



Evaluation of Projects of Common Interest under the Guidelines for trans-European energy network (draft methodology)



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Outline

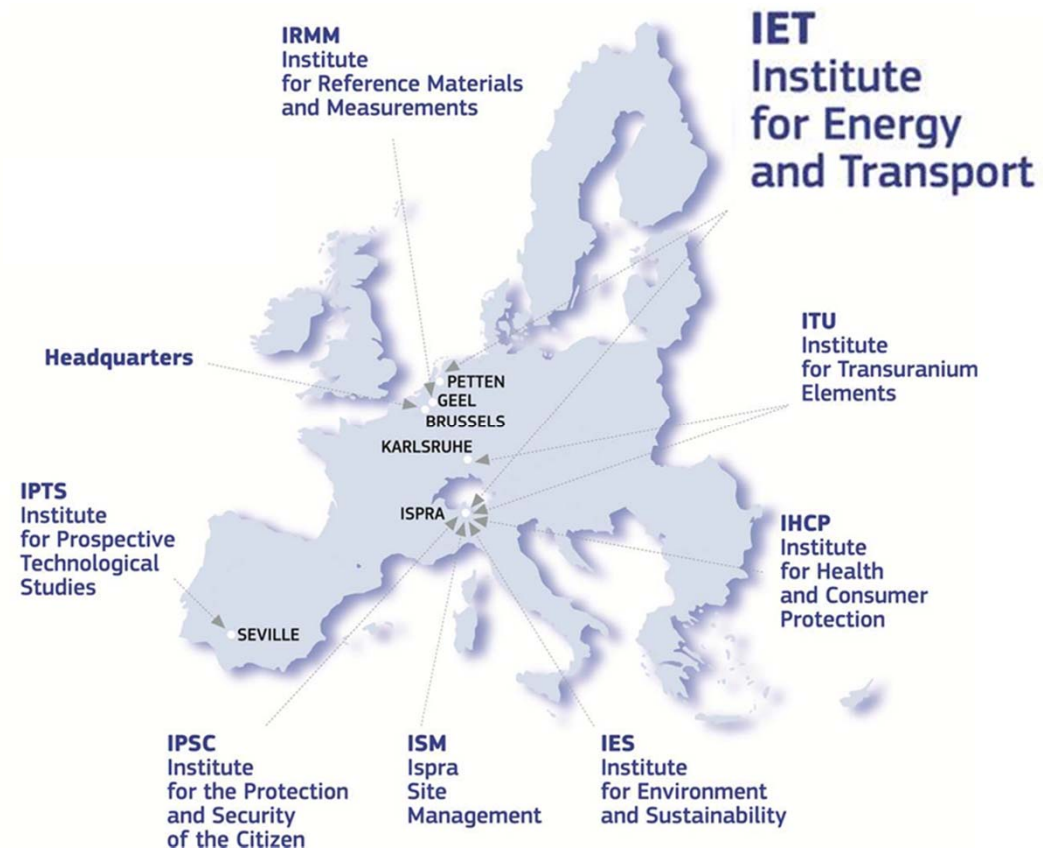
- ❑ JRC role and expertise
- ❑ Methodological challenges
- ❑ JRC assessment methodology
 - ❑ Compliance with the Regulation
 - ❑ Handling of configurations
 - ❑ Description of CBA indicators
 - ❑ Handling of CBA indicators
- ❑ Methodological approach
 - ❑ Mathematical - statistical methodology
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- ❑ Synopsis



JRC ROLE AND EXPERTISE

Joint Research Centre (JRC) - Who are we?

- EC's independent **in-house scientific service**
- A **self-standing DG** providing EU policy makers with impartial advice
- Our mission: ensure **science-based policy making** on a wide range of topics



Unit activities in the area of gas

- European Science and Technology Network on Unconventional Hydrocarbon Extraction
- Risk Assessment of Gas: implementation of Regulation 994/2010 on the security of gas supply.
- Modelling gas crises: mass balance and hydraulic models.
- Techno-economic analysis.
- Oil and Gas Offshore safety.
- Members of the Gas Coordination Group, EU Energy Economists etc.



JRC experience in PCI CBA

- Assessment framework for the identification of smart grid Projects of Common Interest (PCI)
 - First Round PCI evaluation completed in 2013
 - New Round PCI evaluation ongoing (due in 2015)

- <http://ses.jrc.ec.europa.eu/>

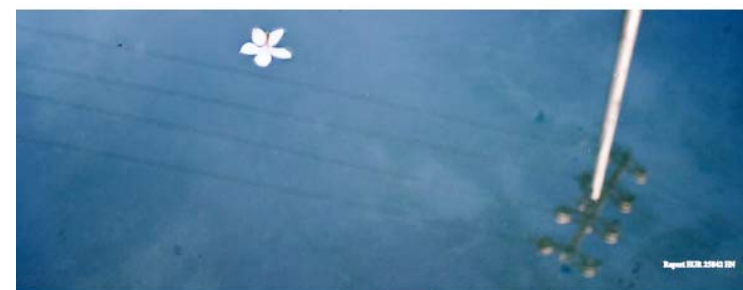
JRC SCIENTIFIC AND POLICY REPORTS

Evaluation of Smart Grid projects within the Smart Grid Task Force Expert Group 4 (EG4)

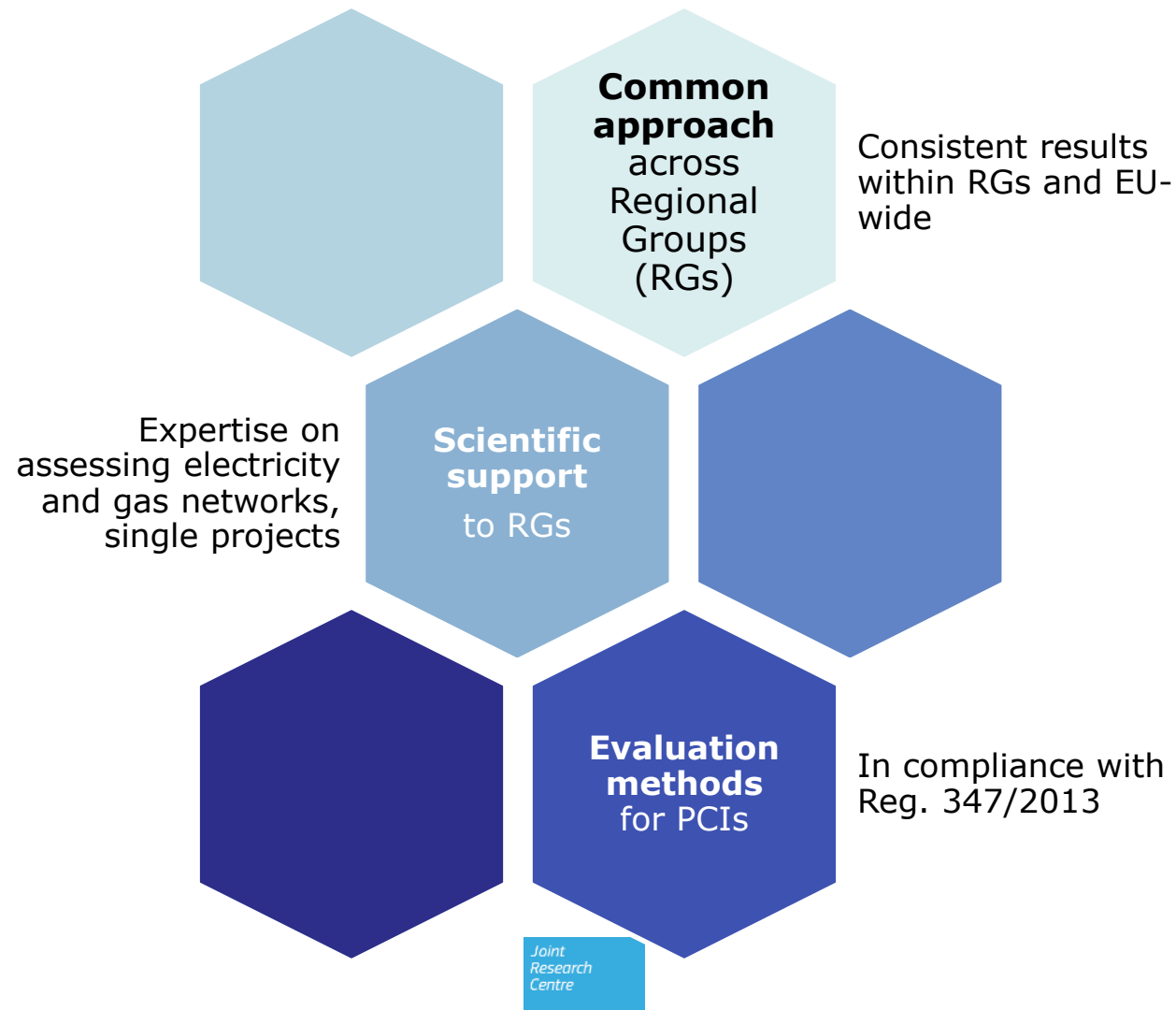
Application of the Assessment Framework for Energy Infrastructure Projects of Common Interest in the field of Smart Grids

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Silvia Vitello, Joint Research Centre

Constantina Filiou, DG Energy
Sebastian Gras, DG Energy
Marija Mrdeza, DG Energy
2013



JRC's role in the PCI process





METHODOLOGICAL CHALLENGES



Some challenges for evaluating project proposals:

- **Information glut and complexity:** many data points, heterogeneous data, configurations, indicators ...
- **Heterogeneity** among the projects. This may impact the choice of assessment criteria – consistency needs to be assured to allow the comparison of results amongst the RGs.
- **Heterogeneity** among the Regional Groups in terms of type and number of projects.
- **Cost data are confidential.**



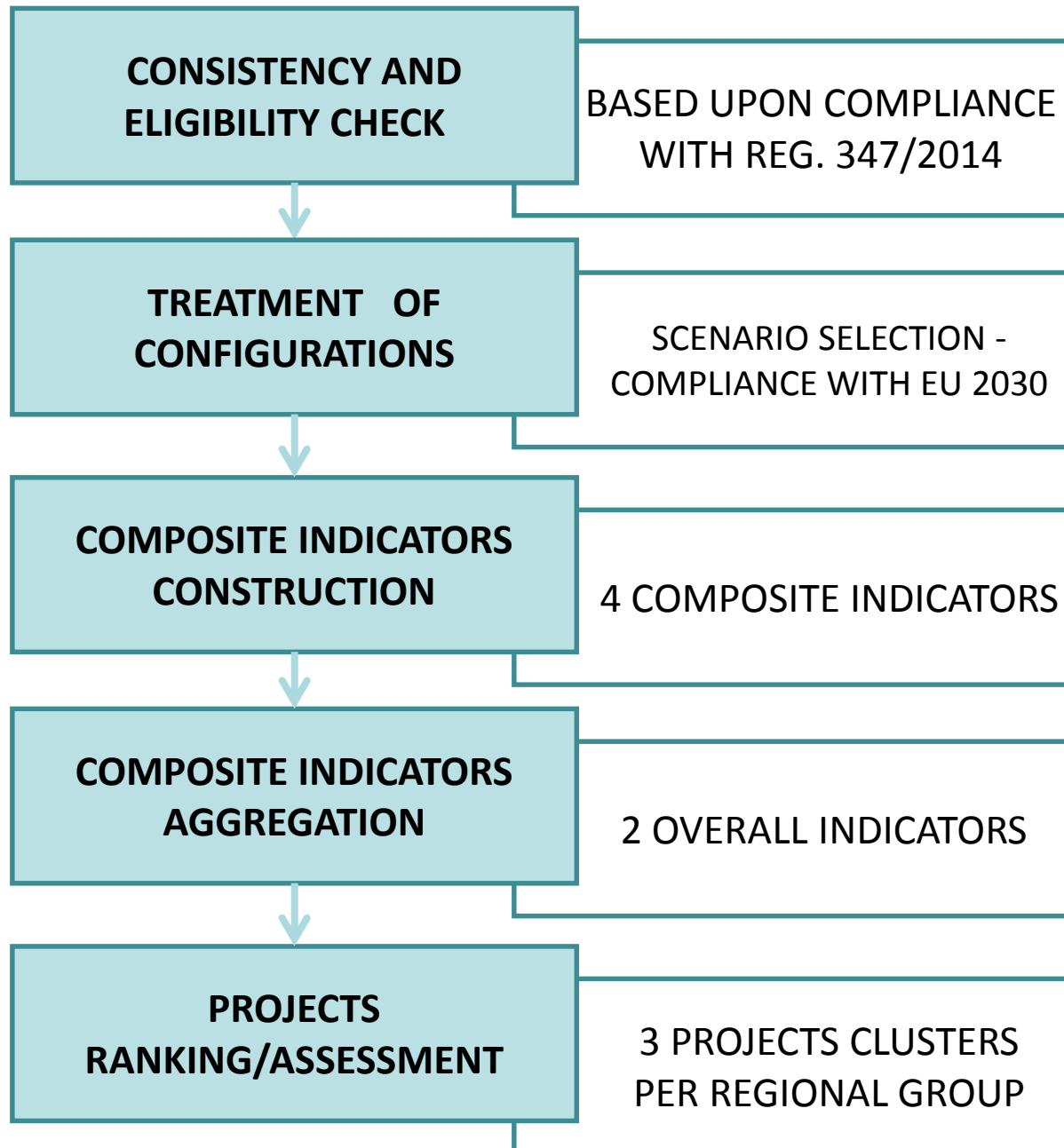
Some challenges for evaluating project proposals (2):

- **The TYNDP will be published after the finalization of the methodology.** Statistical methodologies are dependent on the underlying data.
- **The methodology must be harmonized across the Regional Groups.**
- **Issues of normalizing the data.**
- **High correlation of indicators** (expected).



JRC ASSESSMENT METHODOLOGY

The JRC Methodology





COMPLIANCE WITH THE REGULATION

General criteria of Regulation (EU) No. 347/2013

Projects of common interest shall meet the following general criteria:

- *a. the project is necessary for at least one of the energy infrastructure priority corridors and areas;*
- *b. the potential overall benefits of the project, assessed according to the respective specific criteria in paragraph 2, outweigh its costs, including in the longer term; and*
- *c. the project meets any of the following criteria:*
 - *i. involves at least two Member States by directly crossing the border of two or more Member States;*
 - *ii. is located on the territory of one Member State and has a significant cross-border impact ..*



Specific criteria of Regulation (EU) No. 347/2013

- *for gas transmission, the project concerns investment in reverse flow capacities or changes the capability to transmit gas across the borders of the Member States concerned by at least 10 % compared to the situation prior to the commissioning of the project;*
- *for gas storage or liquefied/compressed natural gas, the project aims at supplying directly or indirectly at least two Member States or at fulfilling the infrastructure standard (N-1 rule) at regional level in accordance with Article 6(3) of Regulation (EU) No 994/2010 of the European Parliament and of the Council;*

"THE BENEFITS MUST OUTWEIGH THE COSTS"

- **Financial Benefit/Cost ratio (FB/C)**

$$FB/C = \frac{\sum_{t=f}^{c+19} \frac{R_t}{(1+i)^{t-n}}}{\sum_{t=f}^{c+19} \frac{C_t}{(1+i)^{t-n}}}$$

If **FB/C > 1**, the project is considered as **financially efficient**.

"THE BENEFITS MUST OUTWEIGH THE COSTS" (2)

- Economic Net Present Value (ENPV)

$$ENPV = \sum_{t=f}^{c+19} \frac{R_t - C_t}{(1+i)^{t-n}}$$

If **ENPV > 0**, then the project generates a **net benefit**.

HANDLING OF CONFIGURATIONS

Description of configurations (project specific step)

- Infrastructure: i) low and ii) high.
- Coal versus gas balance in power generation: i) green and ii) grey
- Import prices from 6 sources: i) low, ii) high and iii) reference

52 configurations

- Five time-steps (21 year horizon).
- With and without the specific project.

Configurations are not forecasts!

The "green" scenario

- Consistent with ENTSO-E's "green transition."
- A high price of CO₂ emissions due to the introduction of a carbon tax.
- A continuous reduction in the oil-price linkage mitigating the increase of gas price.
- Favourable economic and financial conditions.
- Commercial breakthrough of electricity plug-in vehicles with flexible charging.
- High levels of back-up generation.
- CCS storage is not commercially implemented (decentralised and limited).
- Smart grid solutions are partially implemented.

Price configurations

- Six import supply sources:
 - Algeria (pipe)
 - Azerbaijan (pipe)
 - Libya (pipe)
 - LNG
 - Norway (pipe)
 - Russia (pipe)
 - Turkmenistan (pipe)
- Three scenarios:
 - High import price from one individual supplier ("source expensive").
 - Low import price from one individual supplier ("source cheap").
 - No price changes (same average import price of the selected Global context scenario).

Infrastructure scenarios

- **Low Infrastructure:** Existing Infrastructures + Infrastructure projects having a FID status (whatever their PCI status is)
- **High Infrastructure:** Existing Infrastructures + Infrastructure projects having a FID status (whatever their PCI status is) + Infrastructure projects not having a FID status (whatever their PCI status is)

For each infrastructure scenario:

- one scenario with the project data included
- one scenario with the project data excluded

Handling of configurations

- PCIs are selected based on their benefit to the whole EU.
- The EU has set environmental goals (e.g. Europe 2030).

We propose:

- Global context: the **"green"** scenario will be considered as this is more in-line with the Europe 2030 targets.
- Price configurations: although this is not a forecasting exercise, for the **reference case** we will use the **cheap/expensive LNG prices.**
- Infrastructure: **"low infrastructure"** scenario.
- The remaining configurations will be examined for outliers.

DESCRIPTION OF CBA INDICATORS

CBA indicators (outputs)

- Modelling-based indicators
 - Remaining Flexibility (RF)
 - Disrupted Demand (DD)
 - Uncooperative Supply Source Dependence (USSD)
 - Cooperative Supply Source Dependence (CSSD)
 - Supply Source Price Diversification (SSPD_i)
 - Supply Source Price Dependence (SSPD_e)
 - Price Convergence (PC)

CBA indicators (outputs)

- Monetary analysis
 - Gas supply
 - Coal for power generation
 - CO₂ emission from power generation

CBA indicators (outputs)

- Financial Project Specific **Data** (monetary / financial analysis)
 - Promoter revenues
 - CAPEX
 - OPEX
 - Depreciation period
 - Financial discount rate
- Financial analysis
 - Residual Value of the asset corresponding to the project (financial/discount rate)
 - Financial Net Present Value (FNPV)
 - Financial Internal Rate of Return (FIRR)
 - The Financial Benefit/Cost ratio (FB/C)

CBA indicators (outputs)

- Modelling-based indicators
 - Remaining Flexibility (RF)
 - Disrupted Demand (DD)
 - Uncooperative Supply Source Dependence (USSD)
 - Cooperative Supply Source Dependence (CSSD)
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 - Supply Source Price Dependence (SSPD_e)
 - Price Convergence (PC)

CBA indicators (outputs)

- Economic analysis
 - Economic Net Present Value (ENPV)
 - Economic Internal Rate of Return (EIRR)
 - The Economic Benefit/Cost ratio (EB/C)

Other data

- Description of the project
 - technical scale and dimension
 - background, rational and objective of the project
- Qualitative analysis
 - Comment the results of the Quantitative and Monetary Analyses
 - Monetization of demand disruption
 - Describe additional benefits that would not have been sufficiently captured
 - Identify the significantly impacted country as part of the Area of Analysis
 - Identify the environmental impact of the project and associated mitigation measures
 - Describe the complementarity of his Project with other projects

HANDLING OF CBA INDICATORS

Alternative methodologies for evaluating projects

1. For each indicator, group projects by performance.
2. Calculate composite indicators and then group projects by performance.
3. Directly calculate a single composite indicator for each project.

1. For each indicator, grouping projects by performance

Pros

- Simple to implement and to understand.
- Provides transparency.

Cons

- Does not drastically reduce the information load for the RGs.
- Does not provide much insight.
- More appropriate for a smaller number of projects.

2. Build composite indicators, group projects by performance

Pros

- Reduces information load for the RGs.
- Provides an indication of the relative worth of each project.
- Suitable for the number of proposed projects.

Cons

- Underlying choices may impact the evaluation process.

3. Directly build a single composite indicator for each project

Pros

- Provides clear evaluation for the RGs.

Cons

- Loss of information granularity.
- Underlying choices may heavily impact the evaluation process.

Our proposal

Combination of the 2nd and the 3rd alternative:

- Combine the indicators into four, one for each Regulation criterion.
- Combine the four above indicators into one.
- Construct a separate indicator for costs.

METHODOLOGICAL APPROACH

What are composite indicators?

- JRC dedicated Composite Indicators Research Group (COIN):
<http://europa.eu/!db36Ru>
- *"A mathematical combination ("aggregation") of a set of indicators is most often called a "composite indicator": Composite indicators are based on **sub-indicators that have no common meaningful unit of measurement** and there is **no obvious way of weighting these sub-indicators.**"*
- A composite indicator quantifies and simplifies information.
- Trade-offs between scientific accuracy and available information.

Composite indicators: Pros and Cons

Pros

- summarise complex or multi-dimensional issues in view of supporting decision-makers;
- easy to interpret (e.g. ranking countries on complex issues)
- reduce the size of a list of indicators or to include more information

Cons

- if poorly constructed they may be misleading;
- may misguide users to over simplified results;
- do not resolve issues of selection of sub-indicators, choice of model, weighting indicators, treatment of missing values etc.

Methodological overview

- 1st step: combine the "benefit" indicators into 4 composite indicators.
- 2nd step: combine the 4 composite indicators into a single indicator
- 3rd step: construct a single cost composite indicator
- 4th step: evaluate benefit and cost overall indicator in conjunction
- 5th step: based on the above results, create three groups of projects

Handling of indicators

- Aggregation of the indicators by Regulation (EU) No. 347/2013 PCI candidate criteria (**market integration, security of supply, competition, sustainability**) and ENTSO-G's recommendations.

Security of supply

Regulation: "inter alia through appropriate connections and diversification of supply sources, supplying counterparts and routes;"

Relevant indicators

- Bi-directional,
- Import Route diversification,
- "N-1",
- Supply Source Price Diversification,
- Supply Source Dependence,
- Remaining Flexibility
- Disrupted demand

Sustainability

Regulation: *"inter alia through reducing emissions, supporting intermittent renewable generation and enhancing deployment of renewable gas."*

- Coal for power generation,
- CO₂ emission from power generation,
- Commenting and developing on project benefits,
- Infrastructure Environmental Impact

Competition

Regulation: *"inter alia through diversification of supply sources, supplying counterparts and routes;"*

Relevant indicators

- Import Route diversification,
- Supply Source Price Diversification,
- Supply Source Dependence Price convergence
- Gas supply

Market integration

Regulation: *"inter alia through lifting the isolation of at least one Member State and reducing energy infrastructure bottlenecks; interoperability and system flexibility;"*

Relevant indicators

- Bi-directional,
- Import Route diversification,
- Supply Source Price Diversification,
- Remaining Flexibility
- Price convergence,
- Gas supply



Overall indicators

The four composite indicators will be combined to create a single "overall indicator" for the benefits of each project.

Furthermore, an "overall costs indicator" of each project will be calculated.



Handling of results

Regulation (EY) No. 347/2013 states (Article 3:3a):

When a Group draws up its regional list:

(a) each individual proposal for a project of common interest shall require the approval of the Member States, to whose territory the project relates; if a Member State decides not to give its approval, it shall present its substantiated reasons for doing so to the Group concerned;

*(b) it shall take into account advice from the Commission that is aimed at having **a manageable total number of projects of common interest.***

(emphasis added)



Handling of results

Projects will be divided into three ranked groups based on the results of the analysis.



MATHEMATICAL - STATISTICAL METHODOLOGY

Mathematical statistical methodology

- Logarithmic transformation of individual data series (where needed): bring all dimensions on an equal footing, while maintaining the order (rank) of the data.
- Correlation analysis and subsequently *standardisation*.
- Principal Component Analysis for the construction of composite indicators.
- Grouping of projects.

PRINCIPLE COMPONENT ANALYSIS

Principal Component Analysis

- Indicators are random variables that take a specific value for each project
- Each project is characterized by a number of indicators
- These indicators are usually dependent (correlated).
- Independent (non-correlated) indicators carry more information than dependent (correlated) indicators
- Information is interpreted in terms of variability (variance). More spread indicators allow a better discrimination between projects

Principal Component Analysis (2)

- PCA aim at finding the latent (composite) indicators that explain most of the variability contained in the individual ones losing little information
- The number of Principal Components is equal to the number of individual indicators, but normally a few of them contain most of the information. The others are avoidable
- PCA facilitates the selection of composite indicators (providing their actual shape)

Principal Component Analysis (3)

- The results of the analysis depends on the actual units of the indicators (their variances)
- If all individual indicators are considered equally important, the right strategy involves transforming them to similar scales
- **Logarithmic transformation of the data:** pertinent to bring data spread over orders of magnitude to a linear scale, while maintaining the order (rank)
- **Standardisation** to convert the indicators to a common scale.
 - Z-scores (after transformation → all variances = 1)
 - Min-max (after transformation → all data in the range [0,1])

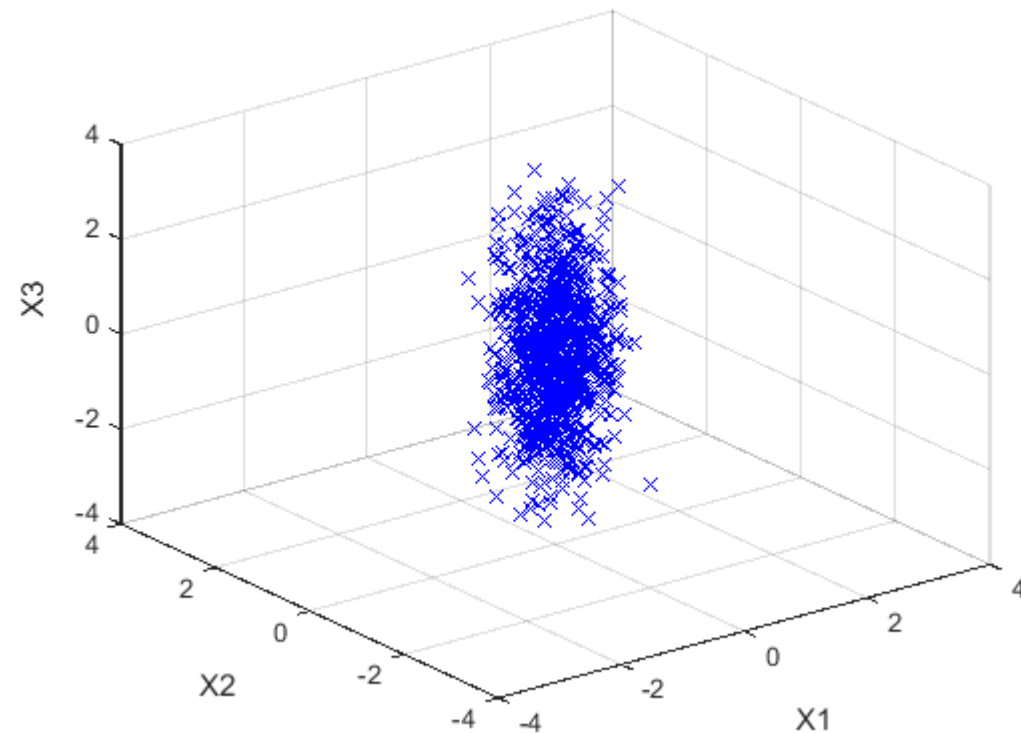
Principal Component Analysis (4)

- **How does PCA actually work?**
- It looks for linear combinations of the original indicators that
 - Are independent (non-correlated)
 - Contain the information of the original indicators in decreasing order (the first PC contains more information than the second one and so on). Information interpreted in terms of variability (variance)
 - Depending on their contribution to the total variance, the less important may be dropped
- Geometrically it is equivalent to find a rotation of the co-ordinate axes such that the projections on them fulfil the previous two sub-bullets

Principal Component Analysis (5)

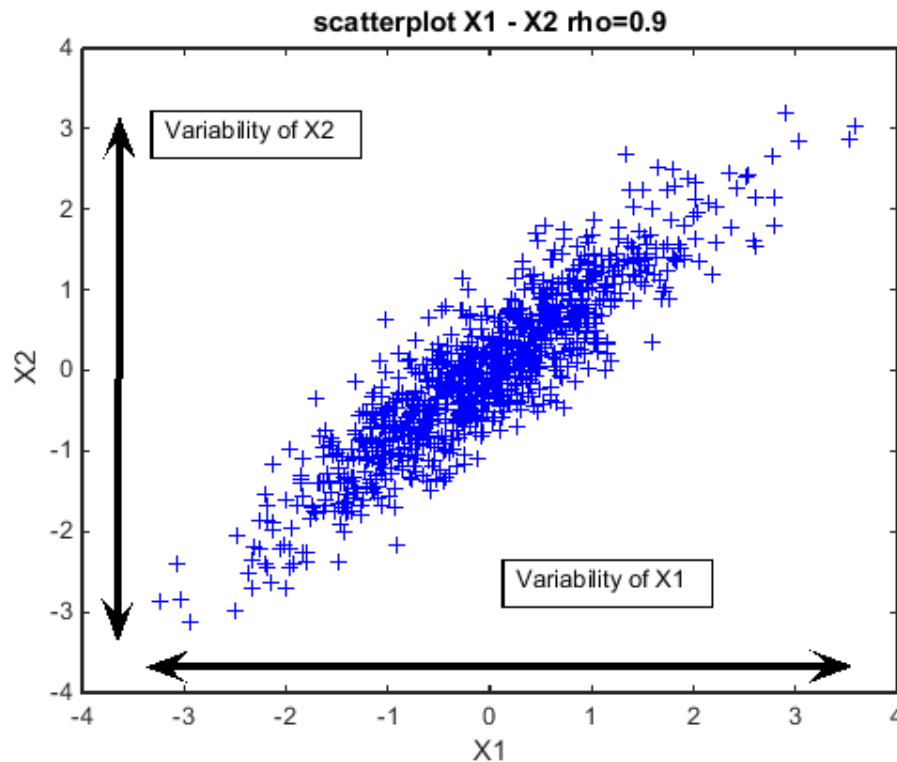
- **Example:** 3 indicators
(X1, X2, X3)
- **Target:** summarize the essential information in as few composite indicators as possible (one if possible)
- Difficult to see anything from the scatterplot (for higher dimensions it is impossible)

scatterplot of individual indicators



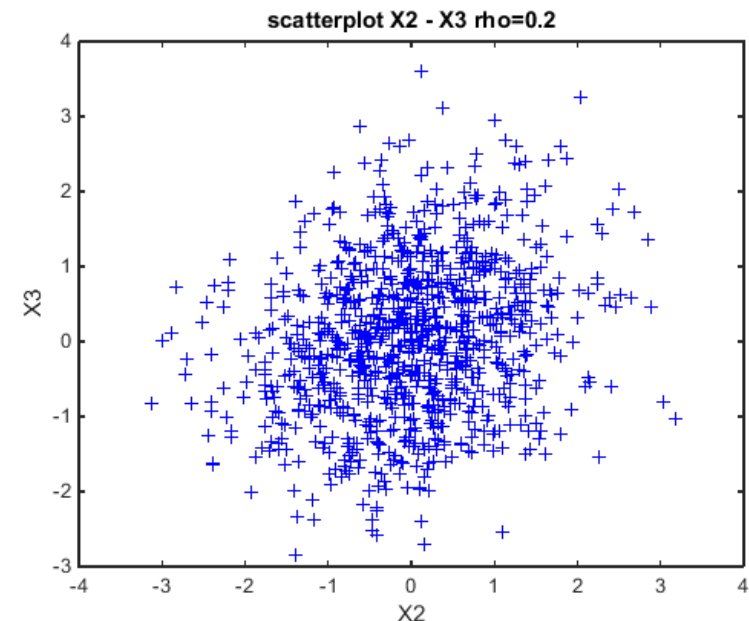
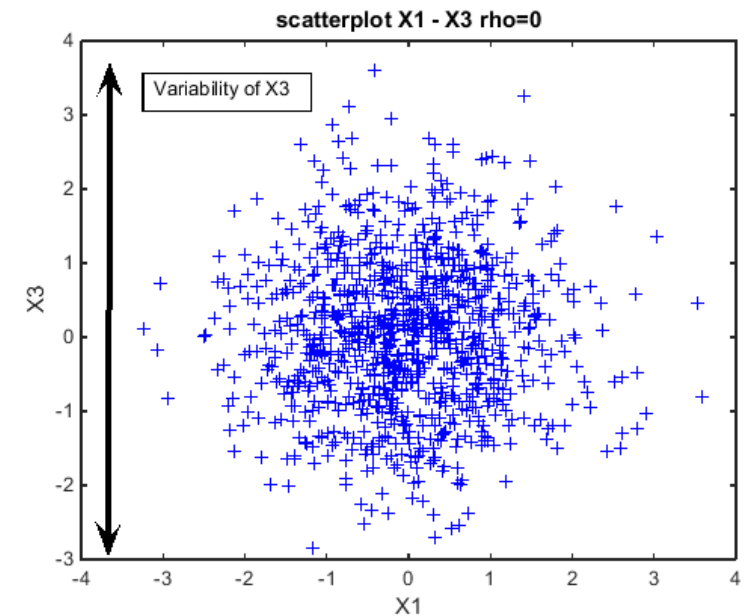
$$S_x^2 = \begin{pmatrix} 1.0 & 0.9 & 0.0 \\ 0.9 & 1.0 & 0.2 \\ 0.0 & 0.2 & 1.0 \end{pmatrix}$$

Principal Component Analysis (6)



Clear dependence between X1 & X2
Much redundant information

No dependence between X1 & X3



Principal Component Analysis (7)

After computing the PC's, we obtain

$$PC1=0.68X1+0.70X2+0.21X3$$

$$PC2=-0.26X1-0.03X2+0.97X3$$

$$PC3=-0.69X1+0.71X2-0.16X3$$

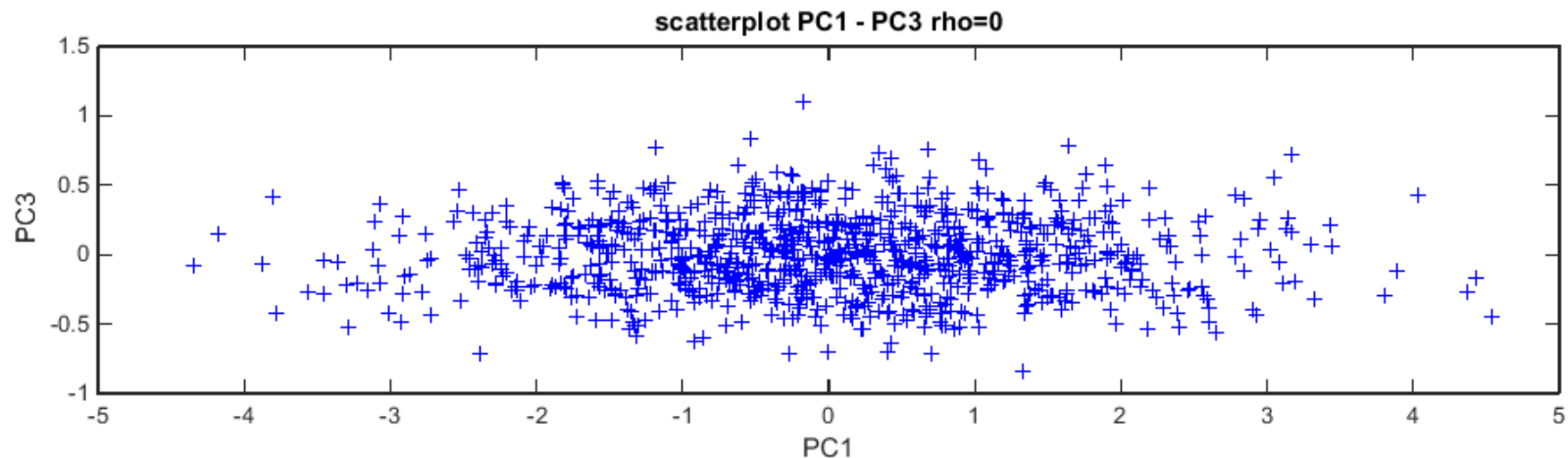
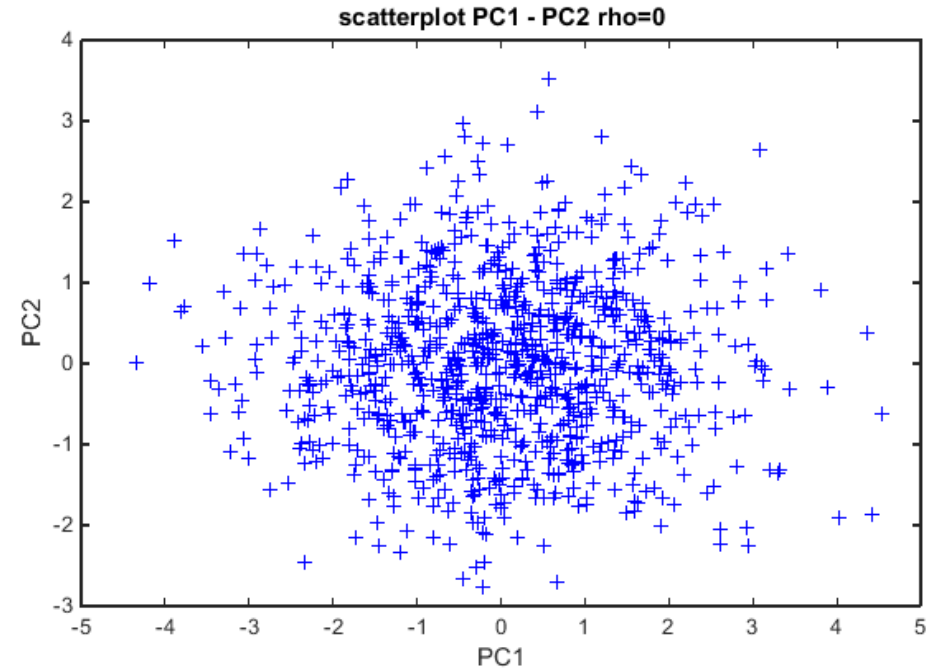
Basically this is a linear transformation of variables

How do the PCs look like?



Principal Component Analysis (8)

Principal component	% of variance
PC1	63.4
PC2	34.1
PC3	2.5



Principal Component Analysis (9)

Taking into account the analysis done, PC1 and PC2 are the two candidates to contribute to the composite indicator. Ignoring PC3 involves losing only 2.5% of the information

There are different alternatives to combining them

Equal weights

weights proportional to the fraction of the variance contributed

Others

The final ranking of projects would be obtained by computing the composite indicator for each project and ranking them according to the value obtained

Had we taken PC1 as the composite indicator the ranking would be given by the projection of the points (projects) on PC1

Principal Component Analysis (10)

Need of examining raw data in order to identify

- need of data transformations
- existence of outliers (which may dramatically affect study results)

Outliers, if they exist, must be analyzed

- In some cases they will be excluded for the design of the composite indicator,
- but included again to rank them

NUMERICAL EXAMPLE

DATA

Subset of the data in ENTSO-E's TYNDP 2014 (pp. 371-387),
assessing electricity TEN transmission projects.

Indicators:

- Security of Supply (SoS),
- Socio-Economic Welfare (SEW),
- Renewable Energy Sources (RES)
- Network Losses
- CO₂ Emissions
- Contribution to network Resilience
- Contribution to network Flexibility
- Grid Transfer Capacity (GTC)

Regulation criteria: Market Integration, Sustainability and Security of supply.



The JRC has a dedicated Composite Indicators Research Group:
<http://composite-indicators.jrc.ec.europa.eu>

The data treatment methodology is based on

- OECD/EC JRC (2008): *Handbook on Constructing Composite Indicators: Methodology and User Guide*, Paris: OECD
- Saisana (2012): "A do-it-yourself guide in Excel for composite indicator development", JRC, European Commission.



Methodological steps

- Step 1: group the indicators in conceptual categories
- Step 2: compute descriptive statistics
- Step 3: conform the indicators' directions
- Step 4: compute correlations between the indicators

Methodological steps (2)

- Step 5: normalise indicators to express in comparable units
- Step 6: conduct a Principal Component Analysis (PCA)
- Step 7: build rankings for each criterion based on PCA values
- Step 8: analyse correlations between criterion indicators
- Step 9: based on the former, do PCA once again to aggregate criterion indicators into an overall composite indicator
- Step 10: build overall project ranking

Step 1: Data

Group indicators based on conceptual associations with the policy criteria Regulation (EU) No. 347/2013

- **Market Integration**
- **Sustainability**
- **Security of supply**

Indicators	Socio-Economic Welfare	RES Integration	Network Losses	CO2 Emission	Resilience	Flexibility	Grid Transfer Capacity
A	240.00	2000000	2100000	-1350	2	5	1000
B	515.00	990000	30000	-2350	2	3	1835
C	40.00	130000	-10950	-400	2	3	500
D	255.00	1650000	-800000	-1100	2	5	2014
E	46.50	155000	40000	-445	3	3	720
F	305.00	2000000	-980000	-1350	1	5	2410
G	255.00	1650000	-800000	-1100	1	5	2008
H	55.00	200000	120000	-510	3	3	700
I	290.00	2650000	290000	-1800	1	4	1400
J	210.00	1850000	215000	-1300	1	4	1000
K	320.00	3000000	845000	-1850	2	4	1400
L	107.00	54500	9000	-400	1	4	1200
M	110.00	655000	230000	-985	1	4	1400
N	170.00	1000000	290000	-1700	2	4	2500
O	40.00	115000	-165000	-700	3	3	1500
P	30.50	50000	43000	44.5	3	3	700
Q	20.50	0	2000	0	1	3	800
R	280.00	265000	-240000	-1100	1	4	2320
S	210.00	200000	-180000	-840	1	3	1740
T	380.00	409750	-4000	-2000	1	4	504
U	455.00	2900000	-1450000	-2000	5	5	3583
V	59.00	0	-375000	-39.5	1	4	800
W	18.50	0	2900	39	1	3	1000
X	325.00	370000	2000	-590	1	3	1000
Y	245.00	2700000	-57500	-1550	1	2	600
Z	0.84	8350	-835	-7.55	4	4	500

Step 2: Descriptive statistics

	Socio-Economic Welfare	RES Integration	Network Losses	CO2 Emissions	Resilience	Flexibility	Grid Transfer Capacity
min	0.84	0.00	-1450000	-2350	1.00	2.00	500
max	515.00	3000000	2100000	45	5.00	5.00	3583
average	191.65	961638	-32476	-976	1.81	3.73	1351
std	145.21	1048244	632043	720	1.10	0.83	768
Skewness coefficient	0.42	0.79	1.00	-0.14	1.40	0.10	1.14
kurtosis	-0.65	-0.90	5.16	-1.06	1.57	-0.70	1.25



Step 3: Direction of indicators

For some indicators, larger values are preferable (e.g.: SEW), whereas the opposite holds for others (e.g.: CO2 emissions).

- ✓ The larger the better \Rightarrow positive direction
- ✓ The smaller the better \Rightarrow negative direction

We reverse the indicators with negative direction.

Step 4: Correlation coefficients

Calculate correlation coefficients between indicators

CORRELATIONS	SEW	RES	Losses	CO2	Resilience	Flexibility	GTC
SEW	1.00	0.64	0.15	0.88	-0.08	0.35	0.56
RES	0.64	1.00	-0.01	0.73	0.04	0.43	0.44
Losses	0.15	-0.01	1.00	-0.02	0.15	0.15	0.49
CO2 Emissions	0.88	0.73	-0.02	1.00	-0.03	0.33	0.52
Resilience	-0.08	0.04	0.15	-0.03	1.00	0.07	0.19
Flexibility	0.35	0.43	0.15	0.33	0.07	1.00	0.55
GTC	0.56	0.44	0.49	0.52	0.19	0.55	1.00

Green = significant positive correlations

Step 5: Normalisation

1. Normalise indicators. Why? To avoid mixing apples with oranges!

Normalising allows adjusting for

- ✓ different units of measurement across indicators
- ✓ different signs (plus or minus)
- ✓ different ranges of variation

2. Application of z-scores normalisation:

- **Z-scores:**
$$\text{new value} = \frac{\text{old value} - \text{mean}}{\text{standard deviation}} * \text{direction}$$

Step 5: Normalisation

Normalised indicator values applying z-scores:

Indicators	SEW	RES	Losses	CO2	Resilience	Flexibility	GTC
z-scores							
A	0.33	0.99	-3.37	0.52	0.18	1.53	-0.46
B	2.23	0.03	-0.10	1.91	0.18	-0.88	0.63
C	-1.04	-0.79	-0.03	-0.80	0.18	-0.88	-1.11
D	0.44	0.66	1.21	0.17	0.18	1.53	0.86
E	-1.00	-0.77	-0.11	-0.74	1.09	-0.88	-0.82
F	0.78	0.99	1.50	0.52	-0.74	1.53	1.38
G	0.44	0.66	1.21	0.17	-0.74	1.53	0.86
H	-0.94	-0.73	-0.24	-0.65	1.09	-0.88	-0.85
I	0.68	1.61	-0.51	1.14	-0.74	0.33	0.06
J	0.13	0.85	-0.39	0.45	-0.74	0.33	-0.46
K	0.88	1.94	-1.39	1.21	0.18	0.33	0.06
L	-0.58	-0.87	-0.07	-0.80	-0.74	0.33	-0.20
M	-0.56	-0.29	-0.42	0.01	-0.74	0.33	0.06
N	-0.15	0.04	-0.51	1.01	0.18	0.33	1.50
O	-1.04	-0.81	0.21	-0.38	1.09	-0.88	0.19
P	-1.11	-0.87	-0.12	-1.42	1.09	-0.88	-0.85
Q	-1.18	-0.92	-0.05	-1.36	-0.74	-0.88	-0.72
R	0.61	-0.66	0.33	0.17	-0.74	0.33	1.26
S	0.13	-0.73	0.23	-0.19	-0.74	-0.88	0.51
T	1.30	-0.53	-0.05	1.42	-0.74	0.33	-1.10
U	1.81	1.85	2.24	1.42	2.91	1.53	2.91
V	-0.91	-0.92	0.54	-1.30	-0.74	0.33	-0.72
W	-1.19	-0.92	-0.06	-1.41	-0.74	-0.88	-0.46
X	0.92	-0.56	-0.05	-0.54	-0.74	-0.88	-0.46
Y	0.37	1.66	0.04	0.80	-0.74	-2.09	-0.98
Z	-1.31	-0.91	-0.05	-1.35	2.00	0.33	-1.11

STEP 5: Normalisation

Correlation coefficients for z-scores:

CORRELATIONS	B2	B3	B4	B5	B6	B7	GTC
B2 SEW vision 3	1.00	0.64	0.15	0.88	-0.08	0.35	0.56
B3 RES vision 3	0.64	1.00	-0.01	0.73	0.04	0.43	0.44
B4 losses vision 3	0.15	-0.01	1.00	-0.02	0.15	0.15	0.49
B5 CO2 vision 3	0.88	0.73	-0.02	1.00	-0.03	0.33	0.52
B6 resilience	-0.08	0.04	0.15	-0.03	1.00	0.07	0.19
B7 flexibility	0.35	0.43	0.15	0.33	0.07	1.00	0.55
GTC	0.56	0.44	0.49	0.52	0.19	0.55	1.00

After conforming the indicators' directions (Step 3), correlations are the same as for the raw data (due to the absence of missing data).

- **Market Integration**: only Socio-Economic Welfare was grouped under this criterion, hence the composite indicator is SEW itself
- **Sustainability**: three indicators (RES integration, Losses and CO₂ Emissions)

Criterion: Sustainability

Extraction: Principal components

PC	Variance (% total)	Cumulative variance explained (%)
1	57.78	57.8
2	33.32	91.1
3	8.91	100.0

two relevant principal components explaining more than 90% of the variation



Sustainability: three indicators (RES integration, Losses and CO₂ emissions) and two relevant principal components explaining more than 90% of the variation

✓ 1st PC: $z_1 = +0.7066 * RES - 0.0304 * Losses + 0.7069 * CO_2$

✓ 2nd PC: $z_2 = -0.0319 * RES + 0.9994 * Losses - 0.0111 * CO_2$

We combine these two principal components (z_1 and z_2) into a single composite indicator.

- **Security of Supply (SoS)**: three indicators (Resilience, Flexibility and GTC)

Criterion: Security of Supply

Extraction: Principal components

PC	Variance (% total)	Cumulative variance explained (%)
1	53.6	53.6
2	31.9	85.5
3	14.5	100.0

two relevant principal components explaining more than 80% of the variation



Security of Supply (SoS): three indicators (Resilience, Flexibility and GTC) and two relevant principal components explaining more than 80% of the variation

- ✓ 1st PC: $z_1 = -0.2918 * Resil - 0.6618 * Flex - 0.6906 * GTC$
- ✓ 2nd PC: $z_2 = 0.9447 * Resil - 0.3124 * Flex - 0.1 * GTC$

We combine these two members (z_1 and z_2) into a single composite indicator.

STEP 7: Rankings

Build rankings for each criterion according to composite indicator values

Composite Indicators with z-scores		
Market Integration	Sustainability	Security of Supply
2.2268	0.6472	0.1402
1.8136	2.2800	2.9267
1.2971	0.2943	-0.7245
0.9184	-0.4275	-0.7450
0.8839	0.4811	0.1840
0.7806	1.2785	0.2195
0.6773	0.7583	-0.3800
0.6085	-0.0246	-0.0262
0.4363	0.8925	0.6313
0.4363	0.8925	0.0650
0.3674	0.9176	-1.1099
0.3330	-1.0826	0.2414
0.1264	0.2847	-0.5338
0.1264	-0.2232	-0.4604
-0.1491	0.1272	0.6070
-0.5623	-0.3049	-0.3800
-0.5829	-0.6387	-0.4569
-0.9135	-0.5433	-0.6107
-0.9410	-0.6177	0.2677
-0.9996	-0.6047	0.2754
-1.0443	-0.5968	-0.3732
-1.0443	-0.3344	0.5754
-1.1098	-0.8880	0.2677
-1.1786	-0.8520	-0.8219
-1.1924	-0.8722	-0.7450
-1.3141	-0.8432	0.9660

STEP 7: Rankings

Build rankings for each criterion according to composite indicator values

RANKS		
Market Integration	Sustainability	Security of Supply
1	7	12
2	1	1
3	9	22
4	16	23
5	8	11
6	2	10
7	6	16
8	12	14
9	4	3
9	4	13
11	3	26
12	26	9
13	10	20
13	13	19
15	11	4
16	14	16
17	21	18
18	17	21
19	20	7
20	19	6
21	18	15
21	15	5
23	25	7
24	23	25
25	24	23
26	22	2

STEPS 8 and 9:

Analyse correlations between composite indicators

CORRELATIONS	MI	Sus	SoS
Market Integration	1.00	0.75	0.22
Sustainability	0.75	1.00	0.43
Security of Supply	0.22	0.43	1.00

Since two of the criteria indicators are significantly correlated, we apply Principal Component Analysis once again to build the final overall composite indicator.

Extraction: Principal components

PC	Variance (% total)	Cumulative variance explained (%)
1	68.33	68.33
2	24.52	92.85
3	7.15	100.0

Step 10: Overall projects ranking (groups)

1

- Projects
- C, E, H ...

2

- Projects
- B, K, Z ...

3

- Projects
- A, F, Q ...

Disclaimers:

- this is just a small and well-behaved data subset (no missing data!); actual data may impose further treatment and other methodological variants
- cost data are missing from the initial dataset: clearly the analysis needs to be improved by taking them into account
- a full set of robustness checks will be performed on the resulting rankings once the actual data is available