ParisTech's Chair Modeling for sustainable development

TIMES model for the Reunion Island:

Addressing reliability of electricity supply

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Power sectors: a period of changes

1. Numerous challenges:
   - Constraints on carbon emission
   - Depletion of fossil fuels
   - Population densification
   - Forecast huge investments in power sectors
   - Liberalization of electricity markets
2. The need to improve energy efficiency:
   - Electricity efficiency is severly disadvantaged by the efficiency of the Carnot cycles
3. Fossil fuels = 66% of the world net electricity production

☞ In this context, renewable and distributed energy sources are attractive alternatives for power generation.

Spread of renewable and distributed energy sources

Benefits

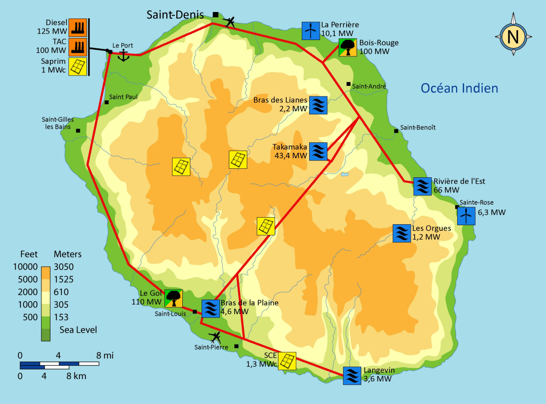
1. The overall efficiency improves:
   - Renewable energy sources decrease electrical losses at production level
   - Distributed generation decrease electrical losses at transmission and distribution levels
2. High shares of renewable and distributed energy sources are expected:
   - In centralized scheme, e.g. Desertec concept
   - In distributed architecture with smartgrids concept

Spread of renewable and distributed energy sources

Challenges

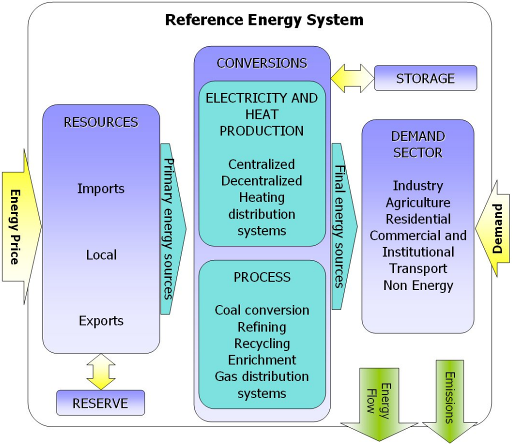
1. Design of energy policies
   - To promote renewable and distributed sources
   - Incentives' system
2. Major technological issues
   - Intermittency
   - **Reliability of electricity supply**: the capability of the power system to withstand sudden disturbances

Why focusing on the Reunion Island ?



1. Blessed with high renewable energy potentials
2. Small, weakly-meshed and isolated power system
3. Binding target in 2030: 100% renewable sources in power generation

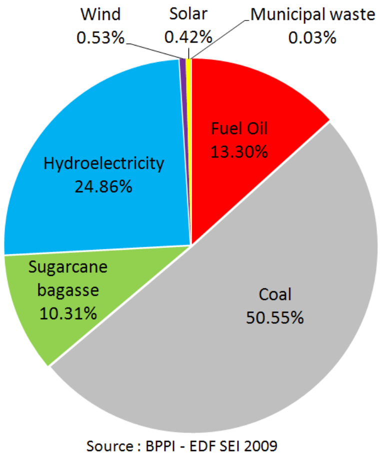
Long-term planning tools: *the MARKAL/TIMES models*



- **Inputs:**
  - Exogeneous demand
  - Available technologies
  - Domestic resources
  - Energy prices
- **Outputs:**
  - Optimal technologies
  - Optimal timing of investments
  - Global cost
  - Emissions

- Technological models driven by energy demand
- Minimization of the global discounted cost of the energy system

The electricity sector in 2008

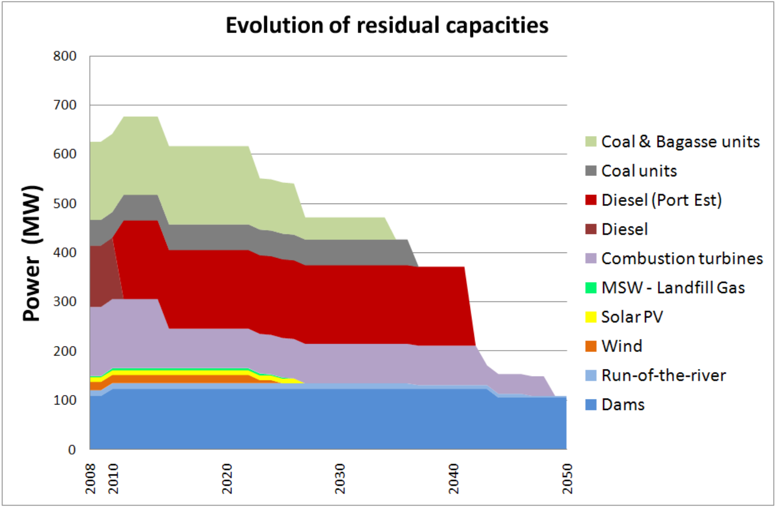


Electricity production: 2 546 GWh

Installed capacities

- **Thermal units** (76%):
  - 476 MW
  - Fuels: coal, fuel oil, sugarcane bagasse
- **Hydroelectricity** (20%):
  - Dams: 109,4 MW
  - Run-of-the-river: 11,6 MW
- **Others** (4%):
  - Wind: 16,8 MW
  - Solar PV: 10 MW
  - Municipal Waste: 2 MW

Existing power plants



General hypotheses

	Unit	2000	2008	2015	2020	2025	2030
Energy Prices[1]:							
Steam Coal	\$2008/t	41.22	120.59	91.05	104.16	107.12	109.4
Crude Oil	\$2008/bbl	34.3	97.19	86.67	100.00	107.50	115.00
Heavy fuel oil	€2008/t	-	196	174	201	216	231
Distillate fuel oil	€2008/hl	-	47	42	48	51	55
Electricity:							
Growth rate	%		3.4	2.6	2.4	1.5	1.5
Consumption	GWh		2 546	3 110	3 500	3 805	4100
Power	MW		408	520	595	670	720

Sources : International Energy Agency, Electricité de France

[1] 2008 real term prices

Renewable energy potentials

Energy sources	Current levels	Potentials
Biomass	260 GWh	400 GWh
Hydropower	121 MW (553 GWh)	177 MW until 2012 268 MW afterwards
Wind	16,8 MW	50 MW
Solar PV	10 MW	160 MW
Ocean Thermal Energy Conversion	–	10 MW in 2020 100 MW in 2030
Wave Energy	–	30 MW (by 2014)
Geothermy	–	30 MW
Storage Capacities	–	1 MW in 2009 10 MW

Scenarios specification

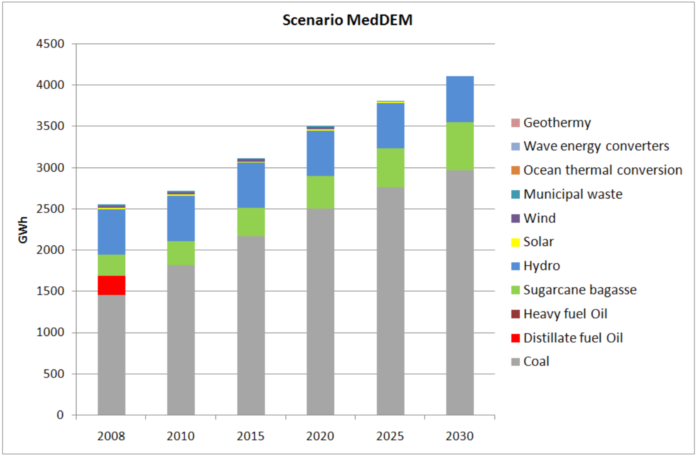
- Potentials for renewable energy sources are set at their maximum values.
- Scenarios are built around 3 assumptions

Fossil fuel imports	No limit Limit on coal Limit on all fossil fuels
Demand	Standard Low
Sugarcane bagasse potential	Standard High

Results: calibration for the year of reference (2008)

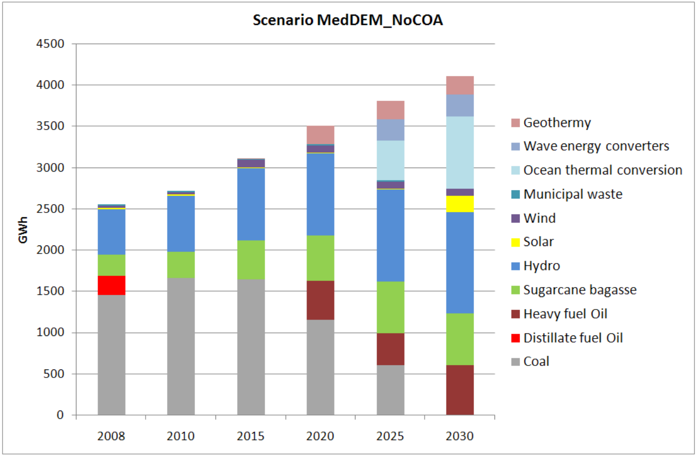
Energy sources	Model (%)	EDF (%)
Coal	56.90	50.55
Fuel Oils *(Distillate and Heavy)*	9.06	13.30
Sugarcane bagasse	10.21	10.31
Hydroelectricity	21.71	24.86
Wind energy	1.19	0.53
Solar energy	0.41	0.42
Municipal waste	0.52	0.03
Production	2 547 GWh	2 546 GWh

Business as Usual



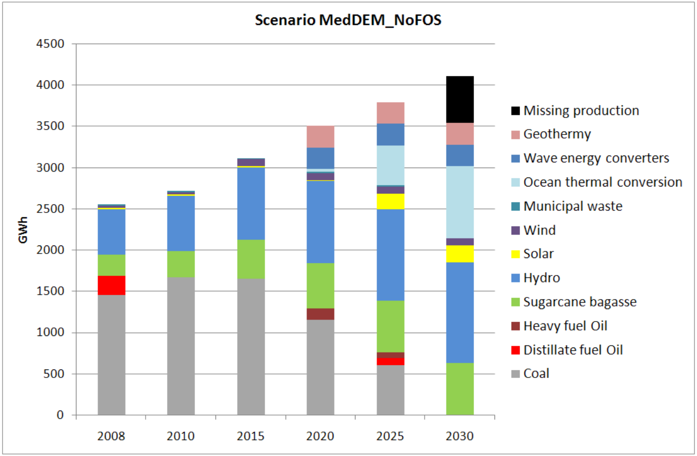
{Imports: No limit / Demand: Standard / Bagasse: Standard}

Limits on coal imports



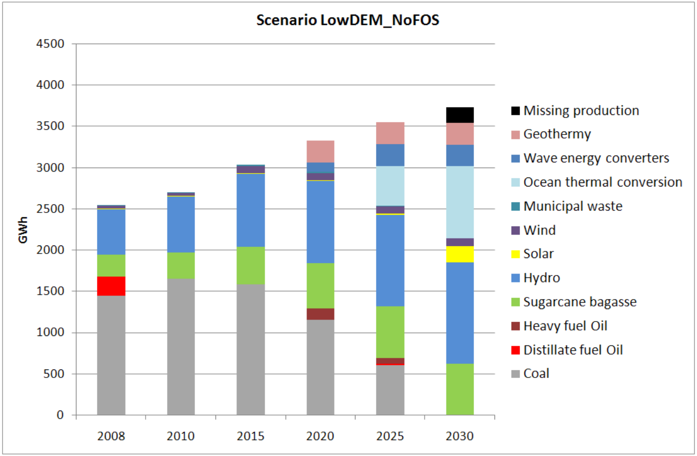
{Imports: Limit on coal / Demand: Standard / Bagasse: Standard}

Limits on fossil fuel imports



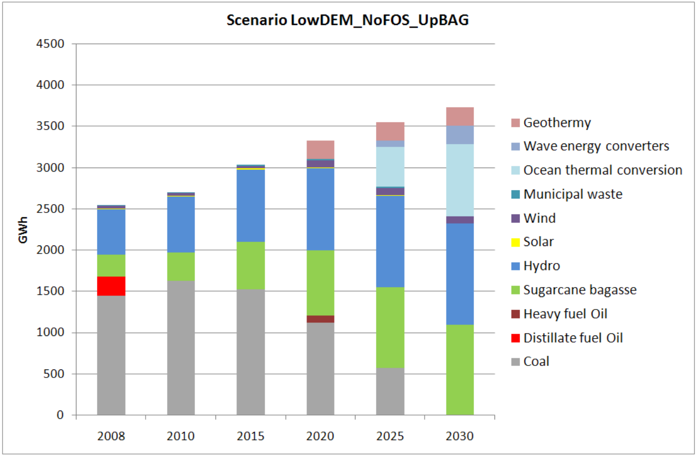
{Imports: Limit on fossil fuels / Demand: Standard / Bagasse: Standard}

Lower demand



{Imports: Limit on fossil fuels / Demand: Low / Bagasse: Standard}

Higher sugarcane bagasse potential



{Imports: Limit on fossil fuels / Demand: Low / Bagasse: High}

Remembering the issues

Challenges with renewable and distributed energy sources

1. Design of energy policies
   - To promote renewable and distributed sources
   - Incentives' system
2. Major technological issues
   - Intermittency
   - **Reliability of electricity supply**: the capability of the power system to withstand sudden disturbances

Economical plausibility

Design of the incentives' system

- Costs and levels of investments in the different scenarios:

Limit on imports	No limit	X				
	On coal		X	X	X	X
	On fuel oils			X	X	X
Demand	Standard	X	X	X		
	Low				X	X
Bagasse	Standard	X	X	X	X	
	High					X
Relative total costs[1]		1	1.32	1.24	1.10	0.98
Relative investment costs[1]		1	5.95	8.19	6.30	5.24
Demand satisfied		yes	yes	no	no	yes

- What are the required level of subsidies to favour these investments?

[1] Deducing the salvage costs

Technological plausibility

Reliability of electricity supply

- It is the capability of a power system to handle load fluctuations
- It mainly relies on:
  - Voltage management, with the electromagnetic coupling energy
  - Frequency management, with the kinetic and spinning reserves
- With renewable and distributed energy sources:
  - Levels of reserves decrease
  - Production fluctuations are more frequent
- At which cost the proposed power systems can be operated reliably?

Conclusions

- Renewable energy sources may cover power generation in 2030
- The model can be further developed: loadcurve, bagasse industry, scenario prices, carbon constraints
- Good case study to address economical and technological issues in the TIMES models:
    - Incentives' system
    - Reliability of electricity supply