A modelling approach for integrated energy and land-use planning

Case Study of the Great Montreal

Communauté métropolitaine de Montréal

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Sheraton Hotel, 3-7 April 2017

Presentation Plan

- **1. Context**
  - 1.1 Problem
  - 1.2 Study Area
  - 1.3 Objectives of the Project
- **2. Methodology**
- **3. Objective 1: Optimization**
  - 3.1 Scenario building
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  - 3.3 GIS
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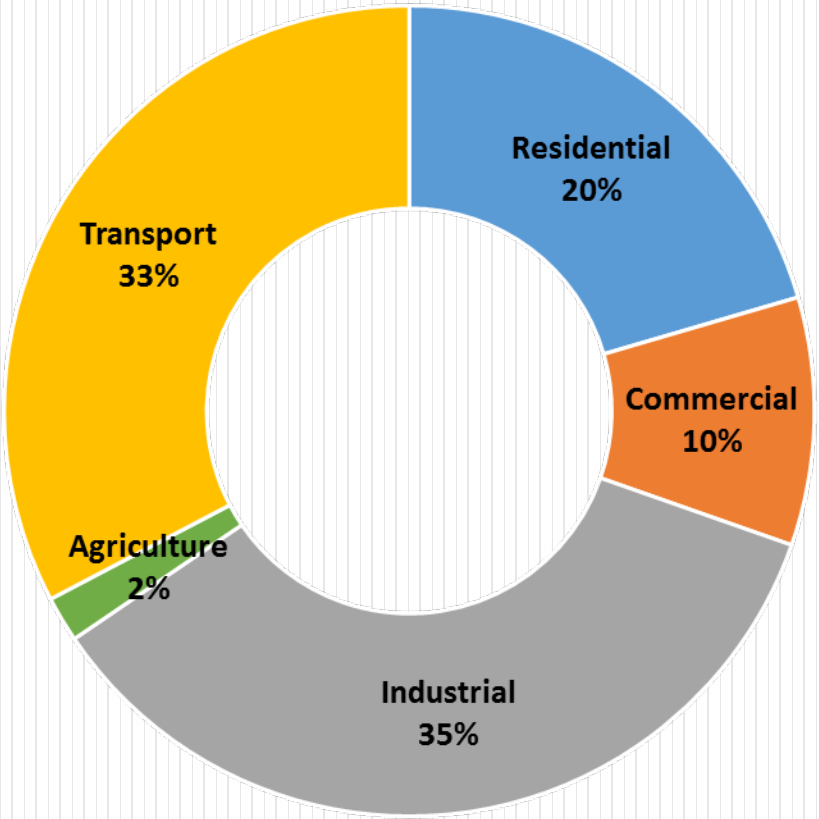
- **4. Objective 2: MCDA**
  - **4.1** Results
  - 4.2 Urban Patterns
  - 4.2 Issues, Criteria and Indicators
  - 4.4 Analysis with PROMÉTHÉE
- **5. Discussion and Conclusion**

1. Context

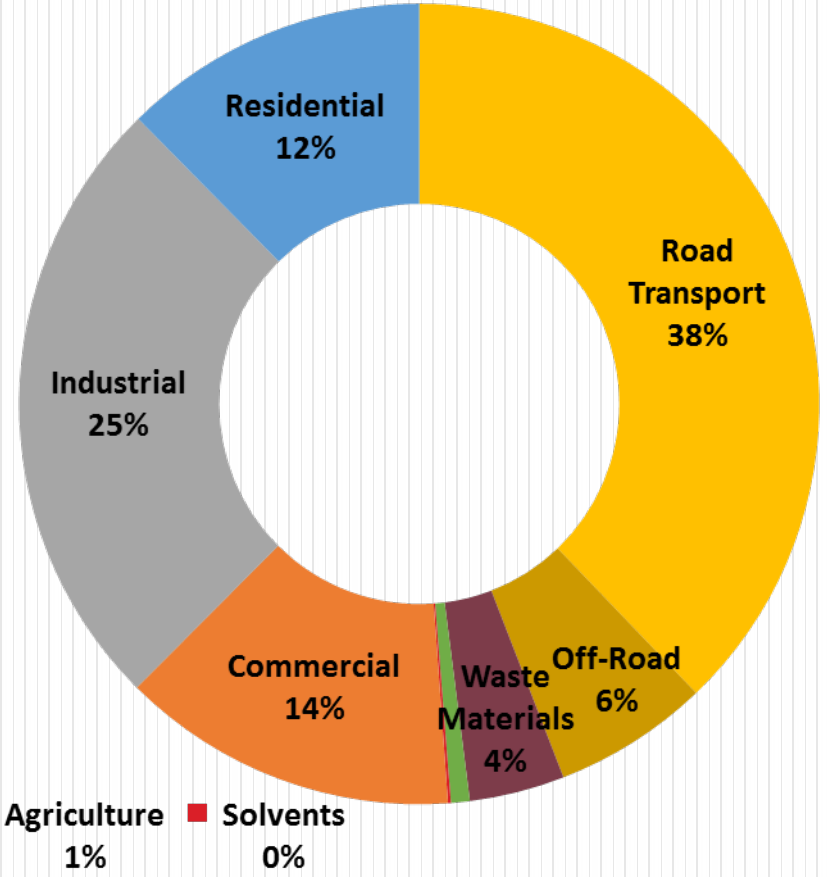
1.1 - Problem

Our energy use depends on the way we use space

Energy use in Quebec



GHG Emissions in the Great Montreal

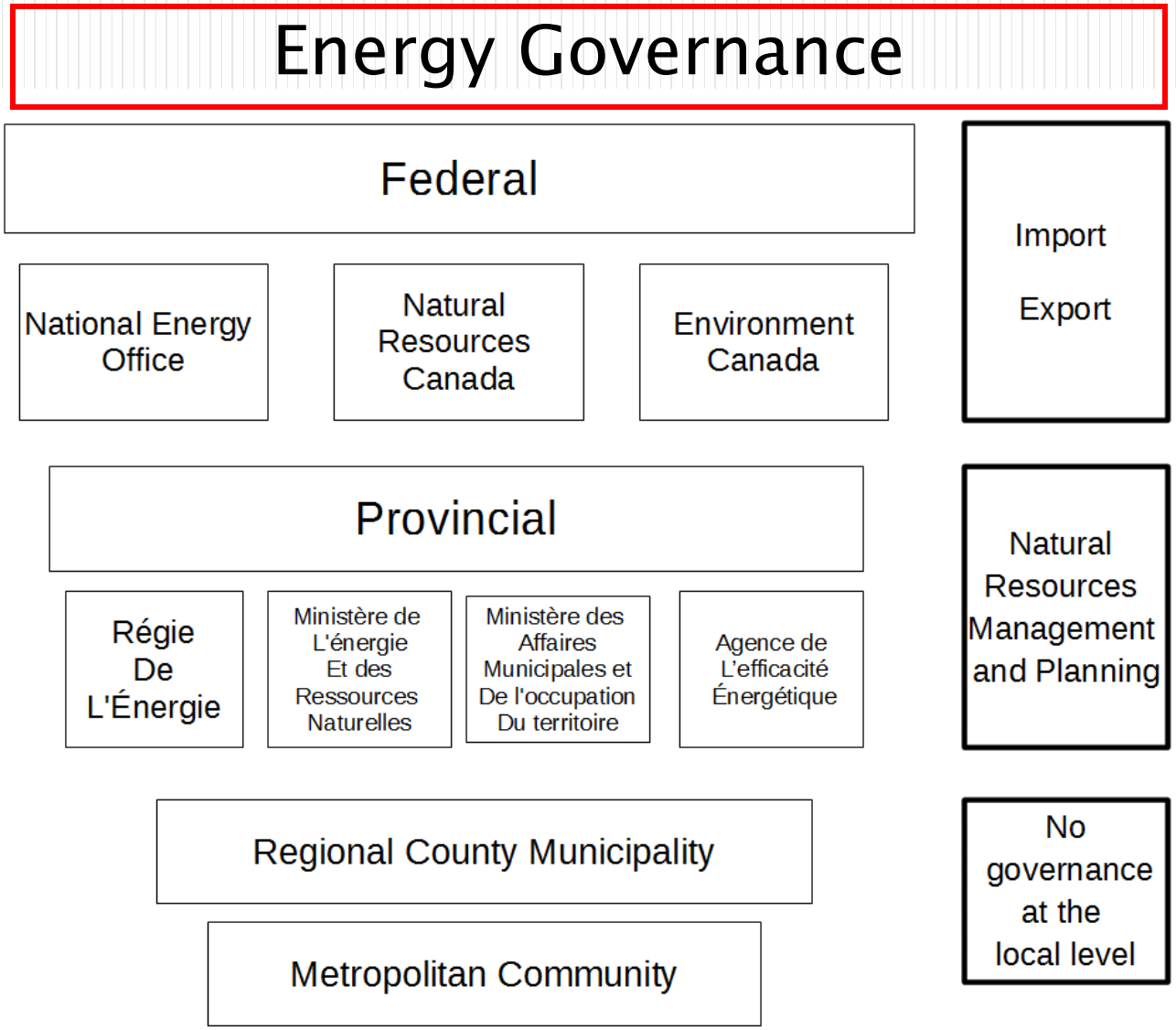


Sources:Brownstone et Golob (2009), Mindali et al (2004), RnCan(2012) & PMAD (CMM, 2010)

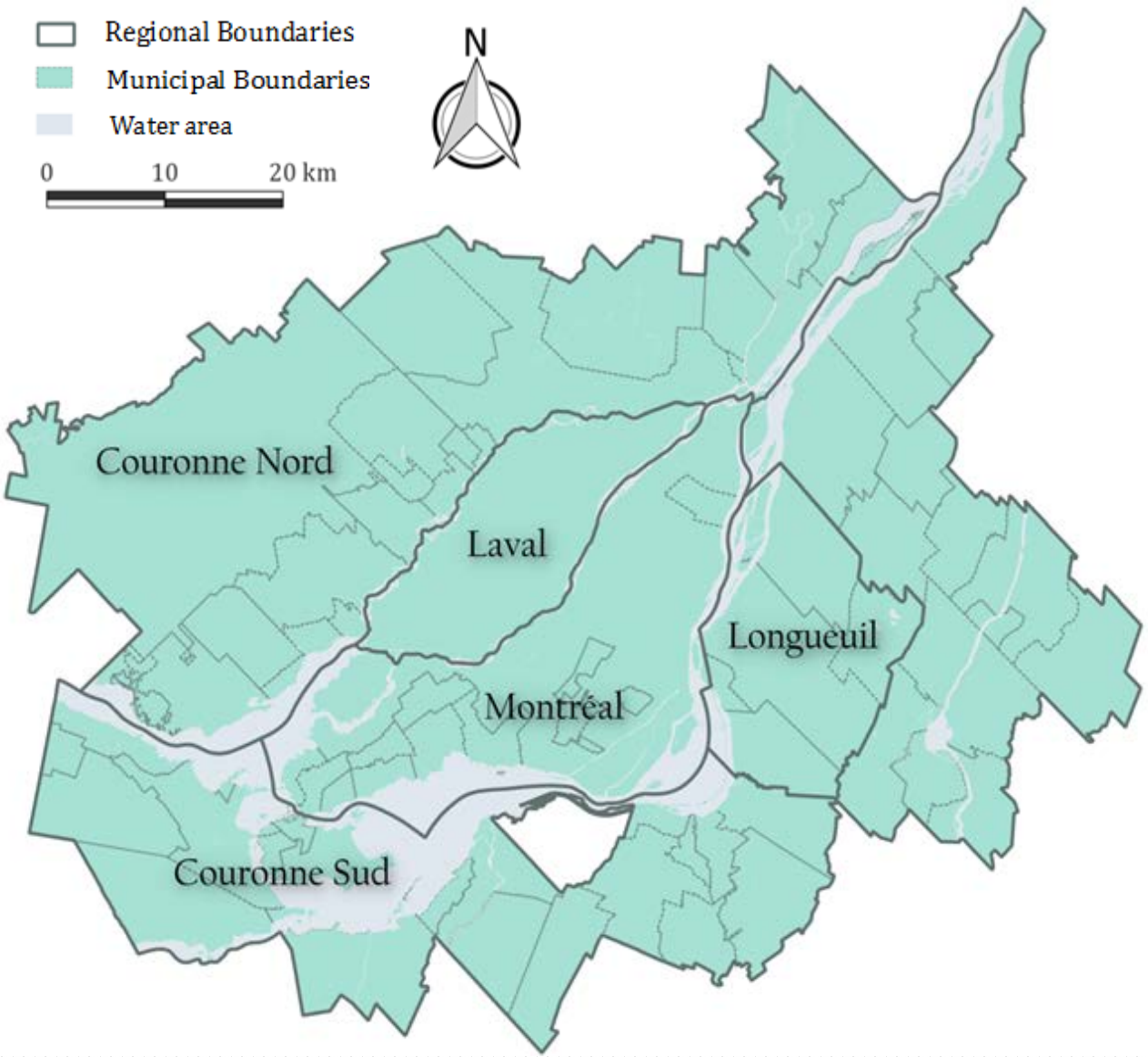
1.1- Problem

Our energy use depends on the way we use space

Brownstone et Golob (2009), Mindali et al (2004)



1.2 - Study Area



- 4360 km^2
- 3 709 045 resident in 2011
- 48% of Quebec population
- 1/3 of industrial activities
- 52% of national GDP
- 2,02 millions jobs in 2014
- 49% of jobs in Quebec

Sources: PMAD (CMM, 2010)
GIS: CMM (2010)- Great Montreal Observatory

1.3 - Objectives of the Project

Create a decision-making aid tool for stakeholders in land-use planning

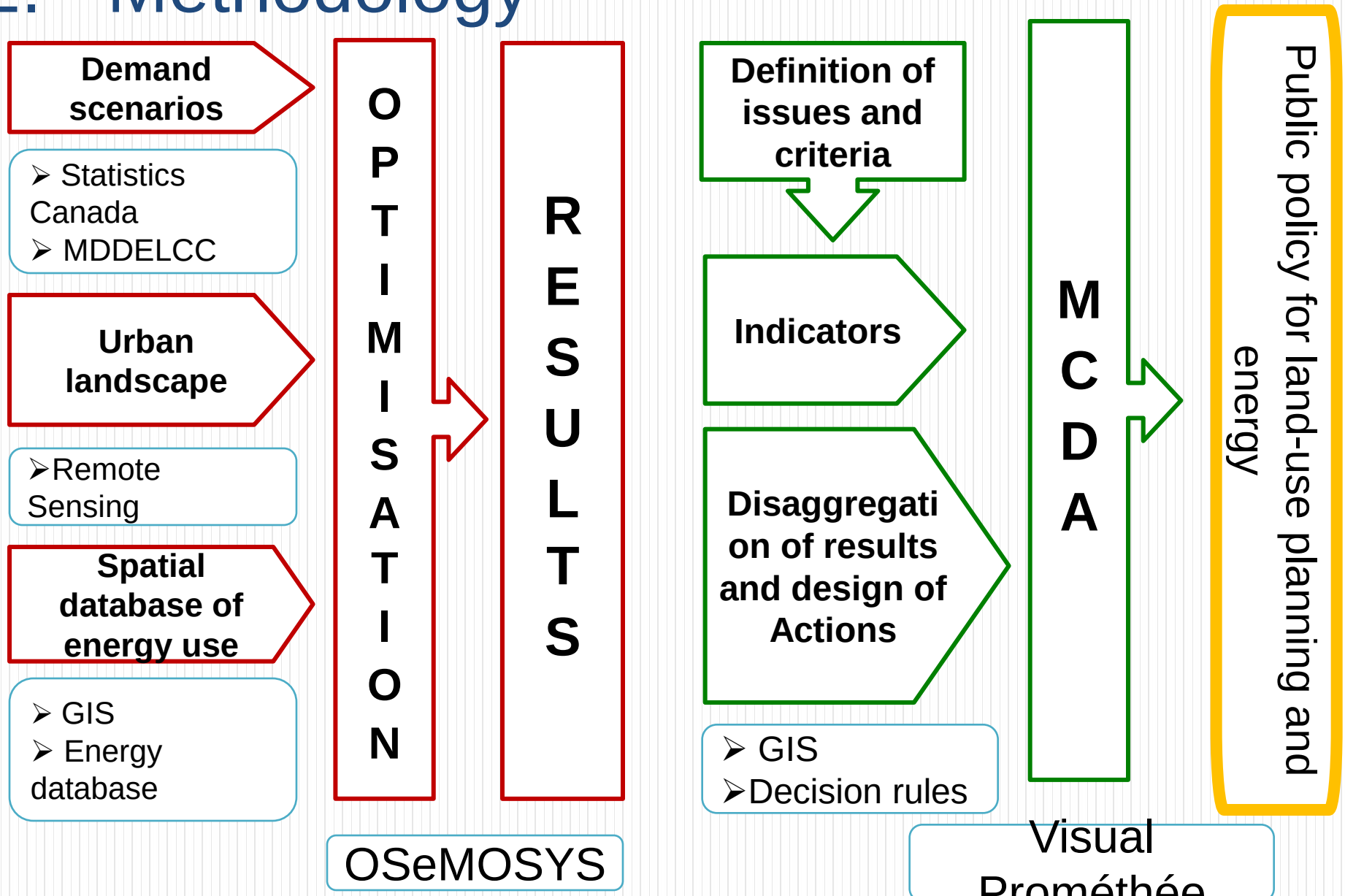
- Objective1:

Design an optimization model to outline links between energy use and land-use planning

- Objective 2:

Measure the impacts of energy choices on issues of sustainable development in land-use planning

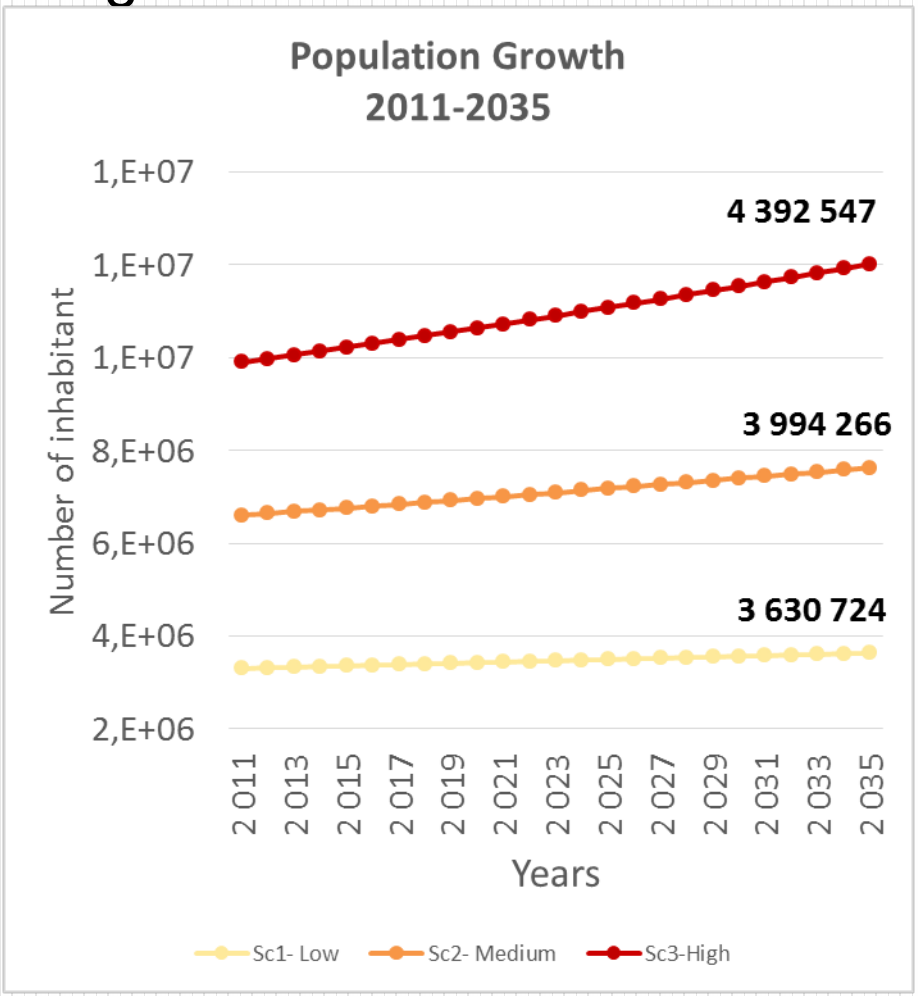
2. - Methodology



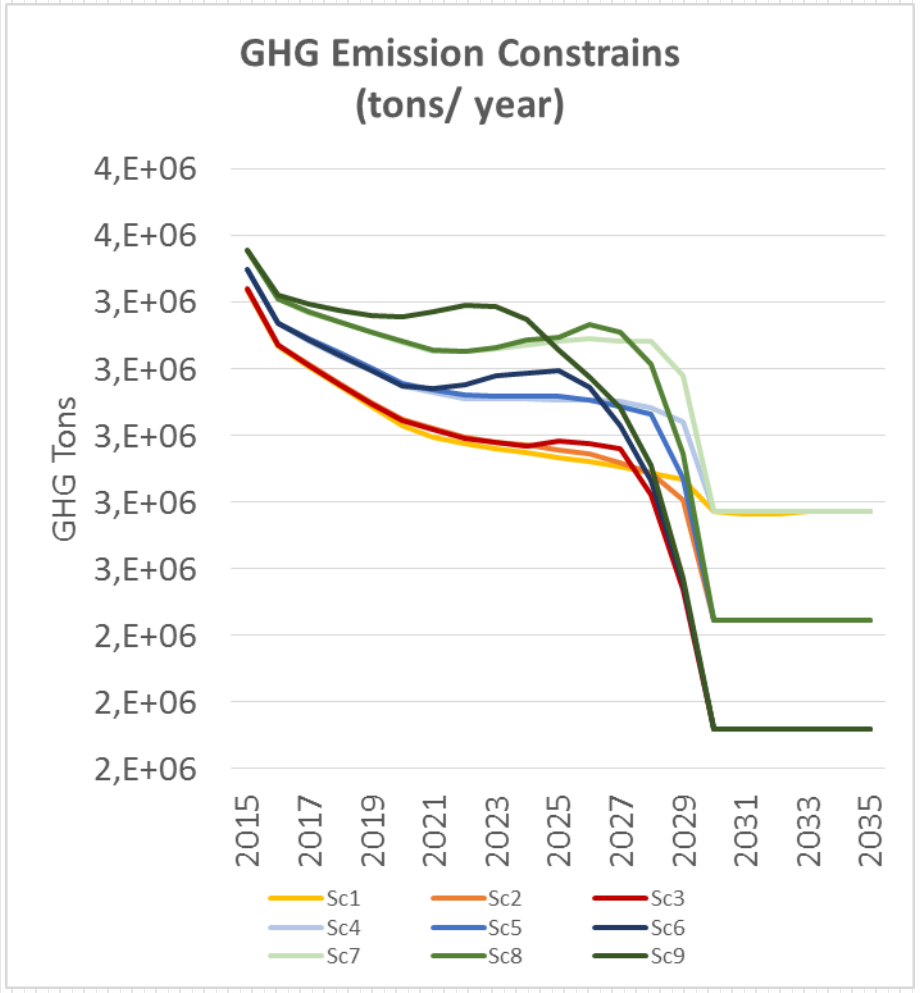
3. Objective 1: OPTIMISATION

3.1- Scenario building

- 3 scenarios of population growth

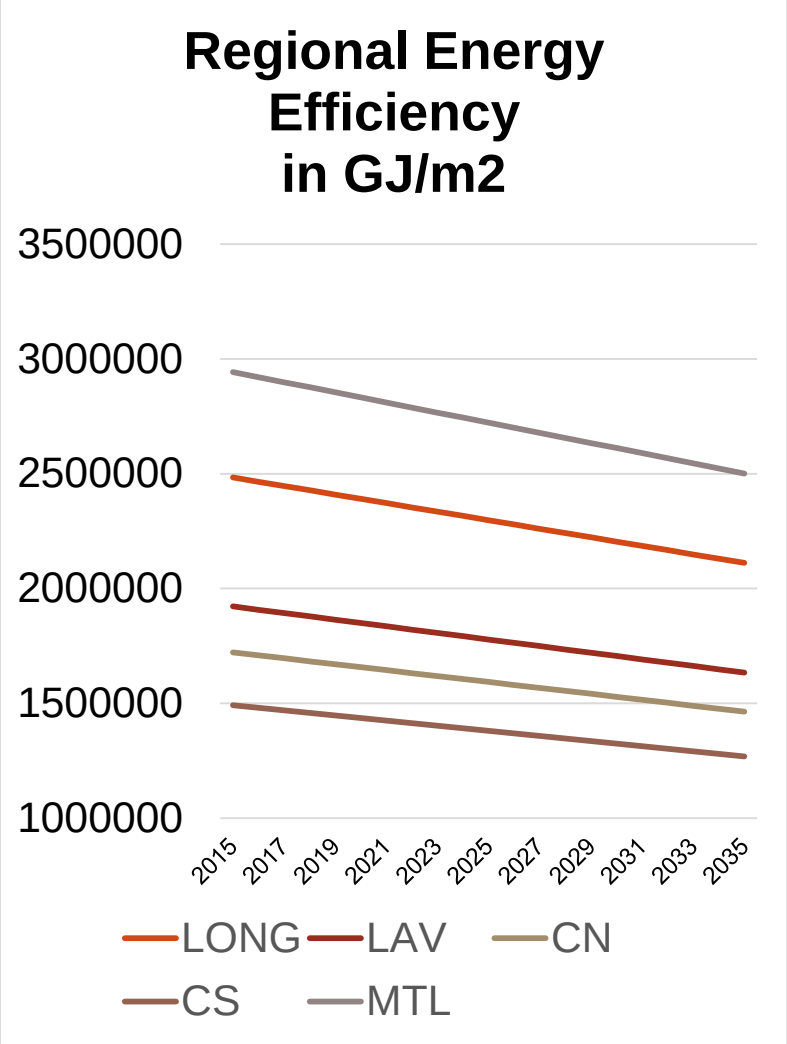


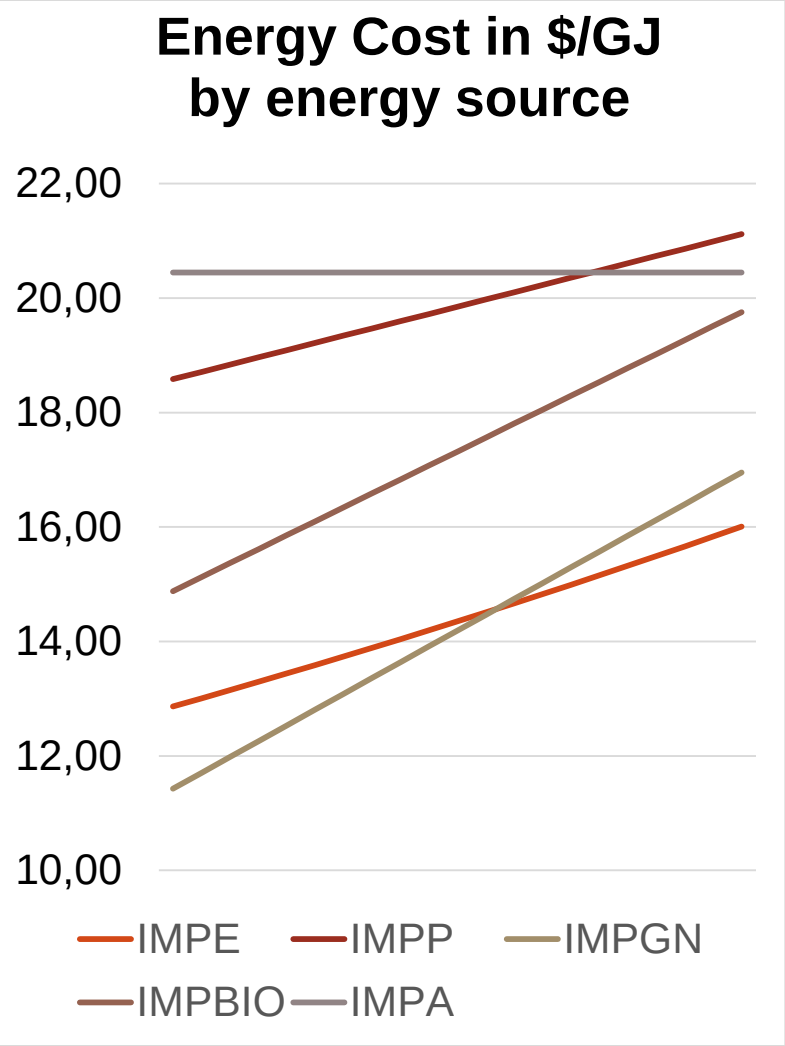
- 3 scenarios of emission constraints



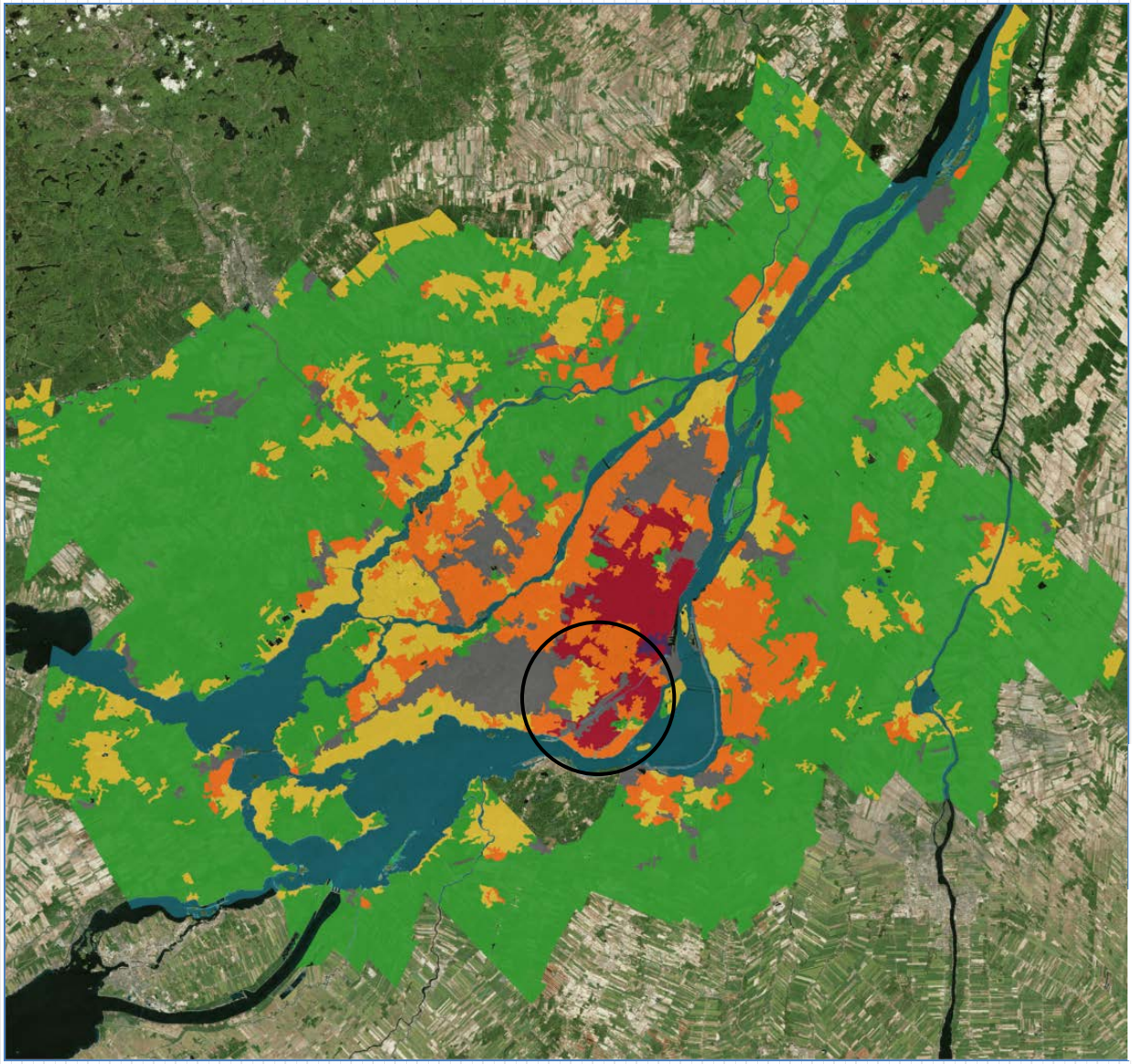
3.1- Scenario building

Constraints in energy efficiency and cost

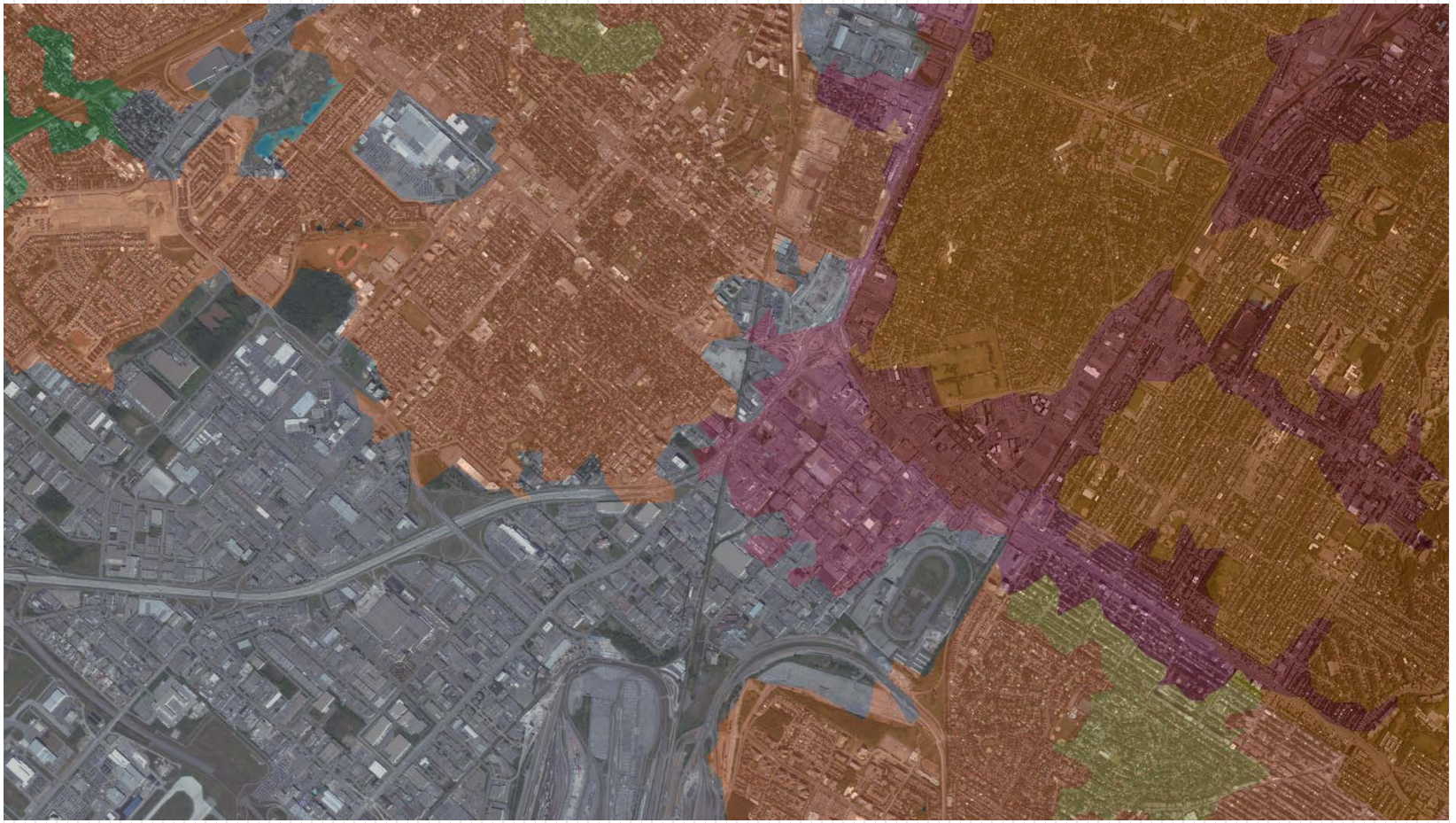




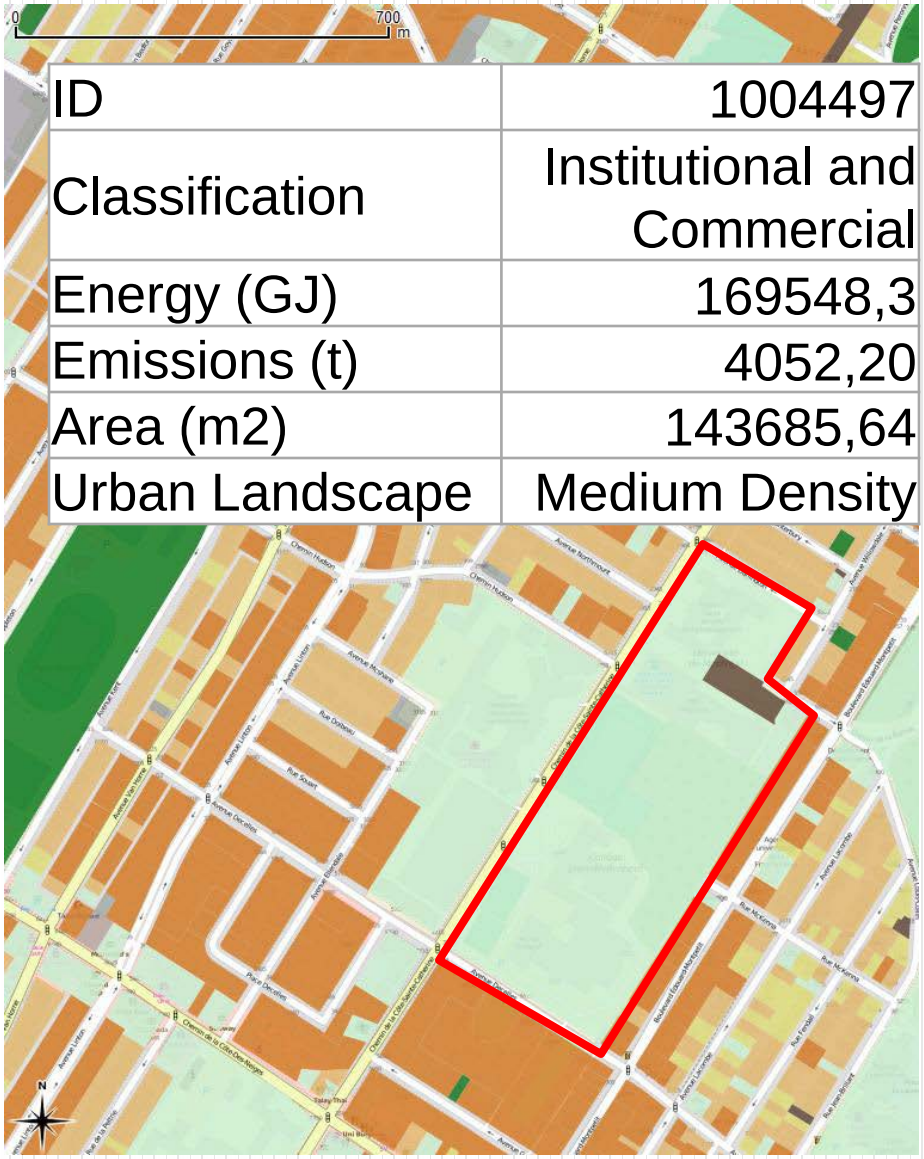
3.2 - Remote sensing: Classification of Urban Landscapes



3.2 - Remote sensing: Classification of Urban Landscapes (zoom in)



3.3 GIS: data by Land-use Unit

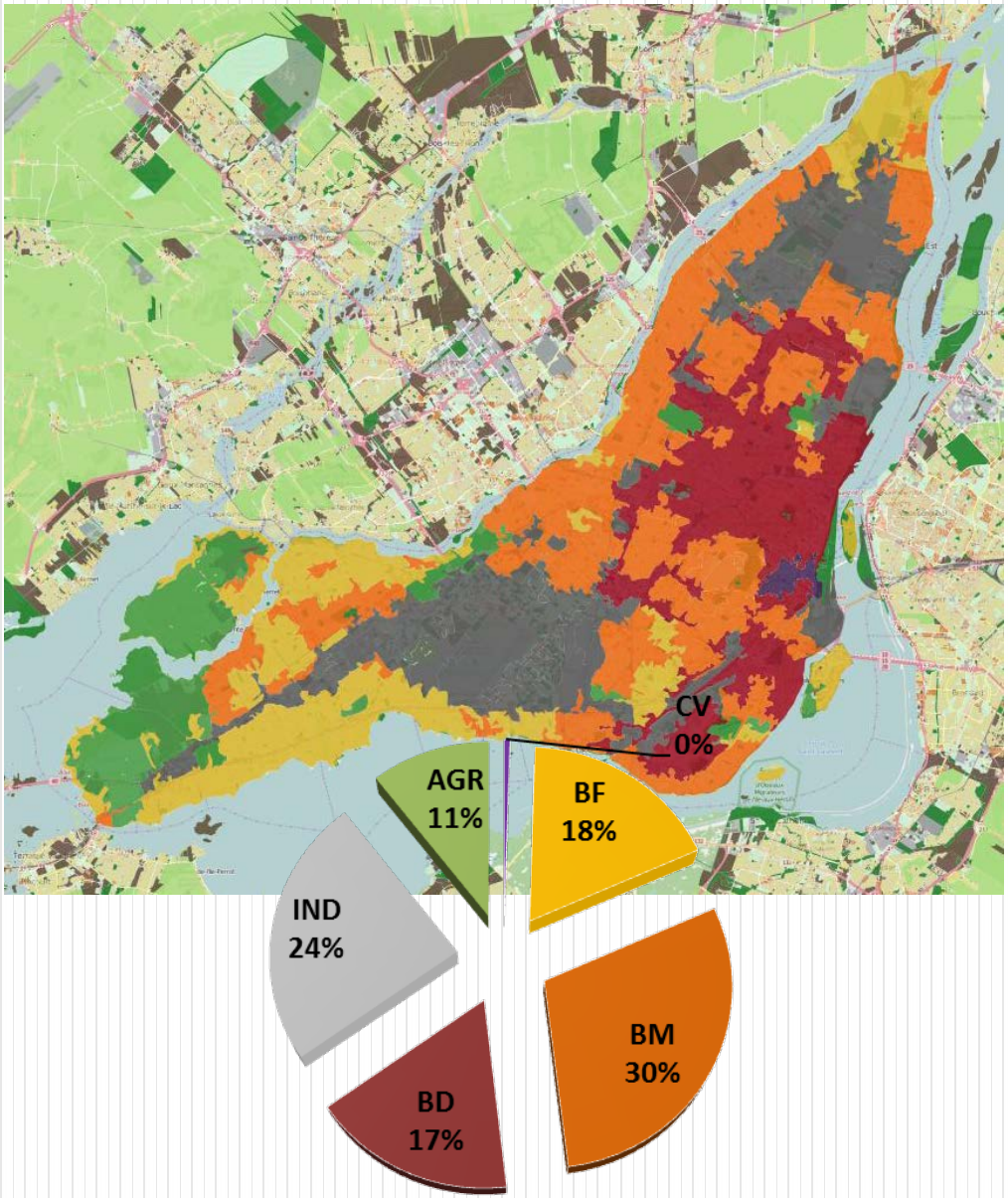


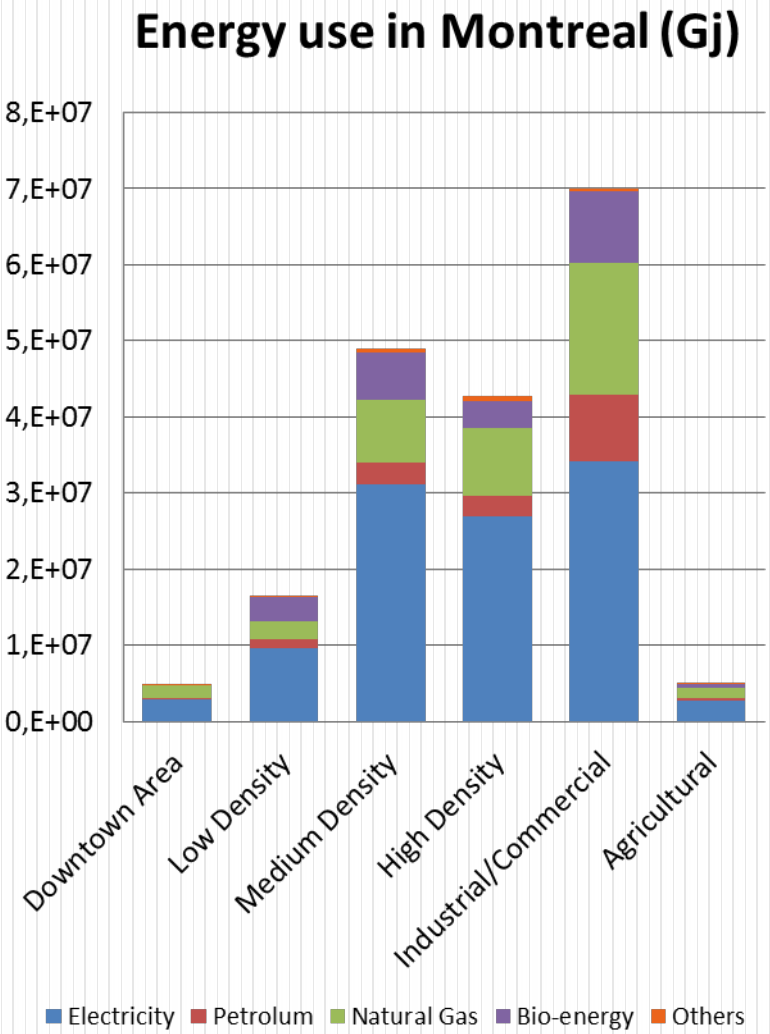
ID	1004497
Classification	Institutional and Commercial
Energy (GJ)	169548,3
Emissions (t)	4052,20
Area (m2)	143685,64
Urban Landscape	Medium Density

	Commercial	
	Energy Intensity (GJ/m2)	GHG Intensity (t/TJ)
Share (%)	***1,18***	***23,9***
Electricity	53,5	0
Natural Gas	40,1	82,5
Petroleum	3,33	10
Other	3,1	7,5
Woods	0	0

Sources: Natural Ressources Canada (2012)
GIS: Observatoire du Grand Montréal

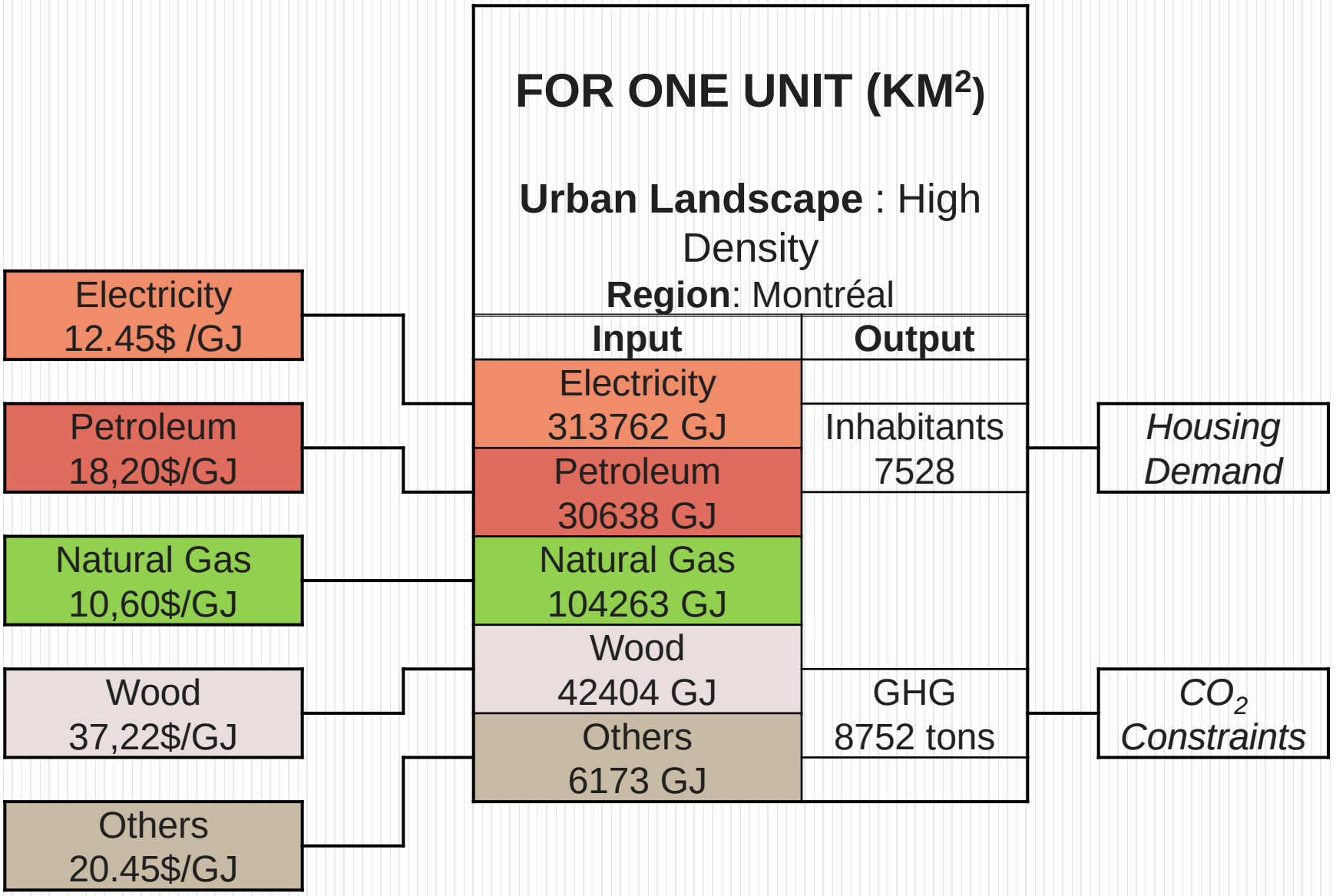
Landscape





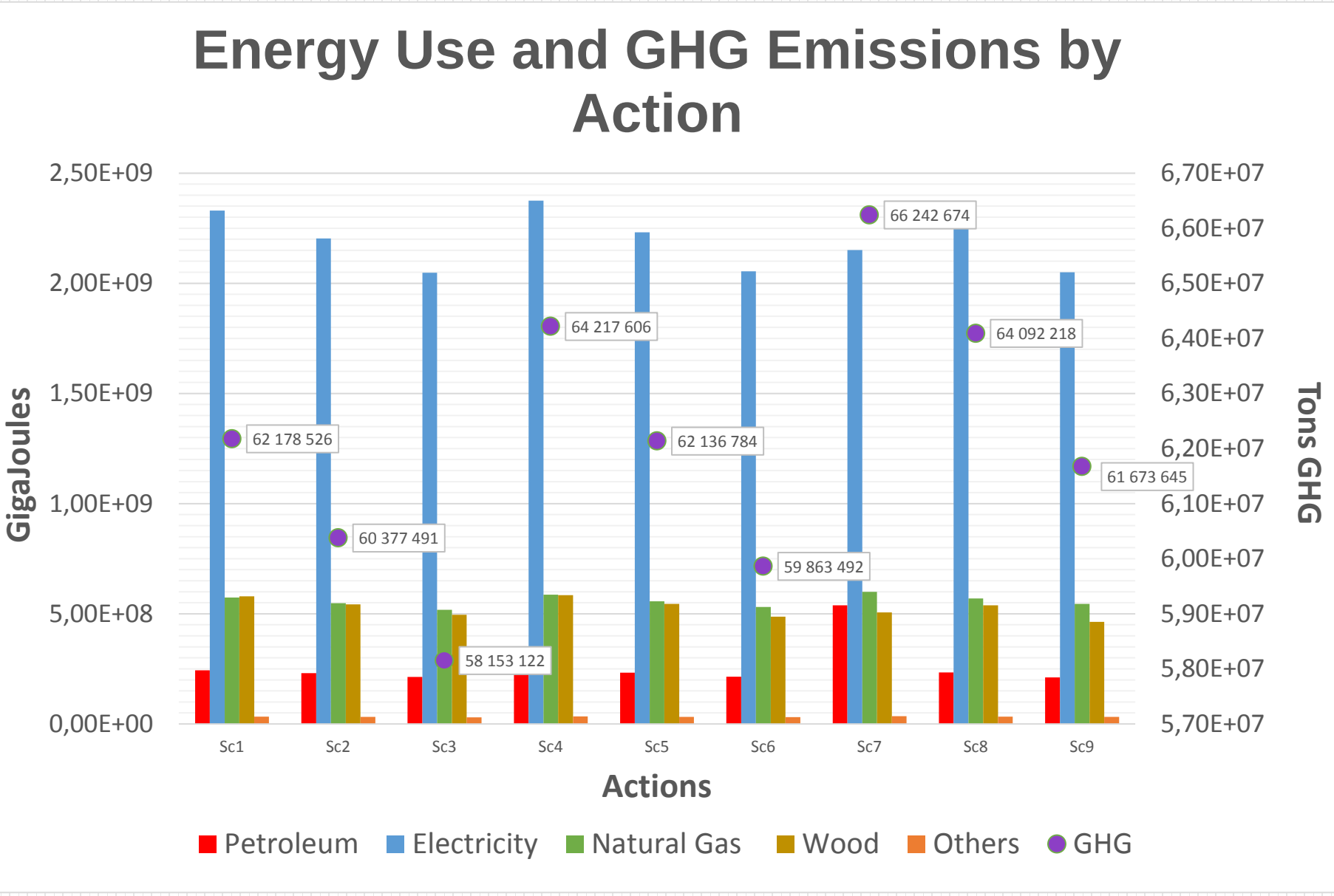
Sources: Natural Ressources Canada (2012)
GIS: Observatoire du Grand Montréal
Landsat 8 (USGS)

3.4 Optimization : Energy Reference System

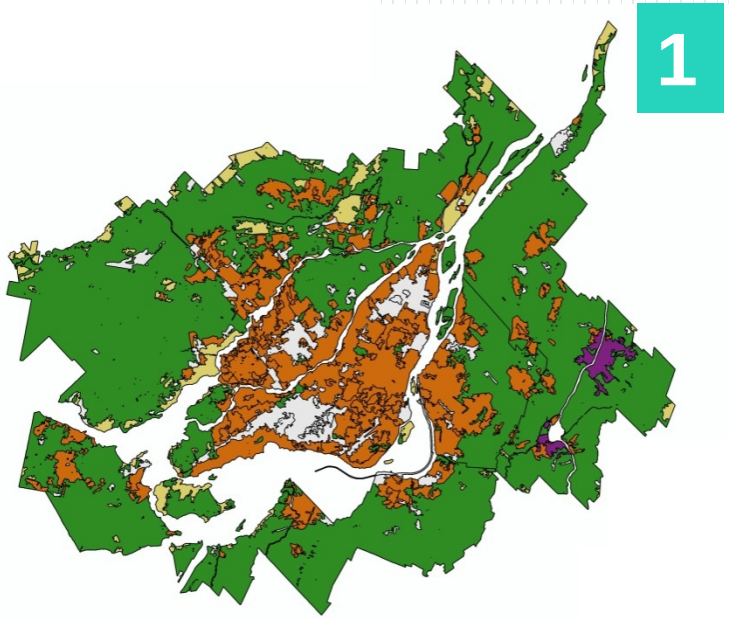


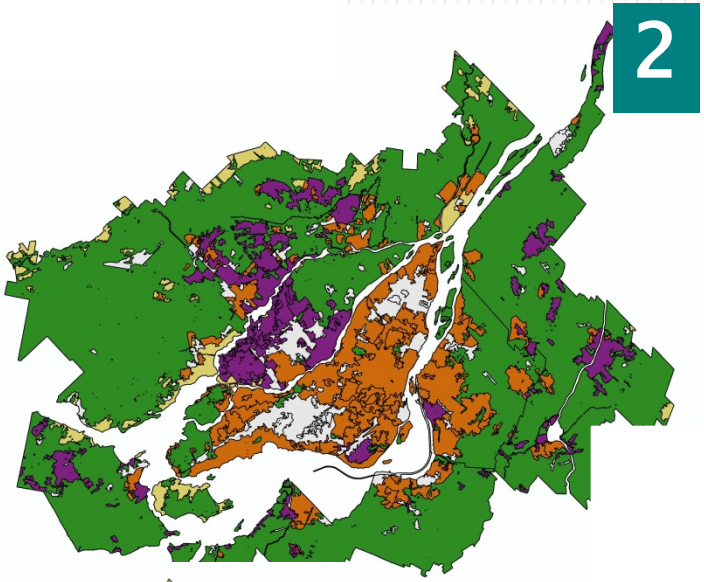
4. Objective 2: MCDA

4.1 - Results

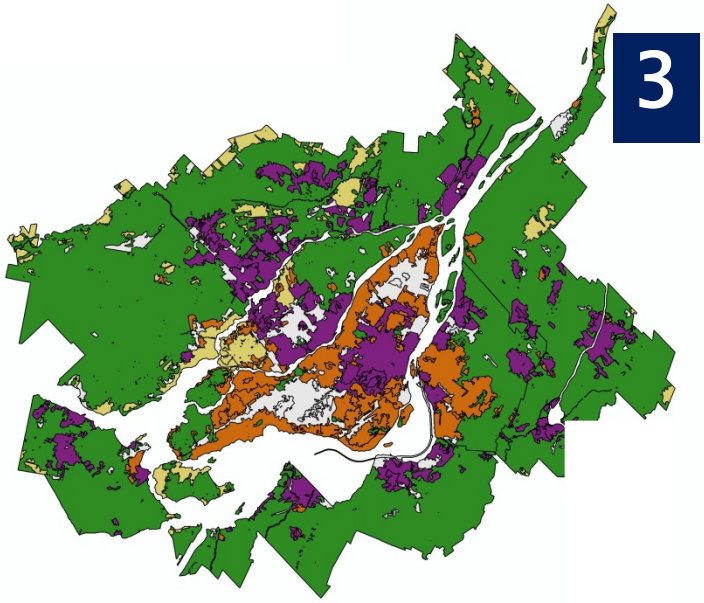

Energy Use and GHG Emissions by Action
GigaJoules
Tons GHG
2,50E+09
2,00E+09
1,50E+09
1,00E+09
5,00E+08
0,00E+00
6,70E+07
6,60E+07
6,50E+07
6,40E+07
6,30E+07
6,20E+07
6,10E+07
6,00E+07
5,90E+07
5,80E+07
5,70E+07
62 178 526
60 377 491
58 153 122
64 217 606
62 136 784
59 863 492
66 242 674
64 092 218
61 673 645
Sc1
Sc2
Sc3
Sc4
Sc5
Sc6
Sc7
Sc8
Sc9
Actions
Petroleum
Electricity
Natural Gas
Wood
Others
GHG

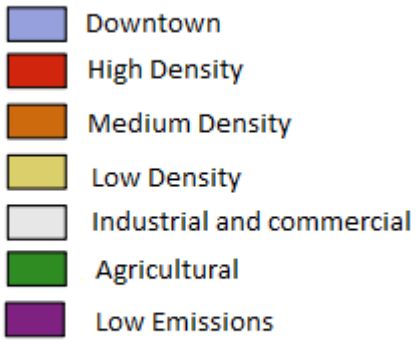
4.2 - Actions: Urban Patterns



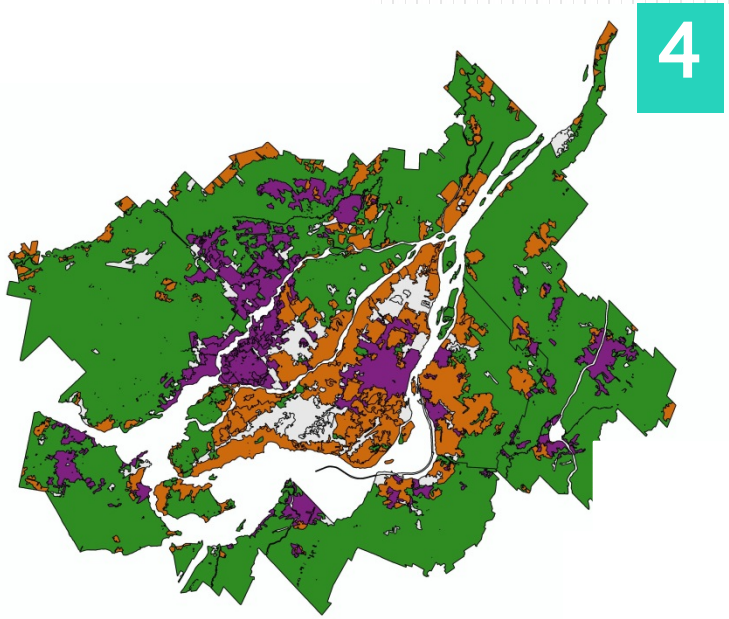


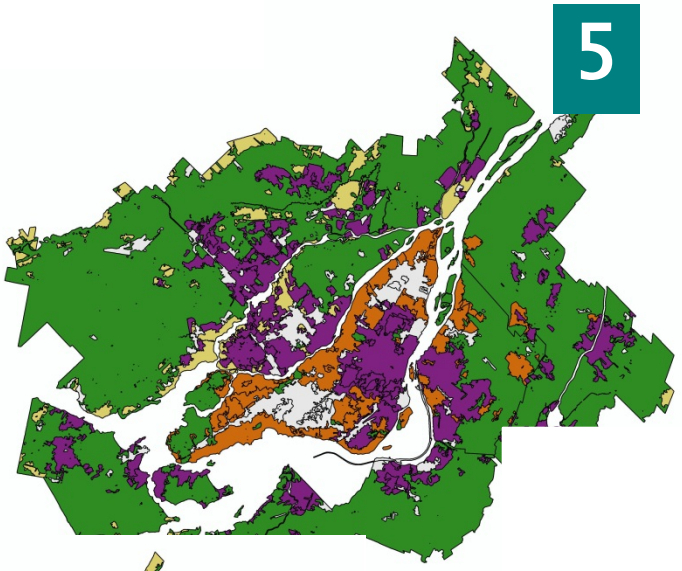
Actions 1-3:
Pop. 0,45%/year,
GHG reductions
15-25-40%



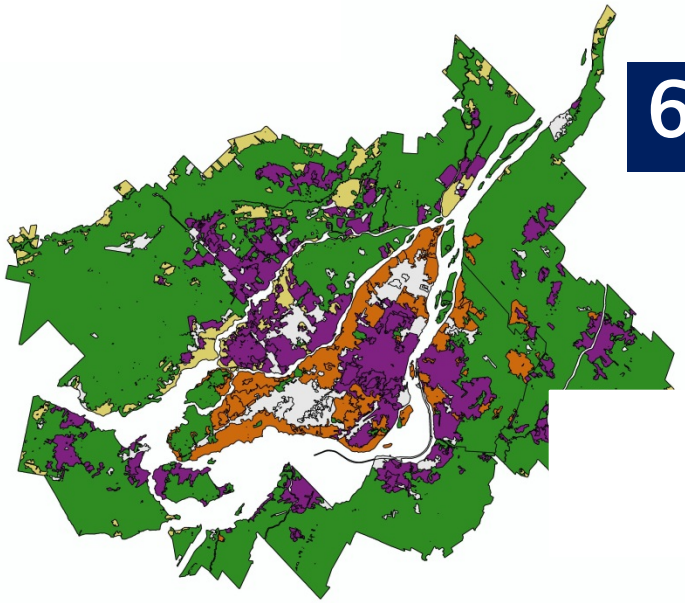


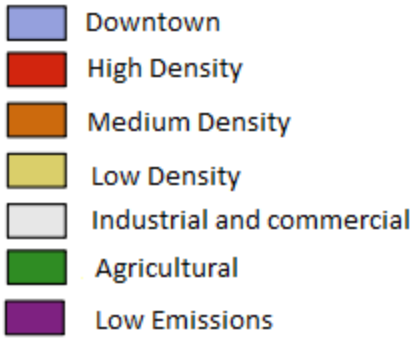
4.2 - Actions: Urban Patterns



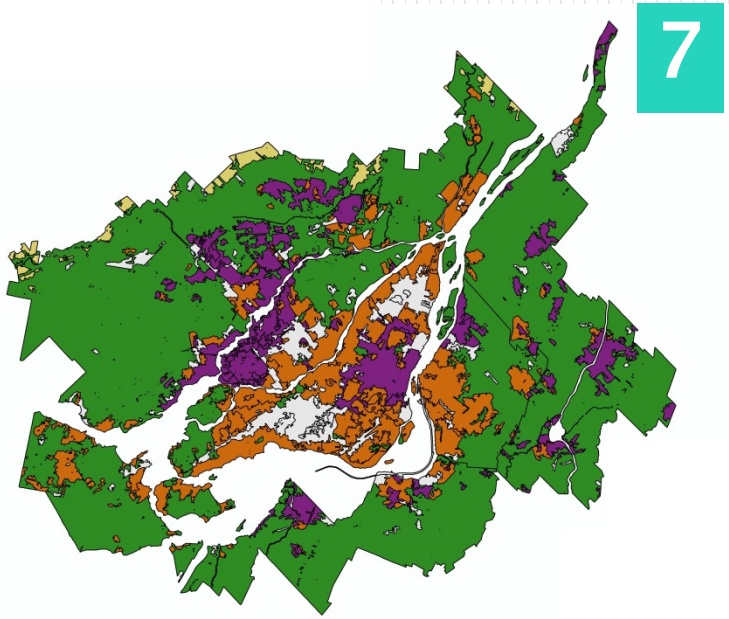


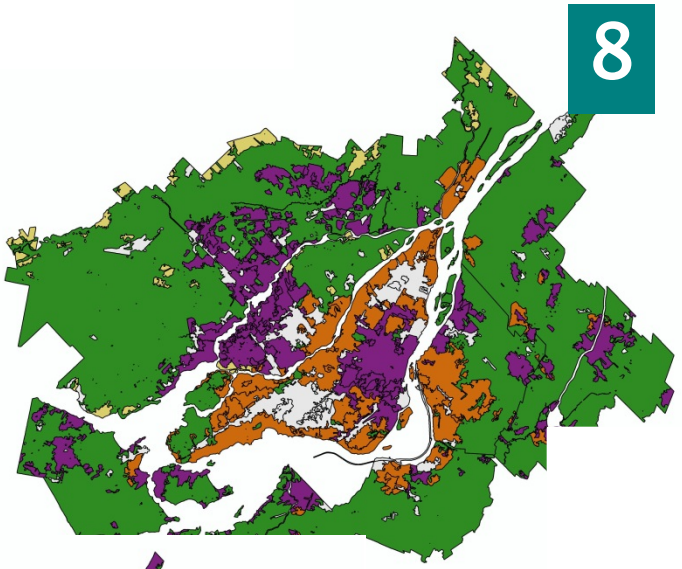
Actions 4-6:
Pop. 0,95%/year,
GHG reductions
15-25-40%



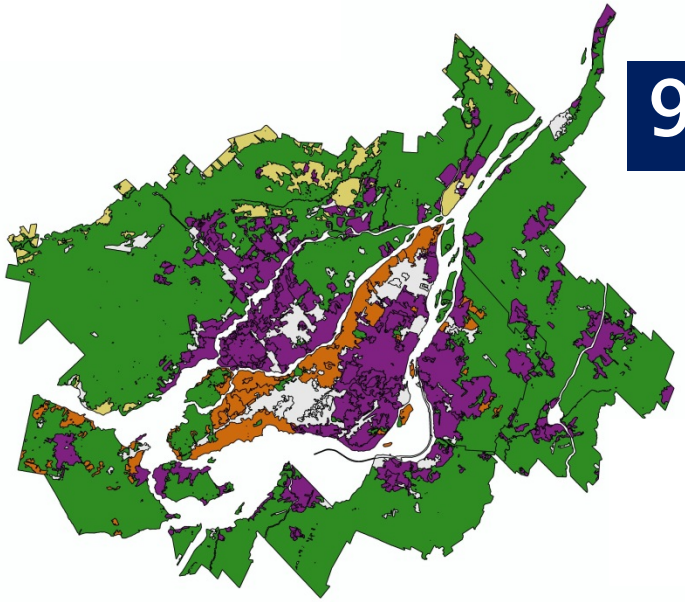


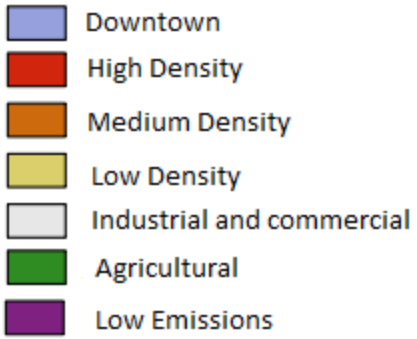
4.2 - Actions: Urban Patterns





Actions 7-9:
Pop. 1,5%/year,
GHG reductions
15-25-40%





4.3 - Issues, Criteria and Indicators

Issues	Criteria	Indicators	Codes and direction	Scales
Global change **CG**	Decrease GHG emissions	GHG emissions per hab.	**CGE** MIN	Tonnes/hab
Environmental **EV**	Preserve biodiversity	Preserve greenspaces	**EVB** MAX	Km2
Economic **EC**	Minimize the cost of energy transition	Mean cost per Km2	**ECC** MIN	$/Km2
Energy **EN**	Encourage energy efficiency	Energy use per Km2	**ENE** MIN	GJ/Km2
	Reduce dependency to hydrocarbon	Emission Intensity	**ENH** MIN	Tonnes/Gj
Social **SO**	Encourage quality of life	Access to public transportation in dense areas	**SOQ** MAX	Impact (Very good to very bad)
	Encourage public health	Heat Islands	**SOS** MIN	%
Space **TE**	Minimize the impact of densification	Ratio of dense area	**TED** MIN	%
	Prevent population migration	Migration flow	**TEP** MAX	Number of habs.

4.4 – Analysis with PROMÉTHÉE: Actions and stakeholders

Actions	Pop. Growth	GHG Limits
1	0,4	15
2	0,4	30
3	0,4	45
4	0,8	15
5	0,8	30
6	0,8	45
7	1,2	15
8	1,2	30
9	1,2	45

	Sc. Base	Sc. CG	Sc. EV	Sc. EC	Sc. EN	Sc. SO	Sc. TE
CG	16	31	13	13	13	13	13
EV	16	13	31	13	13	13	13
EC	16	13	13	31	13	13	13
EN	18	15	15	15	33	15	15
SO	16	13	13	13	13	31	13
TE	18	15	15	15	15	15	33

Weighing Scheme by Stakeholder

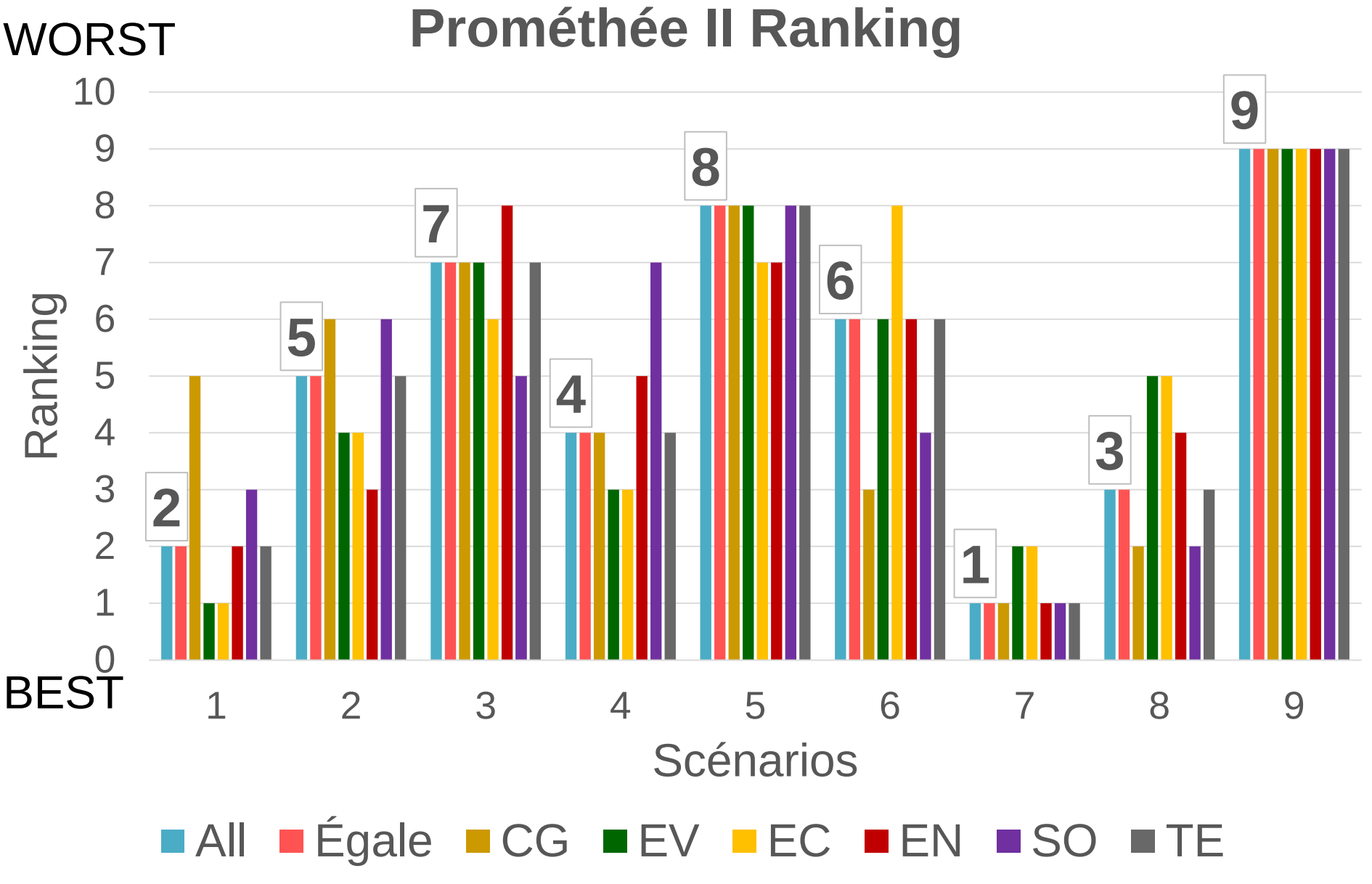
4.4 Analysis with PROMÉTHÉE: Decision Matrix

Actions	CGE	EVB	ECC	ENE	ENH	SOQ	SOS	TED	TEP
1	0,763	166,739	10061997	43429	0,001939	2	0,00868	0,72	1150051
2	0,674	161,796	57841726	35263	0,001807	2	0,07291	0,81	1090000
3	0,584	156,015	128590291	26248	0,001685	1	0,12587	0,86	1155000
4	0,694	162,637	42027610	41209	0,001908	3	0,05865	0,94	909325
5	0,612	157,234	105746930	32271	0,001789	2	0,1125	0,89	1155000
6	0,531	154,592	190722489	23188	0,001678	1	0,15645	0,73	1155000
7	0,631	157,577	101319867	37500	0,001649	1	0,07608	0,70	1155000
8	0,557	154,748	171175924	29691	0,001778	1	0,12222	0,69	1155000
9	0,482	150,967	273135422	19765	0,001694	3	0,19298	0,80	1090000
Min/Max	Min	Max	Min	Min	Min	Max	Min	Min	Min
Pref fn	V-Shape	V-Shape	V-Shape	V-Shape	V-Shape	Usual	Usual	V-Shape	V-Shape

4.4 Analysis with PROMÉTHÉE: Questions to answer...

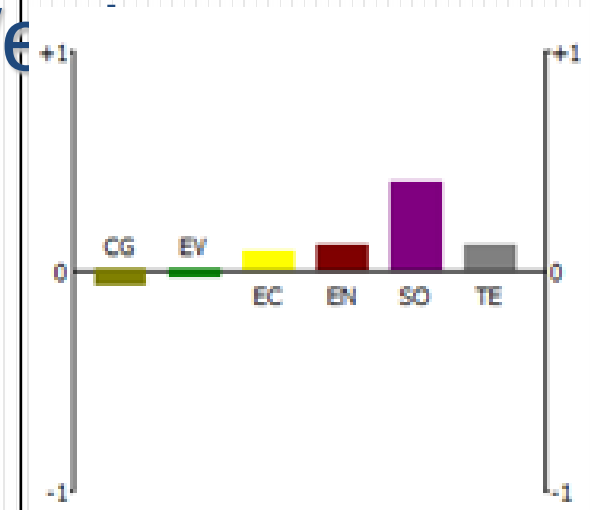
Question for each Stakeholder	
What is the best action?	*PROMETHEE I et II Ranking*
Why is it a good action?	*GAIA, Profils, Arc-en-ciel*
Why not another one?	
What is the influence of weighing on each criteria?	*GAIA, Walking Weights*
Is it robust?	*Visual Stability Interval*
Question for all Stakeholder	
Is there a consensus toward an action?	*PROMETHEE Group Ranking, GAIA-Scenarios*
Who is opposed to that action? and Why?	
Is it robust?	*Visual Stability Interval, Walking weights*

4.4 - Prométhée II Rankings

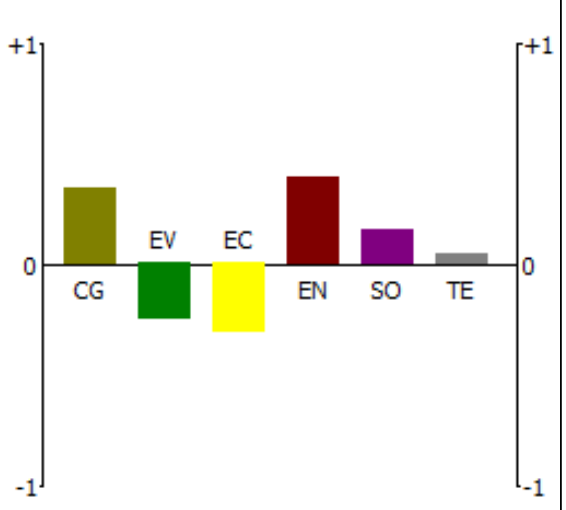


4.4 – Action Profiles: Strengths and We

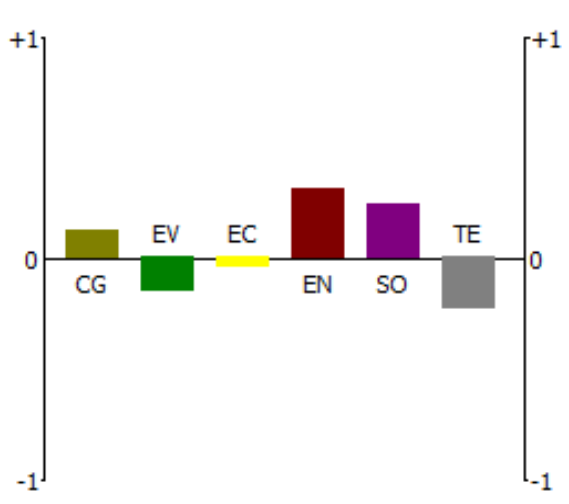
Issue



Rank 1: Action 7

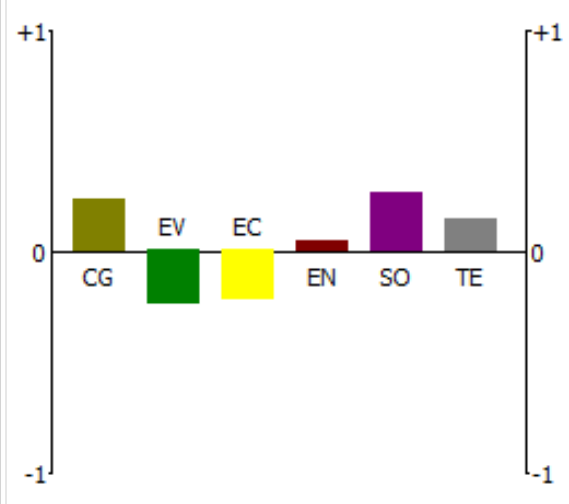


Rank 2: Action 6

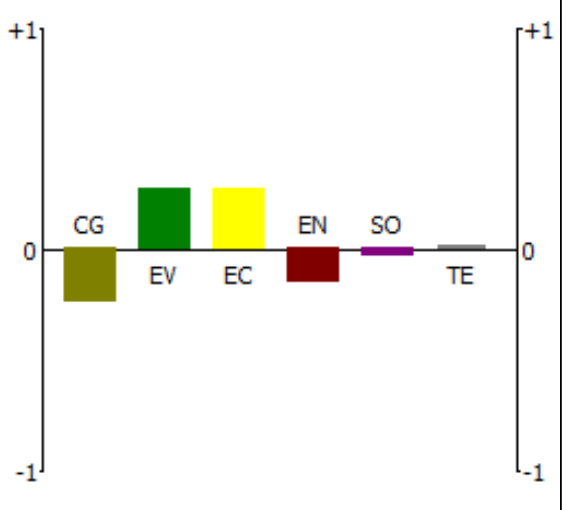


Rank 3: Action 3

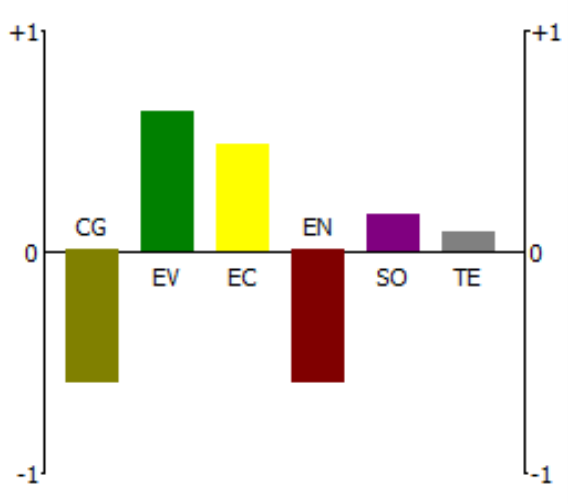
Issue



Rank 4: Action 8

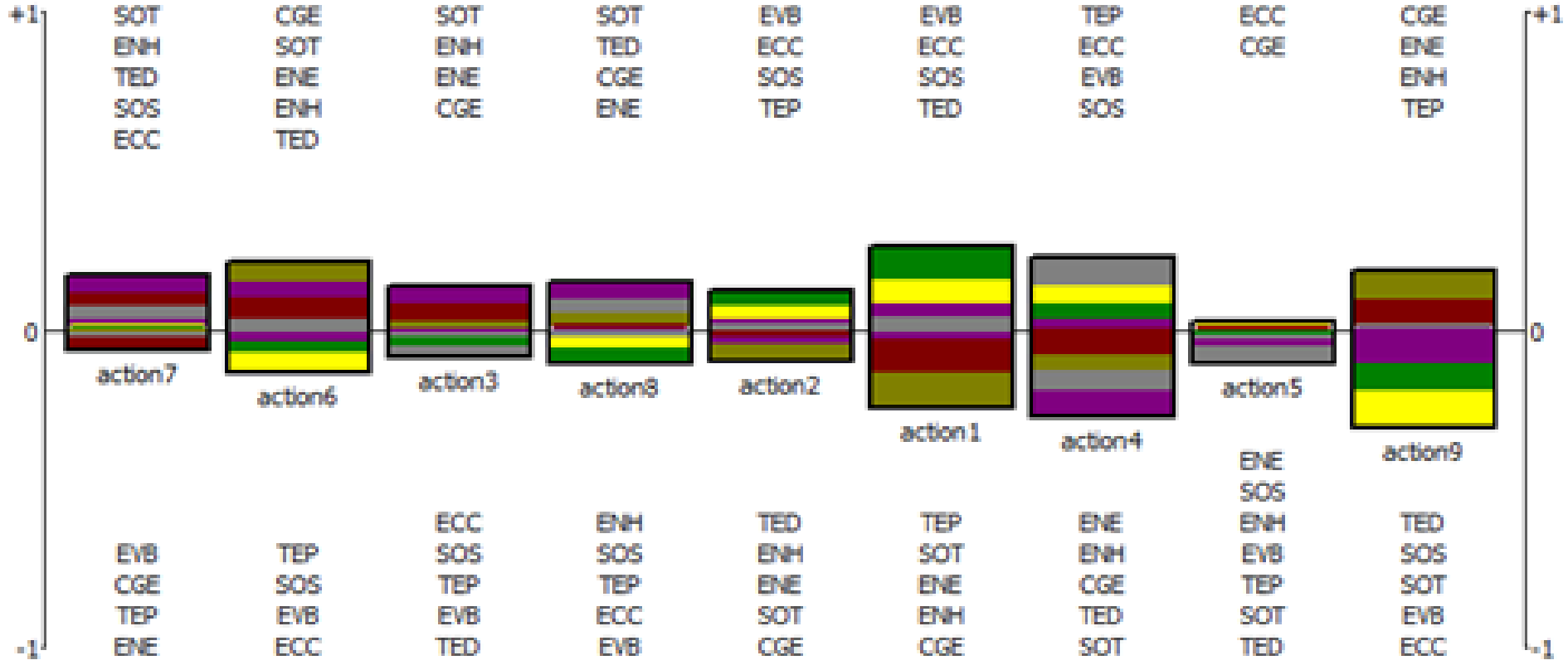


Rank 5: Action 2



Rank 6: Action 1

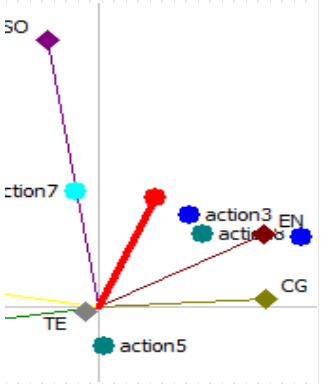
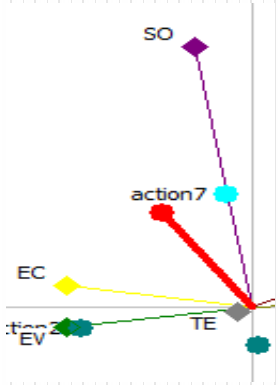
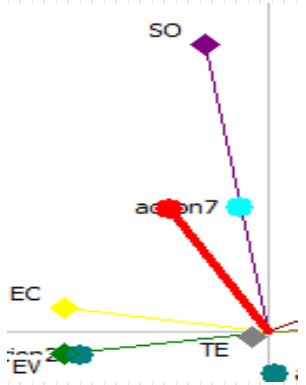
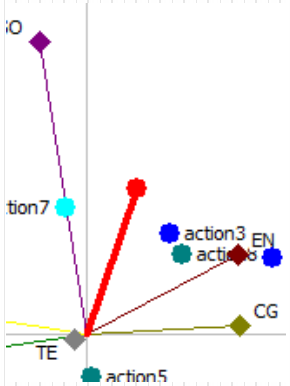
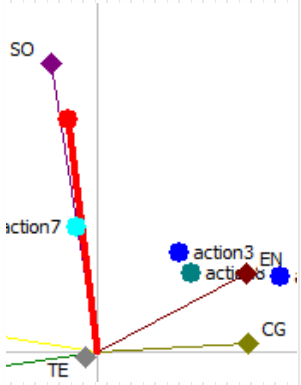
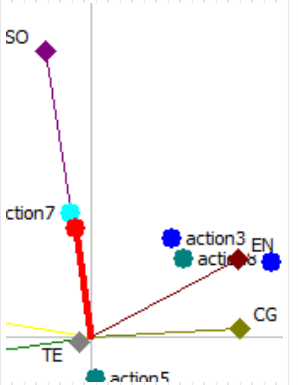
4.4 – PROMETHEE Rainbow



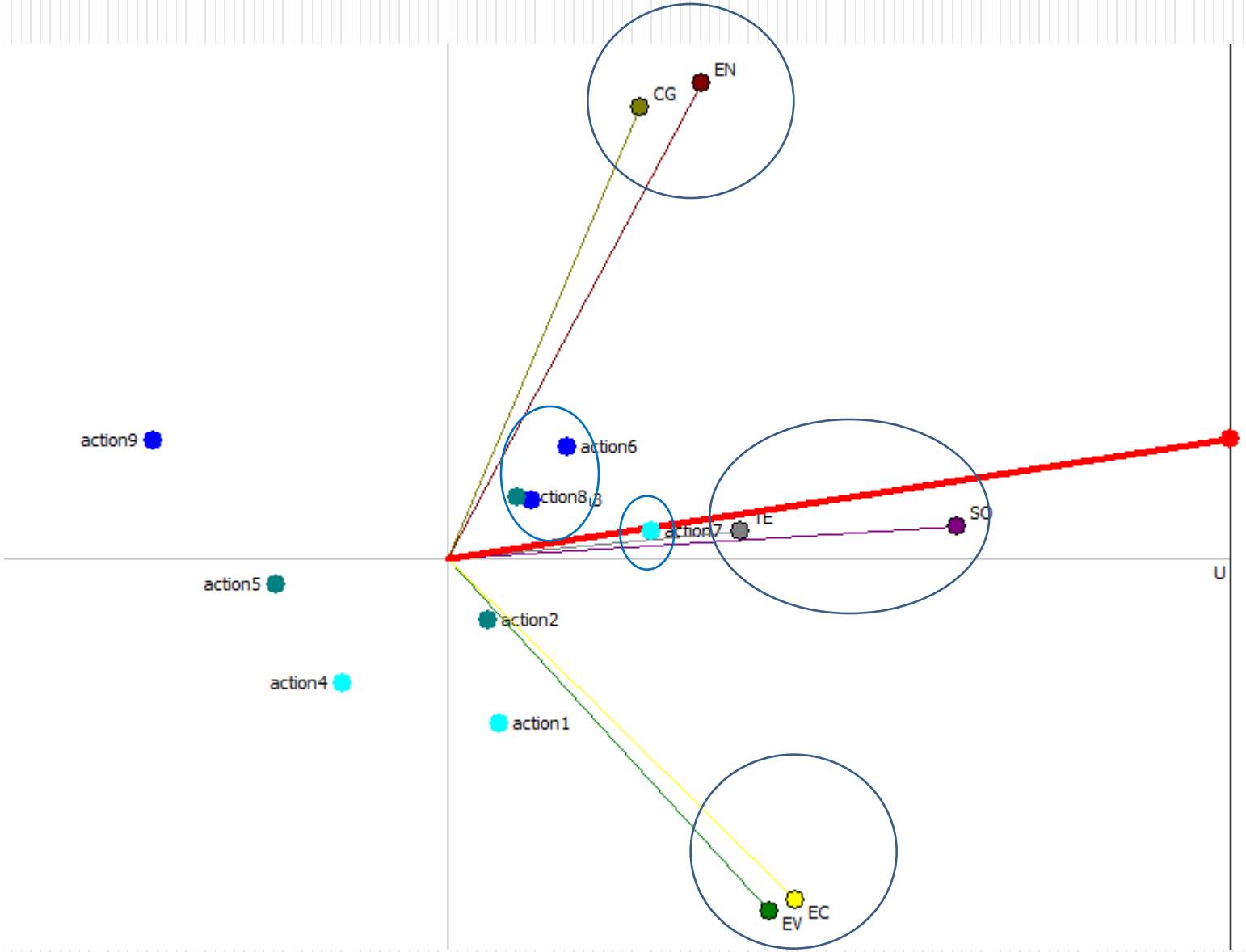
Criteria's contribution to action performance

4.4 - Gaia Profiles

Decision Axis Position by stakeholder

		
Global Change Actions Rank : 6, 8, 7, 3, 9, 2, 5, 1, 4	**Environnent** Actions Rank : 1, 7, 2, 6, 4, 3, 8, 5, 9	**Economic** Actions Rank : 7, 1, 2, 3, 4, 6, 8, 5, 9
		
Energy Actions Rank : 6, 7, 3, 8, 2, 9, 5, 1, 4	**Social** Actions Rank : 7, 6, 3, 8, 1, 2, 5, 4, 9	**Space** Actions Rank : 7, 6, 8, 1, 2, 3, 4, 9, 5

4.4 - Gaia Profile for all Stakeholders

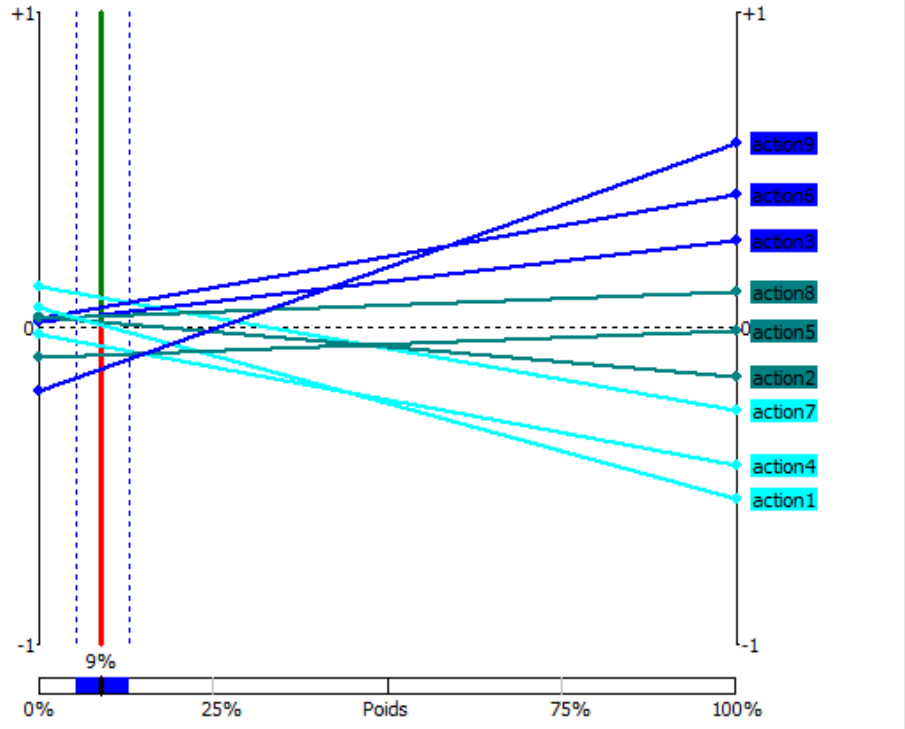


4.4 - Weight Sensitivity Analysis (multi-stakeholders)

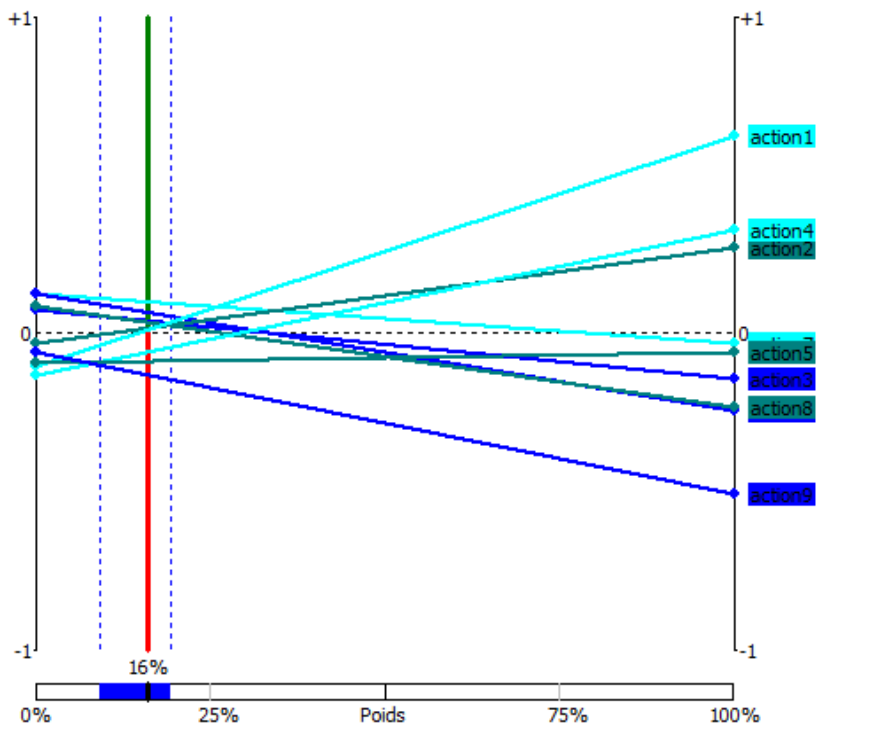
Weight Stability Interval (WSI)		1 Action		2 Actions		3 Actions	
Criteria	Weight (%)	+	-	+	-	+	-
CGE	16	0	22,16	10,68	22,16	12,22	20,94
EVB	16	1,37	25,85	1,37	21,03	9,24	19,25
ECC	16	8,41	31,32	8,41	21,62	12,77	20,82
ENE	9	0	13,05	3,45	13,05	5,43	13,05
ENH	9	1,37	100	3,74	100	7,27	100
SOT	8	0	100	2,45	100	5,26	100
SOS	8	1,66	24,05	1,66	13,31	1,66	11,8
TED	9	0,77	62,23	4,61	22,46	4,69	9,84
TEP	9	0	20,08	0	18,05	0	16,12

4.4 - Weight Sensitivity Analysis (multi-stakeholders)

ENE



EVB



5. – Discussion and Conclusion

- MCDA pilot is successful. Next step is to submit it to real stakeholders.
- Scenarios could be design with more details.
- Energy database needs more calibration.
- 1/3 of energy consumption comes from transportation. Not included in the present analysis.

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- Ressources naturelles Canada (2012). *Tableau 6 : Consommation d'énergie secondaire et émission de GES par utilisation finale et source d'énergie – Excluant les GES liés à l'électricité,* Récupéré le 25 avril 2016 de Ressouces naturelles Canada
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THANK YOU! Questions?

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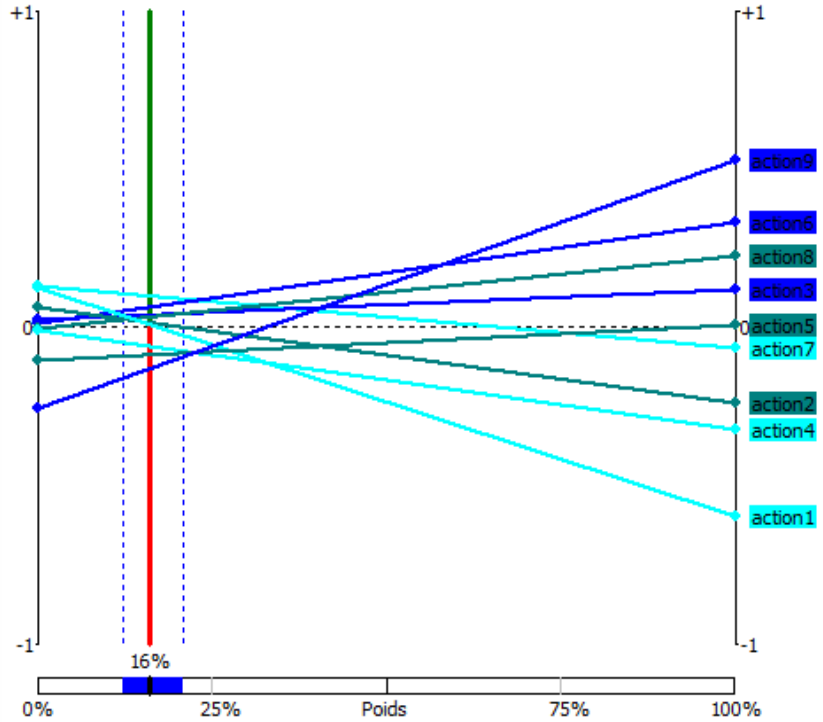
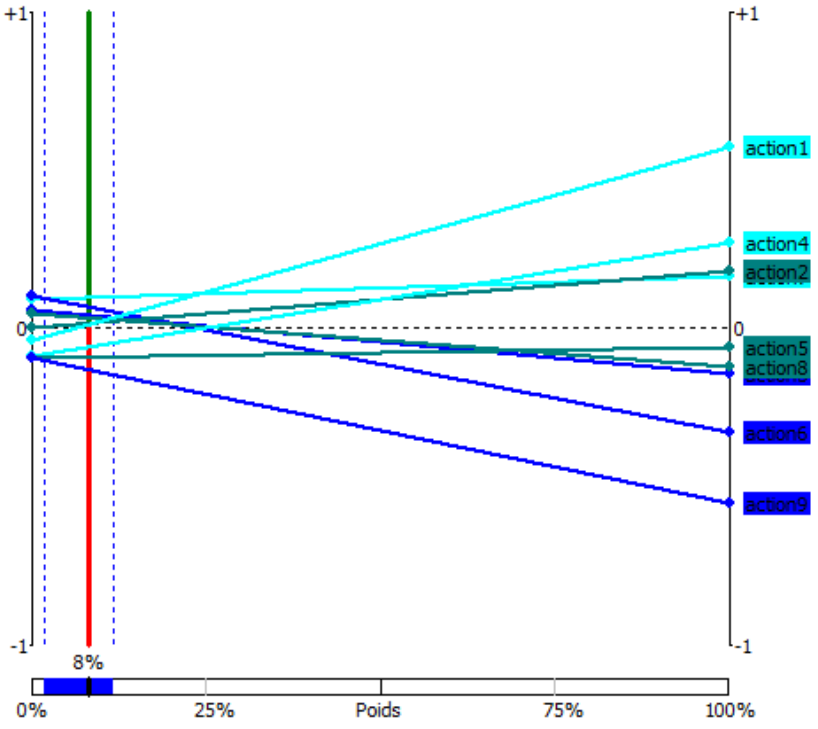
4.4 - Weight Sensitivity Analysis (multi-stakeholders)

CGE

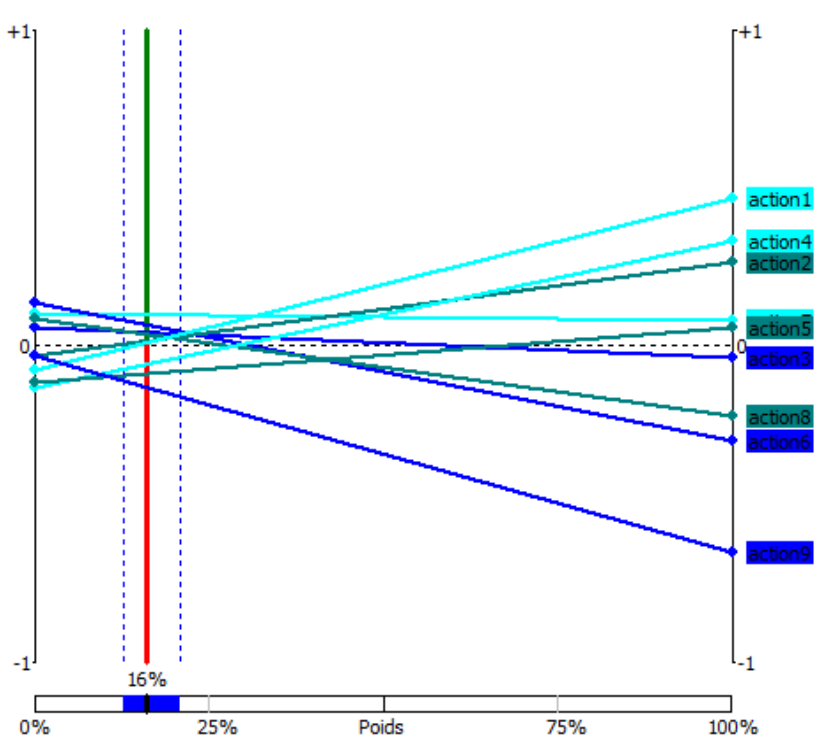


SOS

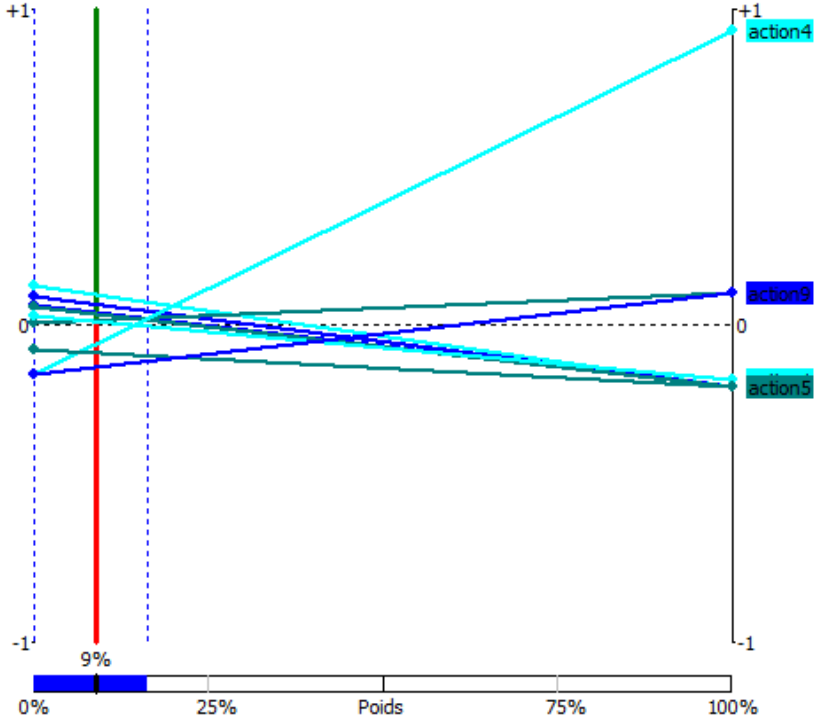


4.4 - Weight Sensitivity Analysis (multi-stakeholders)

ECC



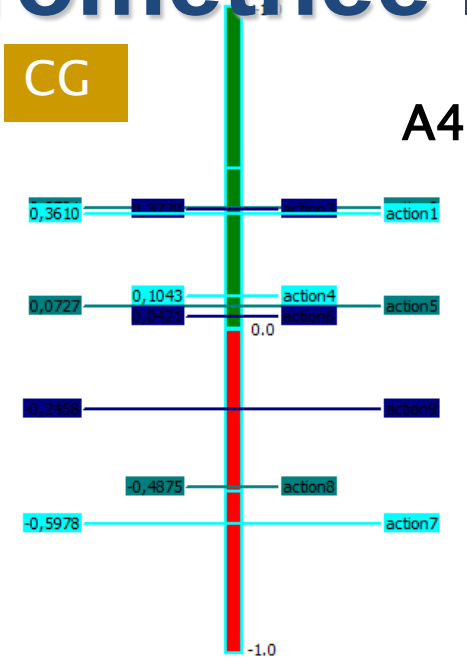
TE



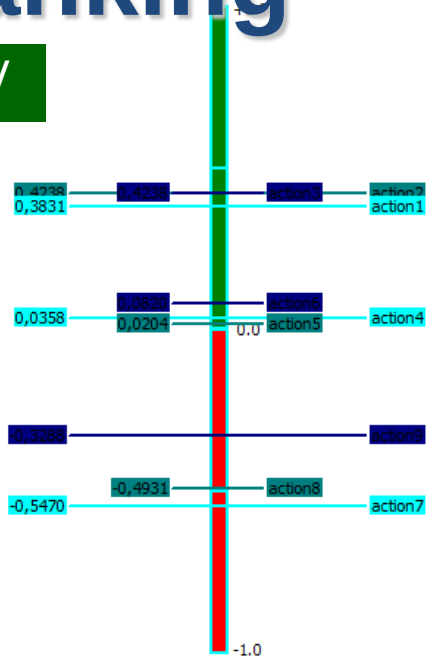
Prométhée II Ranking

CG

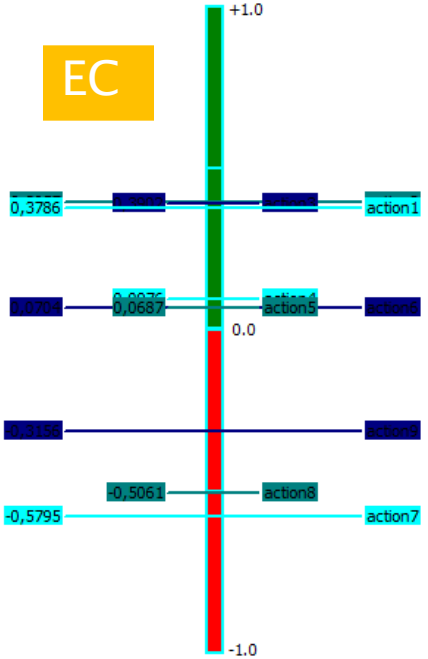
A4



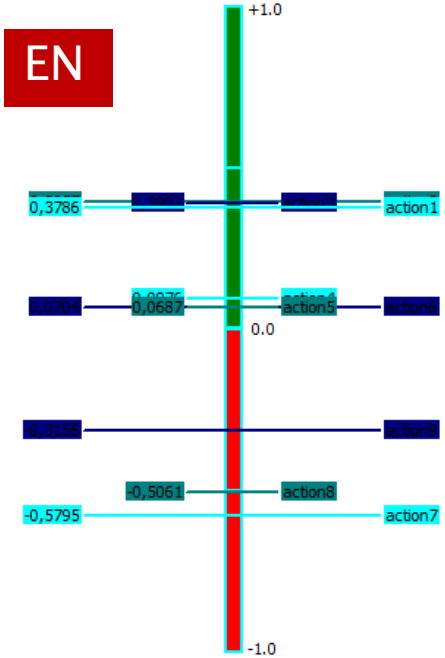
EV



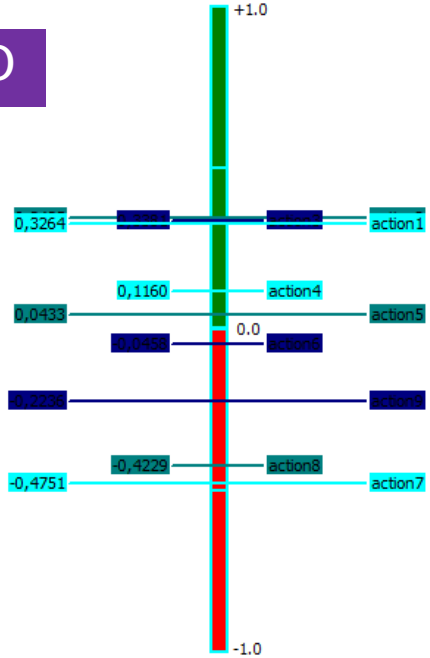
EC



EN



SO



TE