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EVALUATION OF PROJECTS OF COMMON INTEREST UNDER THE GUIDELINES FOR TRANS-EUROPEAN ENERGY NETWORKS

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Projects of Common Interest (PCIs) are key energy infrastructure projects, which will help EU members to integrate their energy markets and, in particular, end the isolation of some Member States from Europe-wide energy networks. Projects of Common Interest are of particular importance for Europe's energy system due to the multiple benefits that they provide. In this paper, it is presented an assessment methodology for PCI candidate project proposals, with an example of how a PCI is selected.

Keywords: RES, PCI, KPIs, integration, cost

1. Cost Benefit Analysis for transmission projects

There are two ways for the project assessment that can be adopted:

- Take Out One at the Time method, consisting in excluding one-by-one the grid elements and evaluate the load flows over the lines with and without the examined network project;
- Put IN one at the Time method, that considers each new item grid element on the given network structure one-by-one and evaluates the network flows over the lines with and without the examined network project.

The first method provides an estimation of benefits for each project, as if it was the last to be commissioned. In fact, the first method evaluates each new development investment/project into the whole forecasted network.

The advantage of this analysis is that it immediately appreciates every benefit brought by each investment, without considering the order of investments.

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Hence, this method allows analyses and assessments, considering the whole future system environment and every future network evolution.

However, it should be noted that strictly competitive projects assessment, i.e. projects delivering the same service to the grid, may need several steps:

- Take one of the time methods: if the benefit is significant, then all the projects are useful.
- But poor benefits in this first assessment do not necessarily mean that none of the projects should be undertaken. Indeed one should take the reference network without all competing projects (but keeping all projects elsewhere in Europe), and adding them one by one. This will allow determining the right level of development to reach in this part of the grid.

2. Investment item assessment

The important projects contained in the network development plan are assessed by clusters using the TOOT (take out one project at a time) approach. Using an excel file we can convert cluster indicator values into investment item indicator values, according to two criteria:

- by splitting indicator values roughly pro rata relative to the GTC increase, so that in a cluster with investment items A, B, and C, cluster indicator values are roughly multiplied by formula 1 to get e.g. A's values;

$$\frac{\Delta GTC_A}{\Delta GTC_A + \Delta GTC_B + \Delta GTC_C} \quad (1)$$

- by taking the ratios between each investment item's GTC increase and the largest GTC increase in the cluster. In this case, cluster indicator values are multiplied by formula 2 to get e.g. A's values.

$$\frac{\Delta GTC_A}{\Delta GTC_{MAX}} \quad (2)$$

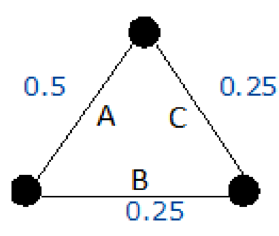

Fig. 1. Investment item indicator values

$$\frac{\Delta GTC_A}{\Delta GTC_A + \Delta GTC_B + \Delta GTC_C} \quad (3)$$

$$\frac{\Delta GTC_B}{\Delta GTC_A + \Delta GTC_B + \Delta GTC_C} \quad (4)$$

$$\frac{\Delta GTC_C}{\Delta GTC_A + \Delta GTC_B + \Delta GTC_C} \quad (5)$$

If ΔGTCA= 1000 MW and ΔGTCB = ΔGTCC= 500 MW, the first procedure yields: 0.5, 0.25 and 0.25 as multiplying factors to get the indicator values.

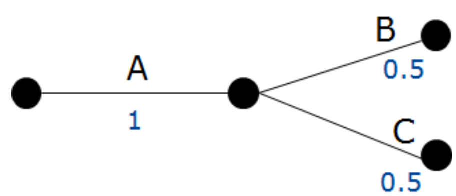

Fig. 2. Investment item indicator values

$$\frac{\Delta GTC_A}{\Delta GTC_{MAX}} \quad (6)$$

$$\frac{\Delta GTC_B}{\Delta GTC_{MAX}} \quad (7)$$

$$\frac{\Delta GTC_C}{\Delta GTC_{MAX}} \quad (8)$$

If $\Delta GTC_A = \Delta GTC_{MAX}$ = 1000 MW and $\Delta GTC_B = \Delta GTC_C$ = 500 MW, the second procedure yields: 1, 0.5 and 0.5 as multiplying factors to get the indicator values.

The second procedure is adopted for clusters with higher complementarity (typically convoy lines like the depicted A-B-C line). If all investment items feature the same GTC increase as the whole cluster (e.g. $\Delta GTC_{CLUSTER} = \Delta GTC_A = \Delta GTC_B = \Delta GTC_C$ = 1000 MW), this results in each investment items getting the same indicator values as the whole cluster.

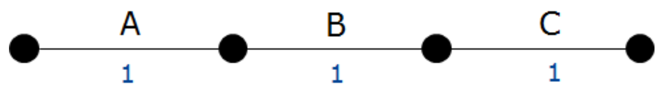

Fig. 3. Investment item indicator values

3. Assessment methodology

The methodology consists in a number of steps that must be accomplished, as presented in Fig. 4.

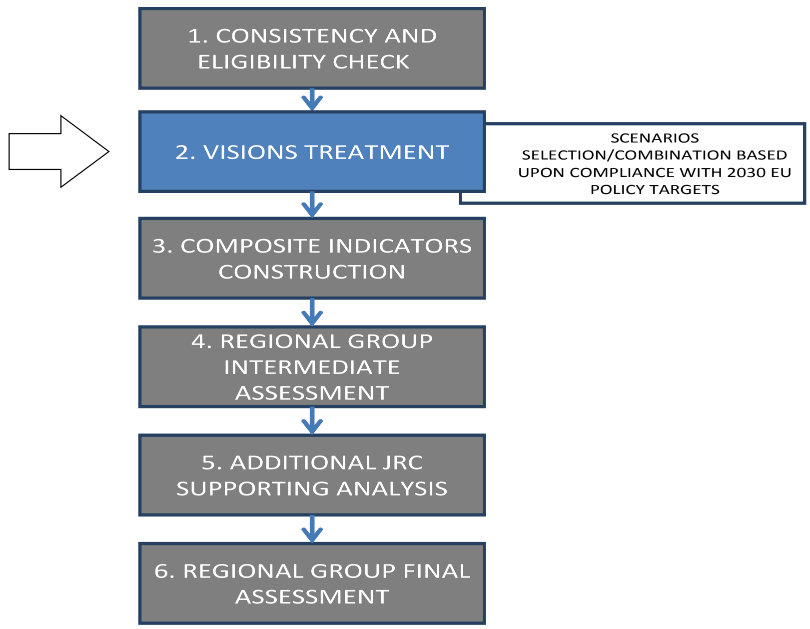

Fig. 4. Assessment Methodology

The first step entails a data consistency check and a compliance check of the proposed projects. Projects of common interest shall meet the following general criteria:

- the project is necessary for at least one of the energy infrastructure priority corridors and areas;
- for electricity transmission, the project increases the grid transfer capacity, or the capacity available for commercial flows, at the border with one or several other borders, or at any other relevant cross-section of the same transmission corridor having the effect of increasing this cross-border grid

transfer capacity, by at least 500 MW compared to the situation without commissioning of the project.

For steps 2-4 is needed a cost benefit analysis that contains a number of different cases to be calculated for each candidate project. In particular, there are considered 4 "visions", with the characteristics presented in Fig. 5.

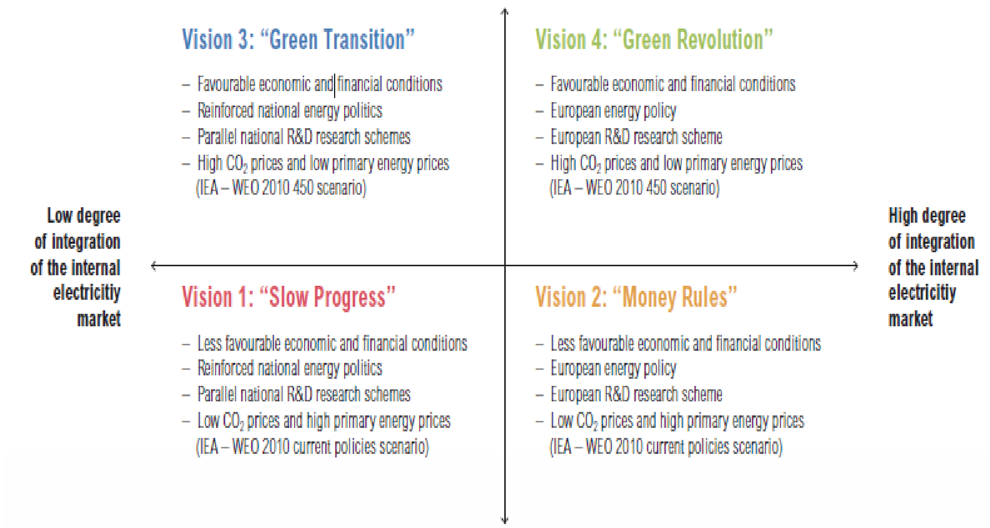

Fig. 5. Overview of the four Visions used in cost benefit analysis

The four visions differ mainly with respect to [1]:

- Fuel and CO2 prices favour coal in Visions 1 and 2 and gas in Visions 3 and 4.
- The consistency of the generation mix development strategy: Visions 1 and 3 build from the bottom-up on each country's energy policy; Visions 2 and 4 assume a top-down approach, with a more harmonized European integration.

The difference between the two Visions (parallel to the one between Visions 3 and 4) essentially lies in the higher degree of EU policy integration, determining a higher level of interconnection which is reflected in the better price alignment across Member States.

As the PCIs are selected on the basis of the benefit for the entire EU, the configurations/visions explored will be those that are more consistent with EU policies and targets. On this basis many of the configurations/visions will have a lower significance and some will not be examined. For electricity projects, Visions 1 and 2 are scenarios of non-compliance to the EU's 2030 environmental policy goals [2]. Therefore, in the current methodology these scenarios are

disregarded and the focus is placed on a combination of Visions 3 and 4, i.e. the ones conforming to EU policy targets.
The cost benefit indicators that are monitored using this methodology are [3-4]:

- Socio-Economic Welfare (SEW)
- Renewable Energy Sources (RES) integration
- Change in technical Network Losses
- Change in CO2 Emissions
- Contribution to network Resilience
- Contribution to network Flexibility

4. Calculation example

For the calculation example we applied the cost benefit analysis on a group of projects, obtaining 33 indicators [4].

Table 1

Group indicators resulted from the cost benefit analysis

	B2 SEW	B3 RES	B4 losses	B5 CO2	B6 resilience	B7 flexibility	B1 SoS	Cost
1	40	20000	5000	-690	3	3	0	300
2	320	1095000	4000	-1550	1	3	0	1130
3	21	0	-16500	-61.5	1	3	0	21.5
4	300	0	-170000	55.5	2	3	0	150
5	5.5	0	-3300	0	1	3	0	60
6	345	3900000	1250000	0	2	3	0	3950
7	390	2350000	440000	-2200	2	4	0	1750
8	90	0	20000	0	1	4	0	600
9	66	2000	-41000	-100	3	3	0	300
10	65	1085000	-78000	-175	3	4	0	396
11	60	195000	130000	-1000	3	3	0	510
12	50	70000	-165000	-1100	3	3	0	205
13	46.5	0	-15500	-109.5	1	3	0	500
14	315	2300000	560000	-1600	2	5	0	2250
15	43	92500	8900	-140	3	3	40.5	21
16	320	4250000	320000	-1300	2	2	0	90
17	425	5350000	545000	-1650	2	2	0	165
18	195	1650000	215000	-1020	1	4	0	685
19	375	1900000	1005000	-3100	3	4	0	2500
20	135	415000	56500	-1150	3	3	0	245
21	125	385000	120000	-840	3	3	0	620

22	260	1250000	210000	-1550	2	5	0	650
23	175	1650000	220000	-840	1	4	0	1050
24	290	2350000	845000	-1650	2	4	0	1700
25	280	2300000	290000	-1550	1	4	0	785
26	255	2000000	385000	-1600	2	4	0	1800
27	195	1650000	155000	-1020	1	4	0	350
28	90	285000	-10800	-755	2	3	0	190
29	375	4700000	545000	-1450	6	4	0	2075
30	50	445000	300000	-280	3	5	0	2650
31	290	2350000	845000	-1650	2	4	0	2200
32	300	0	900000	-1150	2	3	0	2350
33	175	1900000	0	-525	0	0	0	1300

For each indicator, compute descriptive statistics: min, max, average, standard deviation, skewness coefficient and kurtosis.

Table 2

Compute descriptive statistics

Descriptive Statistics	B2 SEW	B3 RES	B4 losses	B5 CO2	B6 resilience	B7 flexibility	B1 SoS	Cost
missing values	0	0	0	0	0	0	0	0
min	5.5	0	-170000	-3100	0	0	0	21
max	425	5350000	1250000	55.5	6	5	40.5	3950
mean	196.0	1392106	268918.2	-962.1	2.09	3.4	1.23	1016.62
std	129.85	1491200	362818	750.32	1.10	0.97	7.05	987.16
skewness	0.08	1.10	1.13	-0.53	1.16	-1.12	5.74	1.14
kurtosis	-1.46	0.64	0.54	0.40	3.70	3.71	33.00	0.77
skew>2 & kurt>3.5	0	0	0	0	0	0	1	0

In order to aggregate 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 ⇒ positive direction (coded by + 1)
- ✓ The smaller the better ⇒ negative direction (coded by - 1)

We reverse the indicators with negative direction. So, all the indicators will have the same direction (correlations are positive)

Table 3

Correlation coefficients between indicators

CORRELATIONS	B2	B3	B4	B5	B6	B7	Cost
B2 SEW	1.00	0.77	0.69	0.69	0.05	0.10	0.52
B3 RES	0.77	1.00	0.60	0.48	0.14	0.03	0.39
B4 losses	0.69	0.60	1.00	0.52	0.14	0.24	0.83
B5 CO2	0.69	0.48	0.52	1.00	0.16	0.26	0.33
B6 resilience	0.05	0.14	0.14	0.16	1.00	0.23	0.15
B7 flexibility	0.10	0.03	0.24	0.26	0.23	1.00	0.32
Cost	0.52	0.39	0.83	0.33	0.15	0.32	1.00

By applying the min-max transformation, the indicators will be normalized

$$newvalue = \frac{oldvalue - \min}{\max - \min} * direction + 0{,}5 * (1 - direction) \qquad (9)$$

Table 4

Normalised indicator values applying min-max transformation

Direction	1	1	1	-1	1	1	1
Indicators	B2 SEW	B3 RES	B4 losses	B5 CO2	B6 resilience	B7 flexibility	Cost
1	0.082	0.004	0.123	0.236	0.500	0.600	0.071
2	0.750	0.205	0.123	0.509	0.167	0.600	0.282
3	0.037	0.000	0.108	0.037	0.167	0.600	0.000
4	0.702	0.000	0.000	0.000	0.333	0.600	0.033
5	0.000	0.000	0.117	0.018	0.167	0.600	0.010
6	0.809	0.729	1.000	0.018	0.333	0.600	1.000
7	0.917	0.439	0.430	0.715	0.333	0.800	0.440
8	0.201	0.000	0.134	0.018	0.167	0.800	0.147
9	0.144	0.000	0.091	0.049	0.500	0.600	0.071
10	0.142	0.203	0.065	0.073	0.500	0.800	0.095
11	0.130	0.036	0.211	0.334	0.500	0.600	0.124
12	0.106	0.013	0.004	0.366	0.500	0.600	0.047
13	0.098	0.000	0.109	0.052	0.167	0.600	0.122
14	0.738	0.430	0.514	0.525	0.333	1.000	0.567

15	0.089	0.017	0.126	0.062	0.500	0.600	0.000
16	0.750	0.794	0.345	0.430	0.333	0.400	0.018
17	1.000	1.000	0.504	0.540	0.333	0.400	0.037
18	0.452	0.308	0.271	0.341	0.167	0.800	0.169
19	0.881	0.355	0.827	1.000	0.500	0.800	0.631
20	0.309	0.078	0.160	0.382	0.500	0.600	0.057
21	0.285	0.072	0.204	0.284	0.500	0.600	0.152
22	0.607	0.234	0.268	0.509	0.333	1.000	0.160
23	0.404	0.308	0.275	0.284	0.167	0.800	0.262
24	0.678	0.439	0.715	0.540	0.333	0.800	0.427
25	0.654	0.430	0.324	0.509	0.167	0.800	0.194
26	0.595	0.374	0.391	0.525	0.333	0.800	0.453
27	0.452	0.308	0.229	0.341	0.167	0.800	0.084
28	0.201	0.053	0.112	0.257	0.333	0.600	0.043
29	0.881	0.879	0.504	0.477	1.000	0.800	0.523
30	0.106	0.083	0.331	0.106	0.500	1.000	0.669
31	0.678	0.439	0.715	0.540	0.333	0.800	0.555
32	0.702	0.000	0.754	0.382	0.333	0.600	0.593
33	0.404	0.355	0.120	0.184	0.000	0.000	0.326

Following normalization of the indicators, we build one composite indicator per each policy criterion using Principal Component Analysis [5], [6] that allows identifying uncorrelated variables explaining most of the variation of the correlated observed variables. Components are ranked based on explanatory power: the first one explains the greatest fraction of indicator variance, and then comes the second, etc. [7]

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

$$Sustainability = 0{,}69 * PC_1 + 0{,}178 * PC_2 + 0{,}132 * PC_3 \tag{10}$$

Table 5

Criterion B Sustainability

Extraction: Principal components (PC)		
PC	Variance (% total)	Cumulative variance explained (%)
1	69.0	69.0
2	17.8	86.8
3	13.2	100.0

- Security of Supply: two indicators (Resilience and Flexibility)

$$SoS = 0{,}616 * PC_1 + 0{,}384 * PC_2 \quad (11)$$

Table 6

Criterion B Security of Supply

Extraction: Principal components		
PC	Variance (% total)	Cumulative variance explained (%)
1	61.6	61.6
2	38.4	100

Table 7

Ranking the indicators

	Indicator			Ranking		
Id	Market Integration	Sustainability	Security of Supply	Market Integration	Sustainability	Security of Supply
1	0.0822	0.1777	0.4515	31	25	5
2	0.7497	0.3613	0.2182	6	15	29
3	0.0369	0.0711	0.2182	32	29	29
4	0.7020	0.0000	0.3313	9	33	18
5	0.0000	0.0655	0.2182	33	32	29
6	0.8093	0.6383	0.3313	5	7	18
7	0.9166	0.6611	0.3640	2	6	14
8	0.2014	0.0701	0.2509	22	30	24
9	0.1442	0.0670	0.4515	24	31	5
10	0.1418	0.1092	0.4842	25	26	3
11	0.1299	0.2742	0.4515	26	19	5
12	0.1061	0.1910	0.4515	27	24	5
13	0.0977	0.0762	0.2182	29	28	29
14	0.7378	0.5988	0.3967	8	8	12
15	0.0894	0.0951	0.4515	30	27	5
16	0.7497	0.5618	0.2987	6	9	22
17	1.0000	0.7351	0.2987	1	2	22
18	0.4517	0.3689	0.2509	16	14	24
19	0.8808	0.9749	0.4842	3	1	3
20	0.3087	0.2859	0.4515	20	18	5
21	0.2849	0.2510	0.4515	21	20	5

22	0.6067	0.4373	0.3967	14	13	12
23	0.4041	0.3383	0.2509	18	17	24
24	0.6782	0.7034	0.3640	11	3	14
25	0.6544	0.5062	0.2509	13	12	24
26	0.5948	0.5297	0.3640	15	11	14
27	0.4517	0.3505	0.2509	16	16	24
28	0.2014	0.1948	0.3313	22	23	18
29	0.8808	0.6770	0.8378	3	5	1
30	0.1061	0.2265	0.5169	27	22	2
31	0.6782	0.7034	0.3640	11	3	14
32	0.7020	0.5393	0.3313	9	10	18
33	0.4041	0.2297	0.0000	18	21	33

5. Conclusions

In this paper is presented the development of the methodology that poses many challenges due to the uniqueness of the exercise, the heterogeneity of the projects proposed, the large quantity of data and cases calculated etc.

This methodology sets out ENTSO-E’s criteria for the assessment of costs and benefits of a transmission project, all stemming from European policies of market integration, security of supply and sustainability. It describes the approach both for identifying transmission projects and for measuring each of the cost and benefit indicators. In order to ensure a full assessment of all transmission benefits, some of the indicators are monetized, while others are measured through physical units such as tons or kWh.

This set of common indicators forms a complete and solid basis for project evaluation and for the PCI selection process. With a multi-criteria approach, the projects can be ranked by the Member States in the groups foreseen by Regulation 347/2013. Art 4.2.4 states: « each Group shall determine its assessment method on the basis of the aggregated contribution to the criteria […] this assessment shall lead to a ranking of projects for internal use of the Group. Neither the regional list nor the Union list shall contain any ranking, nor shall the ranking be used for any subsequent purpose ».

Projects of Common Interest are of particular importance for Europe's energy system due to the multiple benefits that they provide.

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