

Summary findings of the evaluation

Evaluation criteria	Finding	Summary
Step 1: Contribution to objectives	Positive	• Support **greater deployment** and **yield optimisation** • Reduce or **manage environmental impacts along the life cycle** of solar PV systems and components • Contribute towards **achievement of grid parity** for the LCOE of solar electricity
Step 2: Determine the added value of GPP to existing policy instruments	Positive	Potential to play a strong role in promoting **better systems and components** – with a focus on quality, hazardous substances and circular design - but also through **novel procurement routes**
Step 3: Determine if GPP is the most effective instrument to achieve the objectives	Positive	Public sector has a substantial stock of buildings and land on which solar PV could potentially be installed: • the potential influence on the design and specification of components can be **direct** • reverse auctions or the procurement of electricity **extend this influence** to third party, citizen installations
Step 4: Determine the best form of GPP implementation	Proposal	A combined focus on **product** (e.g. quality), **works** (e.g. protocols) and **services** (e.g. maintenance) is proposed.

Open issues for discussion

Possible considerations:

- Should the scope be different for EU GPP?
- Focus primarily on the procurement of PV systems, but with criteria on module and inverter performance
- Possible expansion to cover novel procurement routes in order to facilitate greater PV system deployment?
  - ✓ Power purchase agreements for solar electricity
  - × Solar electricity purchased on basis of guarantee of origin certificates *
  - ✓ Roof/land leasing with solar electricity supply
  - ✓ Reverse auctions for residential systems

* Study in support of revision of EU GPP criteria for electricity showed that purchasing on basis of GOC results in minimal market additionality

Next steps

- Comments on the Task 6 and 7 documents can be made through BATIS until 13th September 2019

Please use BATIS to submit your comments
http://eippcb.jrc.ec.europa.eu/batis/login.jsp

BATIS Helpdesk
JRC-B5-PRODUCT-BUREAU@ec.europa.eu

Thanks for your attention

Discussion with Q&A

European Commission

Transitional Methods for Performance Requirements and Energy Efficiency Index

E. Dunlop, A. Gracia Amillo, E. Salis, T. Sample, N. Taylor
JRC/C.2 Energy Efficiency and Renewables

The European Commission's science and knowledge service
Joint Research Centre

3rd Stakeholder Meeting of the Preparatory Study for applying EU sustainable product policy instruments to solar photovoltaics, Brussels, 10-11 July 2019

European Solar Test Installation

European Commission

Standards are crucial to implementing Ecodesign measures and for subsequent market surveillance. The JRC reviewed over 100 standards. Not all relevant aspects are covered to the same degree.

	Modules	Inverters	Systems
Design Certification	✓	✗	✗
Power	✓	✓	✓
Durability	✗	✗	✗
Energy	✓	✓	✗
Repair/Recycling	✗	✗	✗

See report "Standards for the assessment of the environmental performance of PV modules, power conditioning components and PV systems", 2018

Transitional Methods

….. where certain aspects essential to the implementation of Ecodesign, Ecolabel, Energy Label & GPP are not covered by existing standards, the Commission may choose to specify transitional methods, that are implemented as regulations until suitable standards are adopted.

→ Draft report "**Transitional Methods for PV modules, inverters and systems in an Ecodesign Framework**"

PV Residential System
Energy Label – Proposed Transitional Method

Task 7: Option 3.2 detailed approach

- Performance Requirements
  - ➢ Modules
  - ➢ Inverters

- Energy Yield for an Energy Efficiency Index
  - ➢ Inverter performance
  - ➢ PV system losses
  - ➢ PV system energy yield estimation
  - ➢ Energy Label proposal

European Commission

Module Requirements

1. Quality and Durability

EN IEC 61730 Low Voltage Directive (LVD)

+ optionally

EN 61215 for PV module design qualification and type approval (partial overlap with EN IEC 61730)

2. Electrical Performance

EN 61853 PV module energy rating standard

Module Safety Test (EN61730) and Module Quality Test (EN61215) Standards

13 out of 18 tests in EN IEC 61215 are equivalent to those in EN IEC 61730, although there are differences in the sequences and reporting requirements

EN61703	EN61215	Test Name
MST 02	MQT 06.1	(*Performance at STC*)
MST 03	MQT 02	(*Maximum power determination*)
MST 07	MQT 18.2	(*Bypass diode functionality test*)
MST 16	MQT 03	(*Insulation test*)
MST 17	MQT 15	(*Wet leakage current test*)
MST 22	MQT 09	(*Hot-spot endurance test*)
MST 25	MQT 18	(*Bypass diode thermal test*)
MST 34	MQT 16	(*Static mechanical load test*)
MST 42	MQT 14	(*Robustness of terminations test*)
MST 51	MQT 11	(*Thermal cycling test*)
MST 52	MQT 12	(*Humidity freeze test*)
MST 53	MQT 13	(*Damp heat test*)
MST 54	MQT 10	(*UV test*)

Higher stress level requested IEC 61730

Module Requirements (cont.)

3. Degradation

Prescribed values:

- c-Si: 0.7% per year (linear)
- Thin-film and heterojunction: 1.0% per year (linear)

Product-specific values - requirements for acceptance:

- Robust data from the measurement of field-deployed systems and made available (upon request) to the market surveillance authorities, covering all reference climatic profiles, with data from at least:
  - 5 consecutive years
  - 2 separate geographical locations in each climatic profile
  - 2 mounting options
- Assigned value shall be the average of the collected values

Measurement guidance:
EN 61724-1 and IEC 61724 series (PV guidelines monitoring)

Inverter Requirements

Quality Pre-requisites: conformity to relevant design qualification, type approval and safety tests: EN 62116 (islanding prevention), IEC TS 62910 (test for low voltage ride-through measurements), as well as IEC 61683 and EN 50530 (efficiency measurements).

Degradation

Prescribed values:

- Degradation rate: 0 %/year (no degradation)
- Failure rate: 10% per year

Product-specific values - requirements for acceptance:

- *To be defined*

PV Residential System Energy Efficiency Index

Overview of Proposed Methodology and Excel Tool Example

1. System losses
2. Module and Inverter Performance Ratio
3. System Performance Ratio
4. Lifetime AC Energy Yield estimation
5. Energy Label proposal/example

STEP 1

PV array **DC annual** energy output

EN 61853

Year 0

STEP 2

Inverter **performance**

Transitional method + EN 50530

STEP 3

PV system **losses**

Transitional method

STEP 4

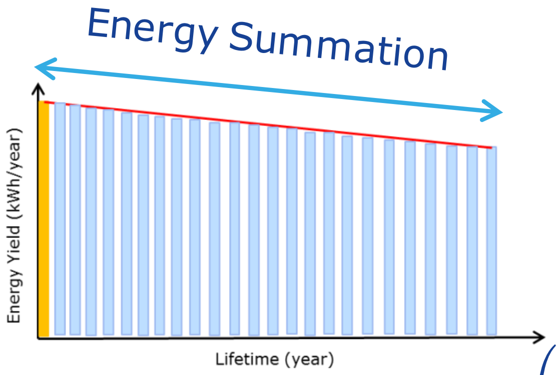
PV array **AC annual** energy output

Transitional method

STEP 5

PV array **AC LIFETIME** energy output

Transitional method

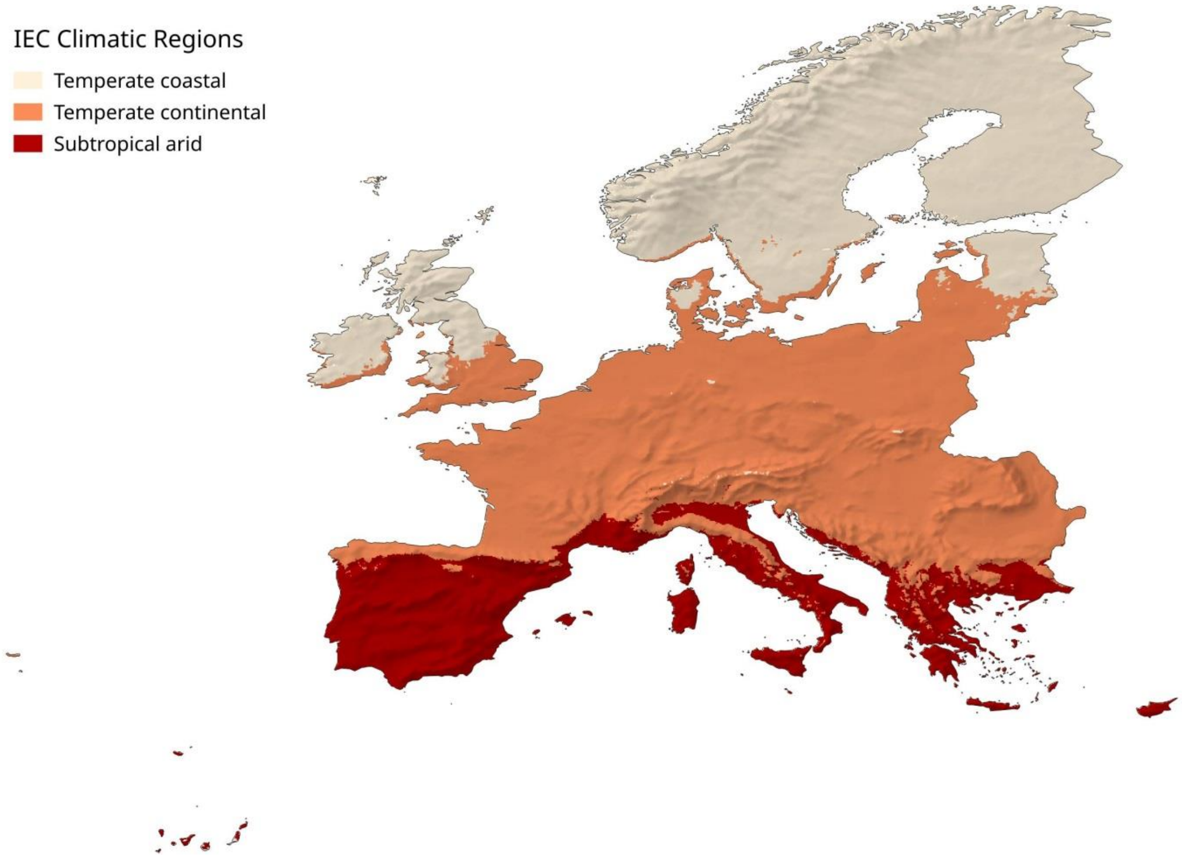


Degradation

Lifetime

$$System\ EY_{AC\_lifetime} = System\ EY_{AC\ year\ 0} \cdot T_{lifetime} \cdot \left(1 - \tau_{deg} \cdot \frac{T_{lifetime}}{2}\right)$$

EN IEC 61853-4 *Standard reference climatic profiles*



Tropical humid
Subtropical arid
Subtropical coastal
Temperate coastal
Temperate continental
High elevation (above 3000m)

Input data – PV module & Inverter

Installation configuration

Orientation (°) (S is 0°S, E is -90°E)	27
Inclination (°)	37
CSER Correction factor	0.998

Possible to consider different configurations (orientation & inclination) from the one applied in the EN 61853

User requested PV power (kW)	3.00

PV module

Datasheet information

Pmax (W)	320
PV module area (m^2)	1.657
Efficiency (%)	19.31

The tool works with the real number of installed PV modules, and takes into account the module efficiency

EN 61853 "Photovoltaic (PV) module performance testing and energy rating"

Climates	*CSER*	Hp (kWh/m^2.year)
Subtropical arid	0.887	2295.452
Temperate coastal	0.922	972.934
Temperate continental	0.915	1266.003

Existing standards

Inverter

Microinverter (Y/N)	N
AC rated power (kW)	2.5

Defines the DC or AC wiring losses

EN 50530 "Overall efficiency of grid connected photovoltaic inverters"

Euroefficiency (%)	96

Input data

Calculated or provided data

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Input data – PV system losses

PV system losses: default values or user defined values, according to some restrictions

Use default values (Y/N)	N	Insert estimated losses in User values (%)

Defined losses cannot be lower than Minimum values

Losses	Default values (%)	Minimum values (%)	Typical values (%)	Average values (%)	User values (%)	Applied values (%)
Module mismatch	3.00	1.50	2.00	1.75	1.80	1.8
DC wiring	3.00	1.00	2.00	1.50	3.00	3
Diodes and connectors	1.00	0.30	0.50	0.40	0.50	0.5
Soiling	25.00	2.00	5.00	3.50	6.00	6
Shading	10.00	0.10	5.00	2.50	4.50	4.5
AC wiring	2.00	0.70	1.00	0.85	0.85	0.85
Inverter temperature derating	1.80	0.10	1.00	0.55	1.50	1.5
…						
…						
…						
	38.26					16.19

PV system losses used in the calculations

Default PV system losses, worst case scenario

Calculation – PV system configuration

PV system configuration - PV array

User requested PV power (kW)	3.00
Installed PV modules	10
Installed PV power (kW)	3.2
Installed PV Area (m^2)	16.57

Requested PV power in comparison to the Installed PV power due to the number of modules

PV system configuration - Inverter

AC rated power (kW)	2.5
Size ratio PV array/Inverter	1.28

Warning: Consider increase size of inverter

A maximum size ratio of 1.25 is assumed

PV system configuration - Losses (%)

	Losses (%)
Default installation	38.26
User defined installation	16.19

PV system losses for the default configuration (worst case scenario) against the PV systems losses defined by the user

Calculation – PV system Performance Ratio

PV module (*CSER* and installation correction) + Inverter Euroefficiency

Calculated Performance Ratio

Product specific

Installation specific

Climates	PV module & Inverter	PV system losses	
		Default	User defined
Subtropical arid	0.852	0.617	0.838
Temperate coastal	0.885	0.617	0.838
Temperate continental	0.878	0.617	0.838

PV system losses: default and user defined configuration

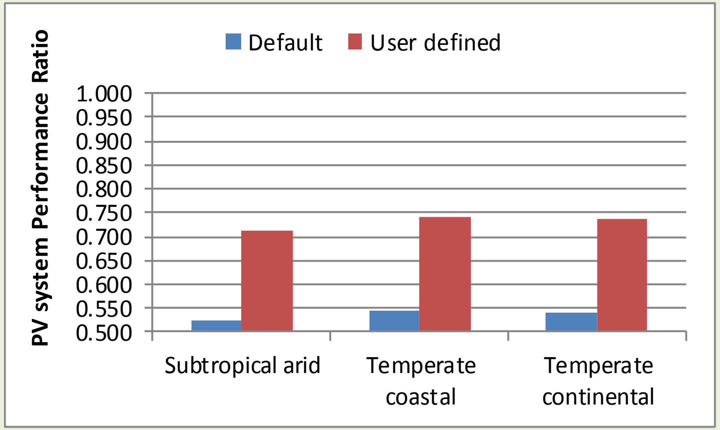
Reference climate dependence

Actual System

PV system Performance Ratio

Climates	PV system configuration	
	Default	User defined
Subtropical arid	**0.526**	**0.714**
Temperate coastal	**0.547**	**0.742**
Temperate continental	**0.542**	**0.736**

PV module + Inverter + PV system losses



Calculation – PV system AC Energy Yield

Input

Reference climate (SA/TS/TN)*	SA
PV system config (C1/C2)*	C2
Installed PV array power (kW)	3.2
PV system Lifetime (yrs)	30
PV system Degradation (%)	1

PV module (W)	320
PV module (m^2)	1.657
Hp ($kWh/m^2.yr$)	2295.452
CSER corrected	0.887
PV syst loss (%)	16.19

Drop down menu

Nomenclature *

Reference climates

SA	Subtropical arid
TS	Temperate coastal
TN	Temperate continental

PV system configuration - PV system losses

C1	Default installation
C2	User defined installation

PV system configuration summary

Lifetime and degradation as input

Input data

Calculated or provided data

Calculation – PV system AC Energy Yield

Results

Defined PV system

PV system AC Energy yield

	kWh	kWh/kWp	kWh/kWp.m^2
Year 0	5242	1638	98.859
Lifetime	**133668**	41771	2521

Year 0

Lifetime estimation

- kWh
- kWh/kWp installed
- kWh/kWp.m^2 installed

Various possible locations and configurations

Lifetime PV system AC Energy yield (kWh/kWp.m^2)

	PV system configuration		Energy Label	
Climates	Default	User defined	**Default**	**User defined**
Subtropical arid	1857	2521	**D**	**D**
Temperate coastal	818	1111	**D**	**C**
Temperate continental	1057	1434	**E**	**C**

Energy Label based on the Lifetime AC Energy Yield expressed in kWh/kWp.m^2 installed

Energy Label proposal

Energy Label based on the Lifetime AC Energy Yield expressed in kWh/kWp.m² installed

	Lifetime AC Energy yield (kWh/kWp.m²)		
Energy Label	Subtrop arid	Temp coastal	Temp continental
A	> 3857	> 1682	> 2173
B	[3857 - 3190)	[1682 - 1394)	[2173 - 1801)
C	[3190 - 2524)	[1394 - 1106)	[1801 - 1429)
D	[2524 - 1857)	[1106 - 818)	[1429 - 1057)
E	[1857 - 1596)	[818 - 706)	[1057 - 912)
F	[1596 - 1334)	[706 - 594)	[912 - 767)
G	< 1334	< 594	< 767

A label defined by:
- 25.35% eff PV module
- 98% Euroefficiency inverter
- 4.91 PV system losses

D label defined by:
- 19.31% eff PV module
- 96% Euroefficiency inverter
- 38.26 PV system losses (worst case scenario)

F label defined by: **Task 6 BAT**
- 14.48% eff PV module
- 94% Euroefficiency inverter
- 38.26 PV system losses (worst case scenario)

Other labels are linear interpolated

European Commission

JRC TECHNICAL REPORTS

Transitional method for PV modules, inverters, components and systems (Draft)

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Thank you for your attention

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