

# **Modeling Energy Security: Critical approach and application to energy corridors in TIMES-Canada**

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Thanks to the team

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## 1. Energy Security: definitions et concepts

### Various definitions.

- IEA : the reliable supply of energy at an affordable price. Energy security is defined according different time horizons :
  - in long run, energy security is mainly related to investment capacity to provide the quantity and quality of energy linked to the economic development and environmental constraints;
  - in short term, energy security can be defined such as the capacity of energy system to react rapidly at any sudden changes of the demand and/or supply.
- World Bank : energy security is approached according three key pillars strategy: energy efficiency, diversification of supply, and minimization of price volatility.

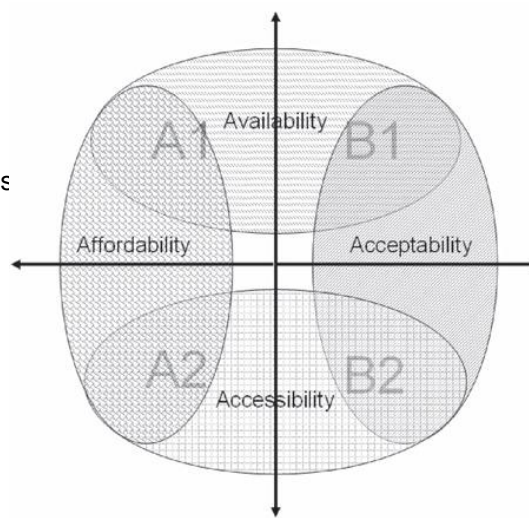
# 1. Energy Security : definitions et concepts

## Two mains ways to conceptualize Energy Security (ES)

- 1- Considers ES in a multidimensional way, with three or four dimensions sometime more.
- 2- Considers that ES can be summarized as security of supply. In this case the different dimensions are still present but in a security of supply perspective.

### **Most popular dimensions of energy security multidimensional approach**

- **Availability** refers to the security of supply question. It is related to energy dependency (of a given country) and diversification of suppliers, geographic sources of supply and in energy mix.
- **Affordability** deals with price and cost issues.
- **Accessibility** refers to the physical access of resources (geopolitical concerns).
- **Acceptability** deals with the sustainability of the energy system (environmental impact).



## Energy security as security of supply

- Concerns mainly importing energy countries.
- Focuses mainly on availability, market and political dimensions.
- IEA constructs an indicator for security of supply based on a measure of market concentration combined with a political risk index.

## Security and risk: conceptual model of risk assessment

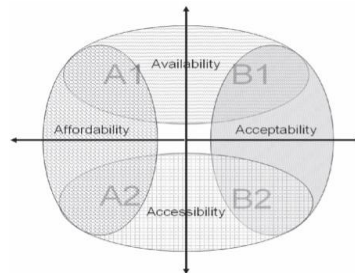
- To model security of energy corridors, we have to assess the associated risks of unforeseen harmful events.
- Minimizing risk is maximizing security

Risk is defined by :

$$R = F (\text{Alea} , \text{Vulnerability})$$

## Conceptual model of risk assessment

**Alea** is the probability that an unforeseen event appears and that affect one or each of the four dimensions of the energy security :



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## Conceptual model of risk assessment

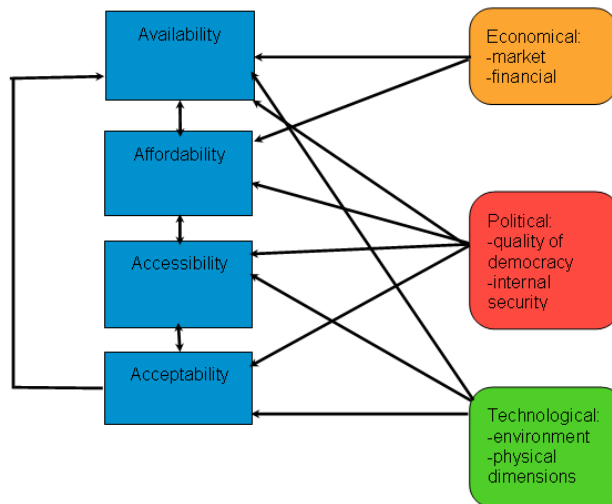
**Vulnerability** can come from :

- Economical factors : *market, financial, etc....*
- Political factors : *quality of democracy, security, etc..*
- Technological factors : *environment, physical dimensions, etc...*

Vulnerability factors influence risk by increasing or decreasing the effects of an unforeseen event.

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$$\text{RISK} = \text{F}(\text{ALEA}, \text{VULNERABILITY})$$



## 2. Security of energy corridors and TIMES-Canada context

- Energy corridors are all the way of transit between a supplier and a buyer (tankers, pipelines) for all energy carriers, and consequently they are directly related to energy security.
- They are exposed to several risks.
- The case of Canada is specific, indeed it is a large exporting country of energy (oil, electricity or gas), but it is also an importing country especially for oil. That is named a dual market. Even more, there is inter-provincial transfers.
- Canada is thus made up of international and inter-provincial corridors.

## 2. Security of energy corridors and TIMES-Canada context

How to implement risk concerns in TIMES-Canada model?

- Aleas are linked to uncertainties that could be modelled by designing scenarios and by using stochastic or robust modelling.
- Vulnerability factors can be taken into account on endogenous or exogenous basis

## 2. Security of energy corridors and TIMES-Canada context

- Endogenous way to take into account vulnerability factors:
  - Ex.: indicator of market concentration (related to the market diversification criteria) is directly linked to outputs of the model from one period to another. It can be modelled by implementing constraints;
  - Good for economical vulnerability factors;
  - They are sensitive to discount rate: variable discount rates (time preference, business cycles, sustainability issues)
  - System of constraints have to be developed separately for imports and exports.

## 2. Security of energy corridors and TIMES-Canada context

- Exogenous way to take into account vulnerability factors:
  - Certain vulnerability factors can be implemented in the model by computing indexes.
  - Those indexes can be considered as “penalties” and thus be managed as constraints.
  - As other exogenous variables, they can be calibrate for the starting period according available data. They can be computed for other periods by projecting data in the future according “drivers”.
  - Need to be implemented for technological and political vulnerability factors

## 2. Security of energy corridors and TIMES-Canada

- The aim for exogenous factors is to implement a global vulnerability index by corridor in TIMES having a technological component (physical and environmental) and a political one (land unit crossed).
- In TIMES a corridor can be modeled as a technology but we need more details on each corridors to implement such a vulnerability index.
- Consequently to compute such an index we use a multicriteria approach.



### 3. Assessing political vulnerability by using a Multicriteria approach

We have used the multicriteria outranking **PROMETHEE** method (Preference Ranking Optimization METHod for Enrichment Evaluation) to make the multicriteria analysis with **D-Sight software**.

This method compares the different provinces and territories of Canada according to the political vulnerability criteria chosen and provides a ranking from the more vulnerable province or territory to the less.

We weighted all criteria according two different ways: the International Country Risk Guide Methodology (ICRGM) and a so-called “Homemade perspective”

#### Assessing political vulnerability : territories under evaluation

Name	ShortN.	Group
Canada	CA	CANADA
Newfoundland	NL	EAST
Prince Edwards Island	PE	EAST
Nova Scotia	NS	EAST
New Brunswick	NB	EAST
Quebec	Qc	CENTRAL
Ontario	ON	CENTRAL
Manitoba	MB	WEST
Saskatchewan	SK	WEST
Alberta	AL	WEST
British Columbia	BC	WEST
Yukon	YT	NORTH
North West Territories	NT	NORTH
Nunavut	NU	NORTH

## Assessing political vulnerability : criteria

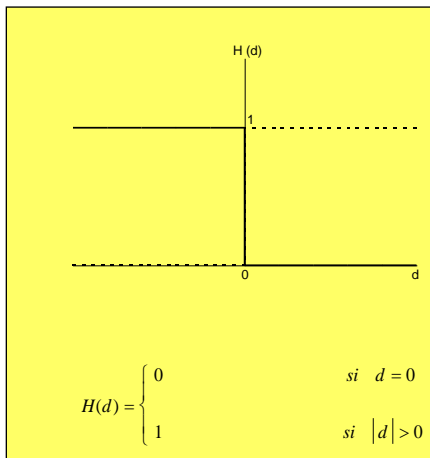
	Name	ShortN.	Category
<input checked="" type="checkbox"/>	Unemployment	UEM	Socioeconomical
<input checked="" type="checkbox"/>	Financial Protection Unempl...	FPU	Socioeconomical
<input checked="" type="checkbox"/>	Private expenditure Health	PEH	Socioeconomical
<input checked="" type="checkbox"/>	Police	POL	Internal security
<input type="checkbox"/>	Military expenses	MIL	External conflict
<input checked="" type="checkbox"/>	Quality of democracy	QOD	Democracy
<input checked="" type="checkbox"/>	Government expenditures	GvE	Public services

## Assessing political vulnerability : parameters

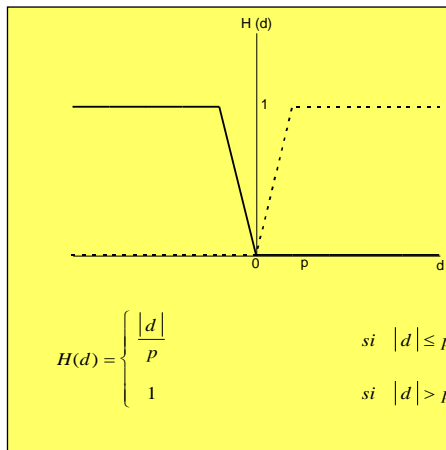
Criteria	Type	Min/...	Function	.. .. Pref.	.. Unit	Scale
Unemployment	Pair Wise	Minimize	V-Shape	...	10,26 ... %	Numerical
Financial Protection Unempl...	Pair Wise	Maximize	V-Shape	...	35 ... %	Numerical
Private expenditure Health	Pair Wise	Minimize	V-Shape	...	2,46 ... %	Numerical
Police	Pair Wise	Minimize	V-Shape	...	270,66 ... Nb/1...	Numerical
Military expenses	Pair Wise	Minimize	V-Shape	...	1 ... \$/GDP	Numerical
Quality of democracy	Pair Wise	Maximize	Usual	...	... 1-5	Democracy
Government expenditures	Pair Wise	Maximize	V-Shape	...	1 ... \$/capita	Numerical

- Preference functions defined as any differences between two evaluation matters for all numerical scales
- Preference threshold defined according data amplitude of variation

## Types of preference functions



Usual

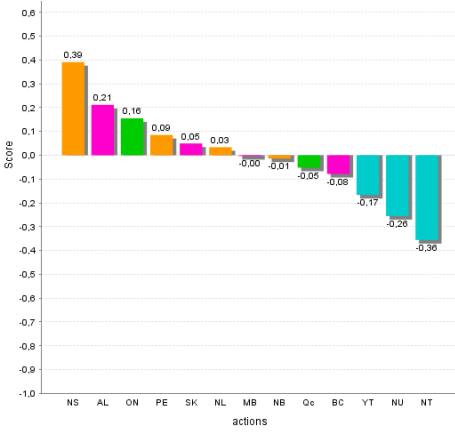


V-Shape

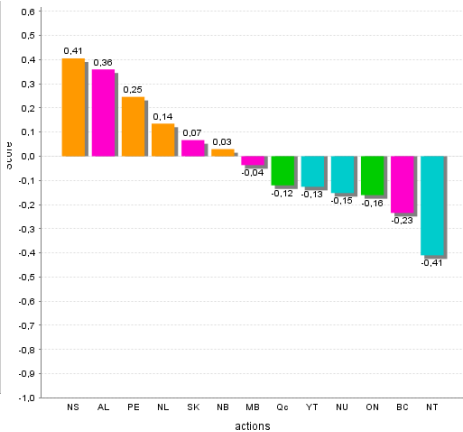
## Assessing political vulnerability : weighting criteria

Categories	ICRGM	Homemade
Socioeconomical	27%	30%
Internal security	34%	30%
External conflict	0%	0%
Democracy	27%	10%
Public services	12%	30%
Socioeconomical criteria		
	ICRGM	Homemade
Unemployment	48%	48%
Financial Protection Unemployment	12%	12%
Private expenditure Health	40%	40%

# Results: ranking of provinces and territories



ICRGM weight set



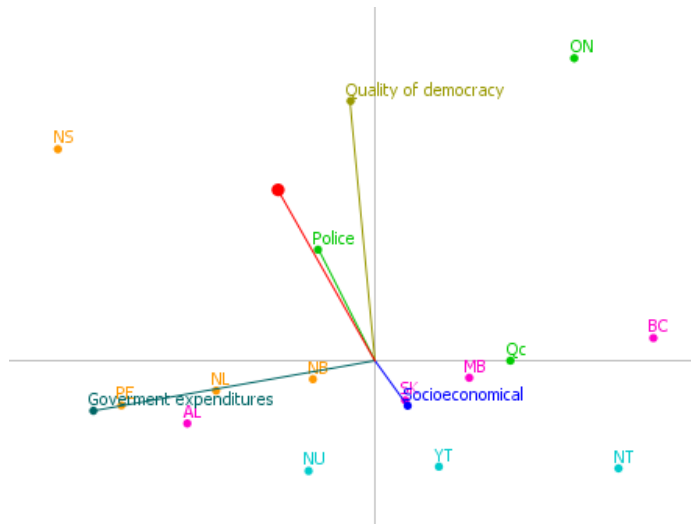
Homemade weight set

# Scores: provinces and territories

Alternative	Rank ▲	Score
Nova Scotia	1	0,391
Alberta	2	0,212
Ontario	3	0,155
Prince Edwa...	4	0,085
Saskatchewan	5	0,050
Newfoundland	6	0,034
Manitoba	7	-0,003
New Brunswick	8	-0,014
Quebec	9	-0,052
British Colu...	10	-0,079
Yukon	11	-0,167
Nunavut	12	-0,256
North West ...	13	-0,356

To be normalized on a 0-1 scale to be implemented into TIMES-Canada

## Additional information to decision makers: conflict between criteria (ICRGM)



## Additional information to decision makers: stability intervals and sensitivity analysis

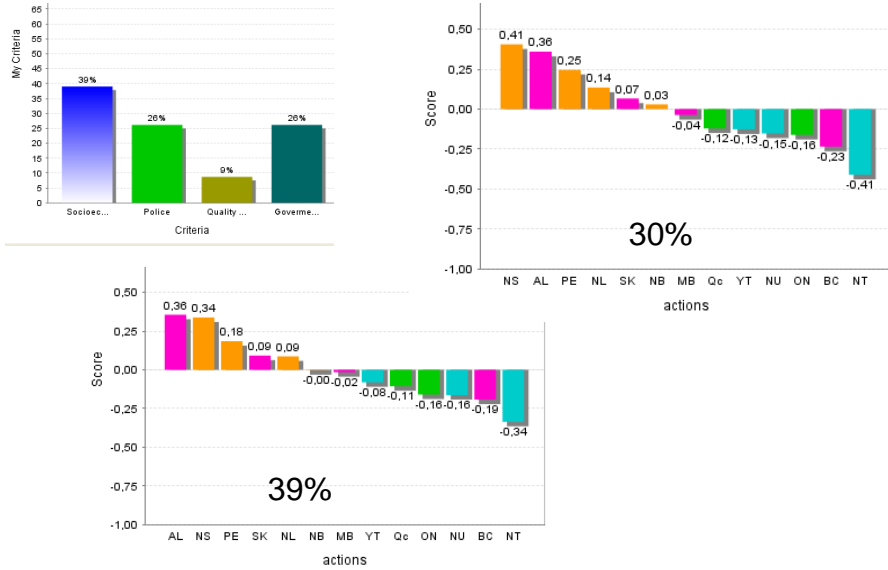
Stability level :

Criteria	Min Weight	Value	Max Weight
Police	0,0%	34,0%	77,2%
Quality of d...	12,5%	27,0%	30,6%
Government ...	8,6%	12,0%	50,0%
Socioecono...	17,3%	27,0%	47,9%

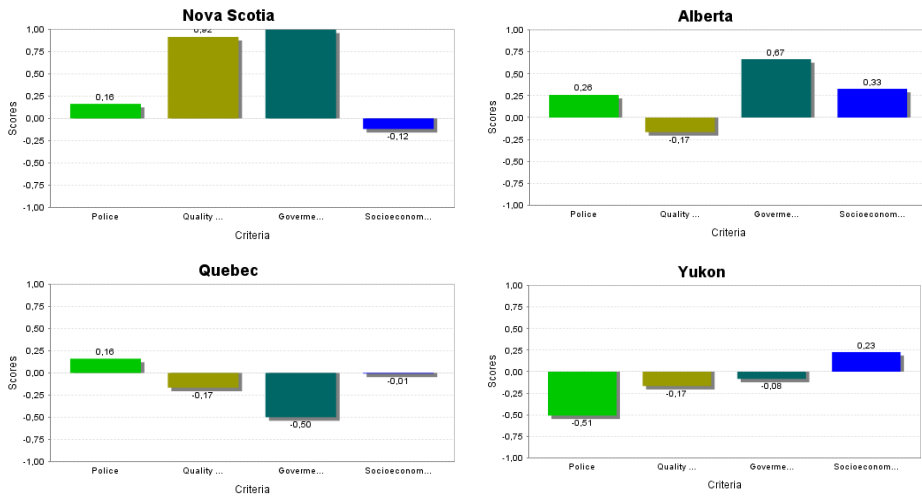
Stability level :

Criteria	Min Weight	Value	Max Weight
Police	0,0%	30,0%	52,8%
Quality of d...	6,0%	10,0%	39,2%
Government ...	18,9%	30,0%	58,4%
Socioecono...	12,1%	30,0%	36,5%

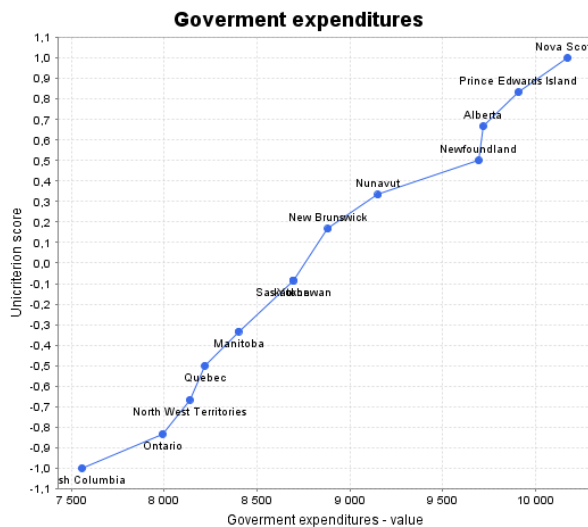
## Sensitivity analysis to the socioeconomic criteria weight (Homemade set)



## Additional information to decision makers: profile strengths and weaknesses



## Additional information to decision makers: unicriterion score viewer



## 4. Future works

This model will be generalized for :

- each energy carrier
- each corridor
- each land unit
- import and export constraints