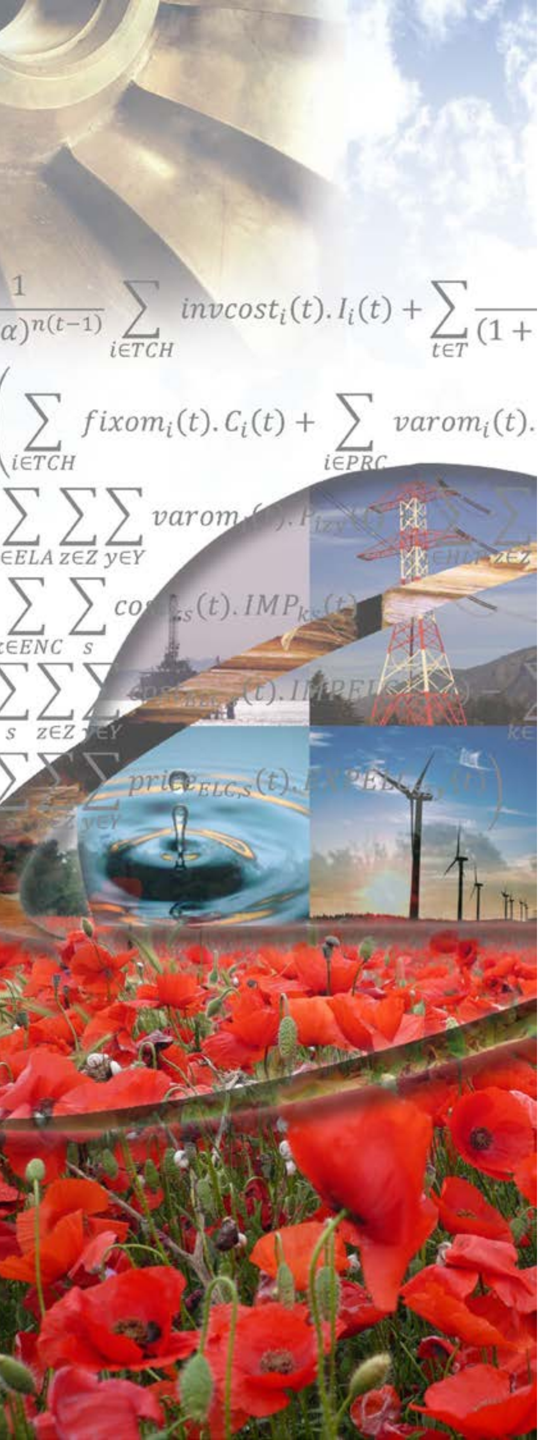


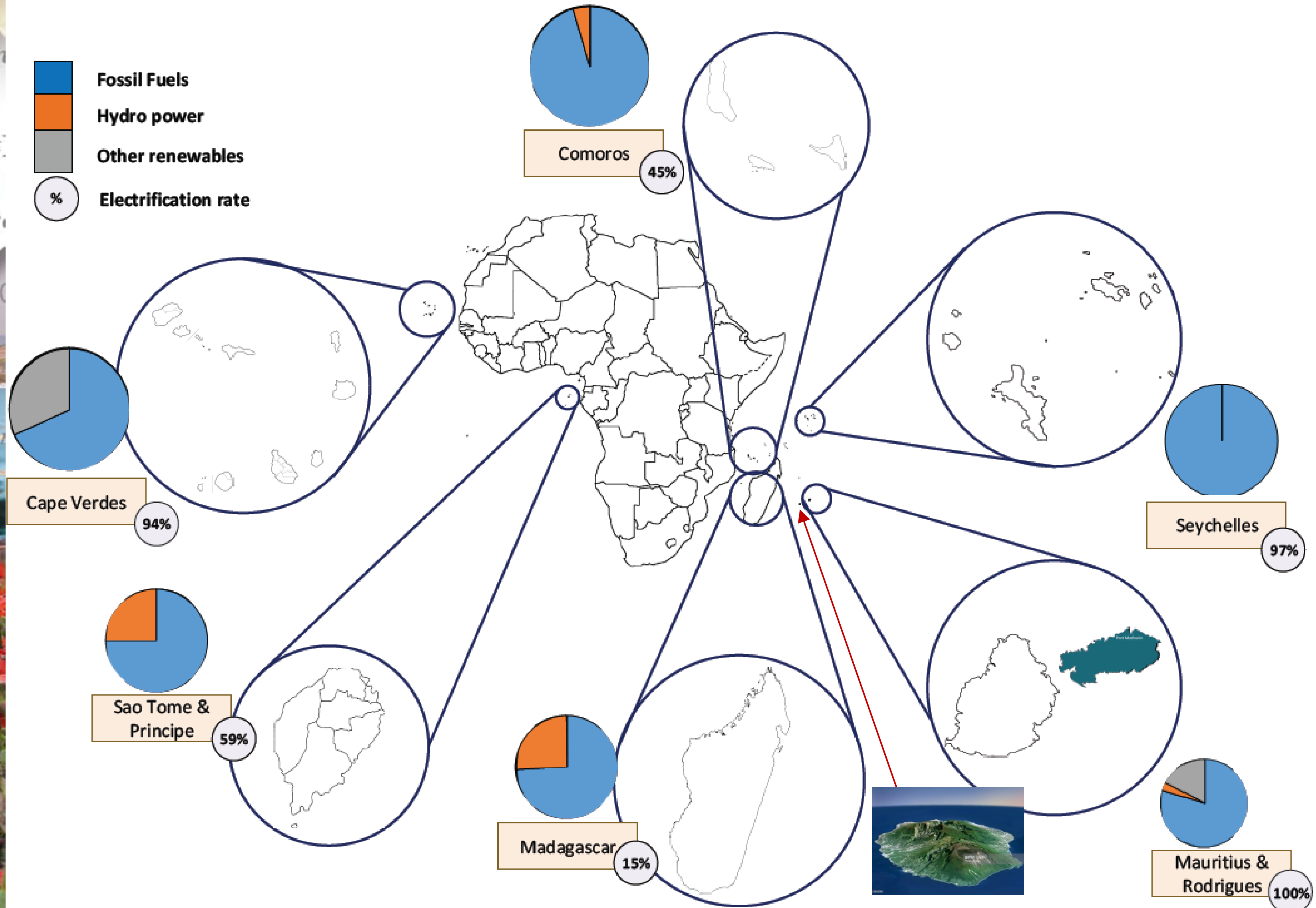
# Low carbon pathways in Reunion Island

Sandrine SELOSSE
MINES ParisTech – Centre for Applied Mathematics
Chair Modeling for Sustainable Development

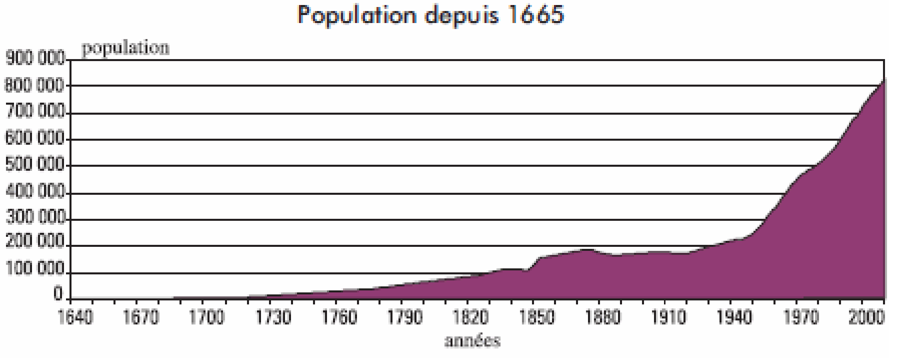
November 16th, 2017

COP 23 – Bonn
CITIES AND REGIONS PAVILION

# Energy mix in African SIDS (Dinesh Surroop, University of Mauritius)



# Reunion Island, a French overseas territories and collectivities

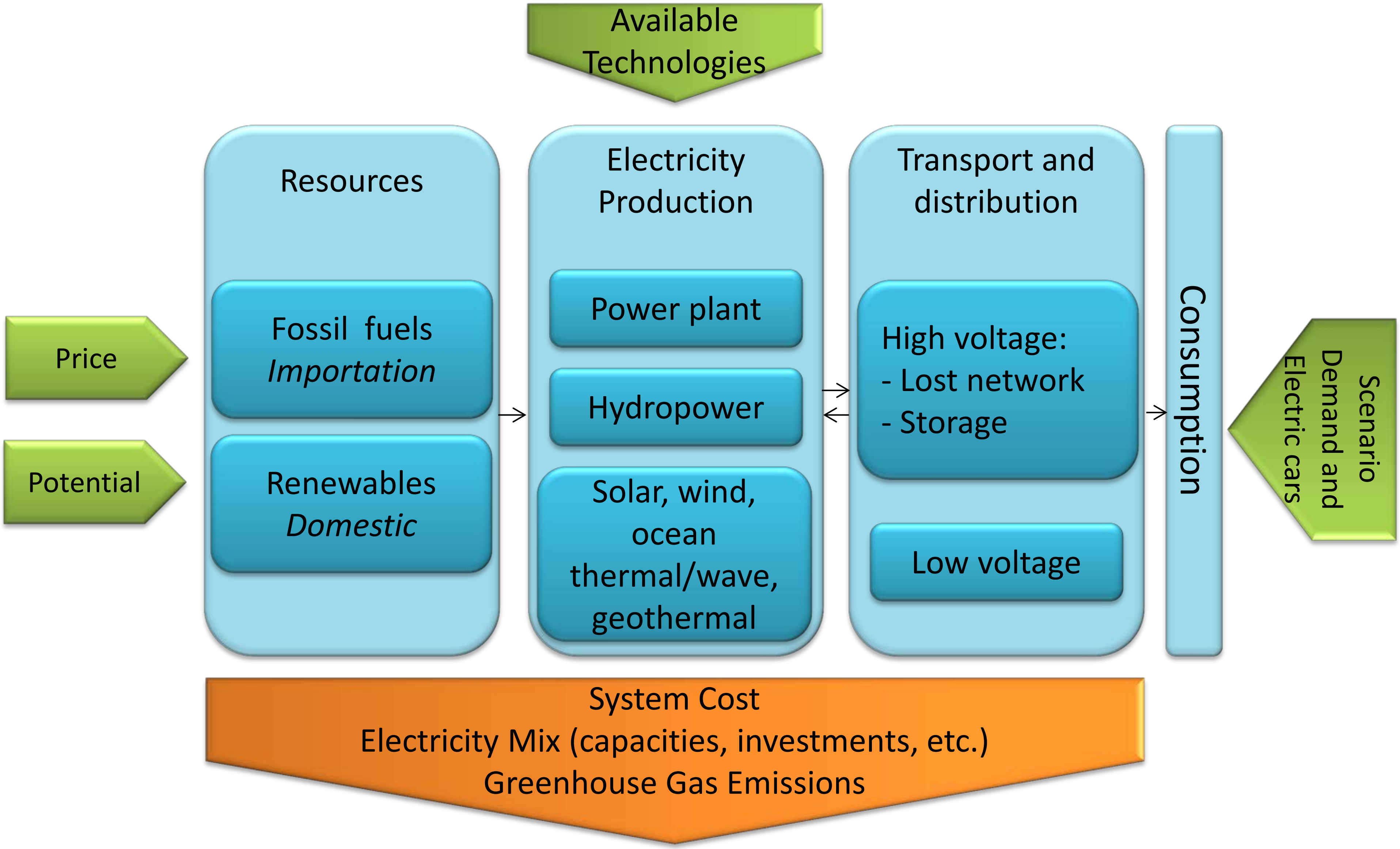



- Demography
  - 1970: 450,000
  - 2012: 837,900
  - 2040: 1,061,000
- Energy
  - Isolated (isolated energetic system)
  - In 80s: energy came from hydroelectricity
  - Gradual dependence on imported fossil fuels
  - In 2012:
    - ➢ Fossils represent 87.2% of primary energy
    - ➢ 65% of the power is generated by fossil fuel

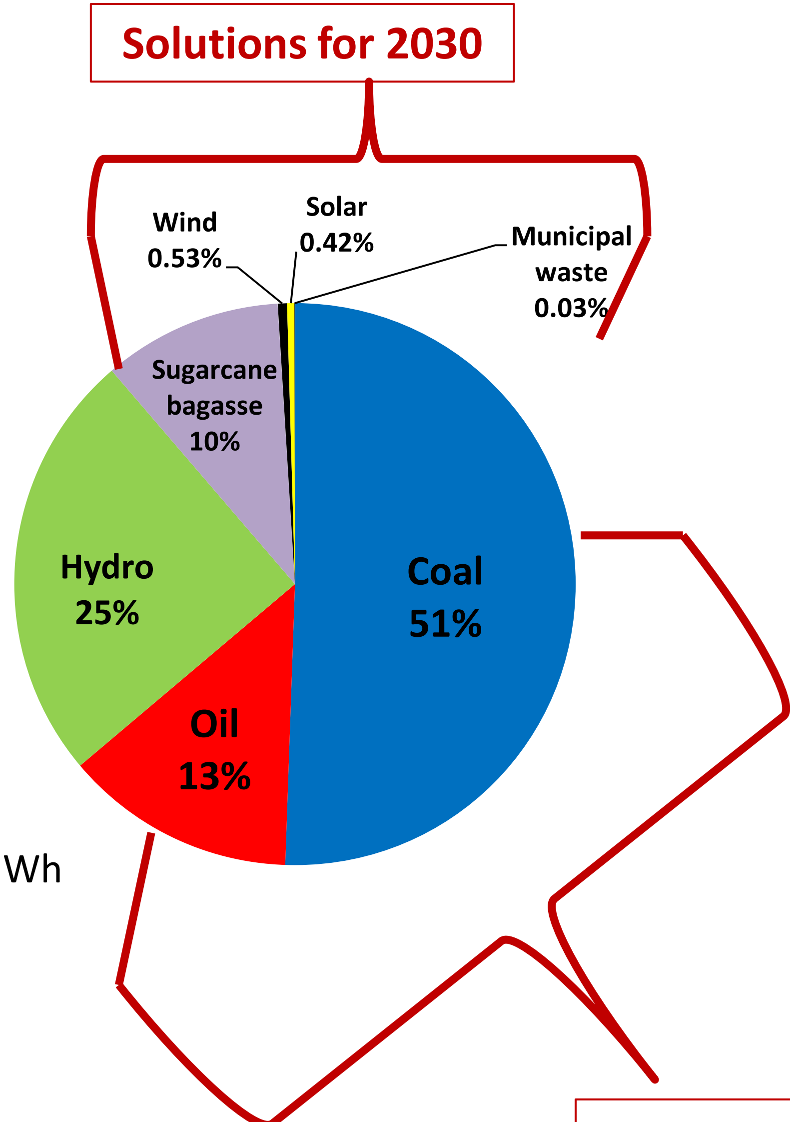

- High potential of renewable energy sources (Solar, Wind, Geothermal, Ocean energy (wave et OTEC), Biomass, Hydropower)
- Autonomy objective by 2030 → 100% RE

# TIMES model of the Reunion Island's electric system

*Conception of the model: PhD of Mathilde DROUINEAU (2012)*



# Electricity production in 2008




2 546 GWh

Zero imported fuel by 2030

*Source: BPPI – EDF SEI 2009*

## Installed capacities

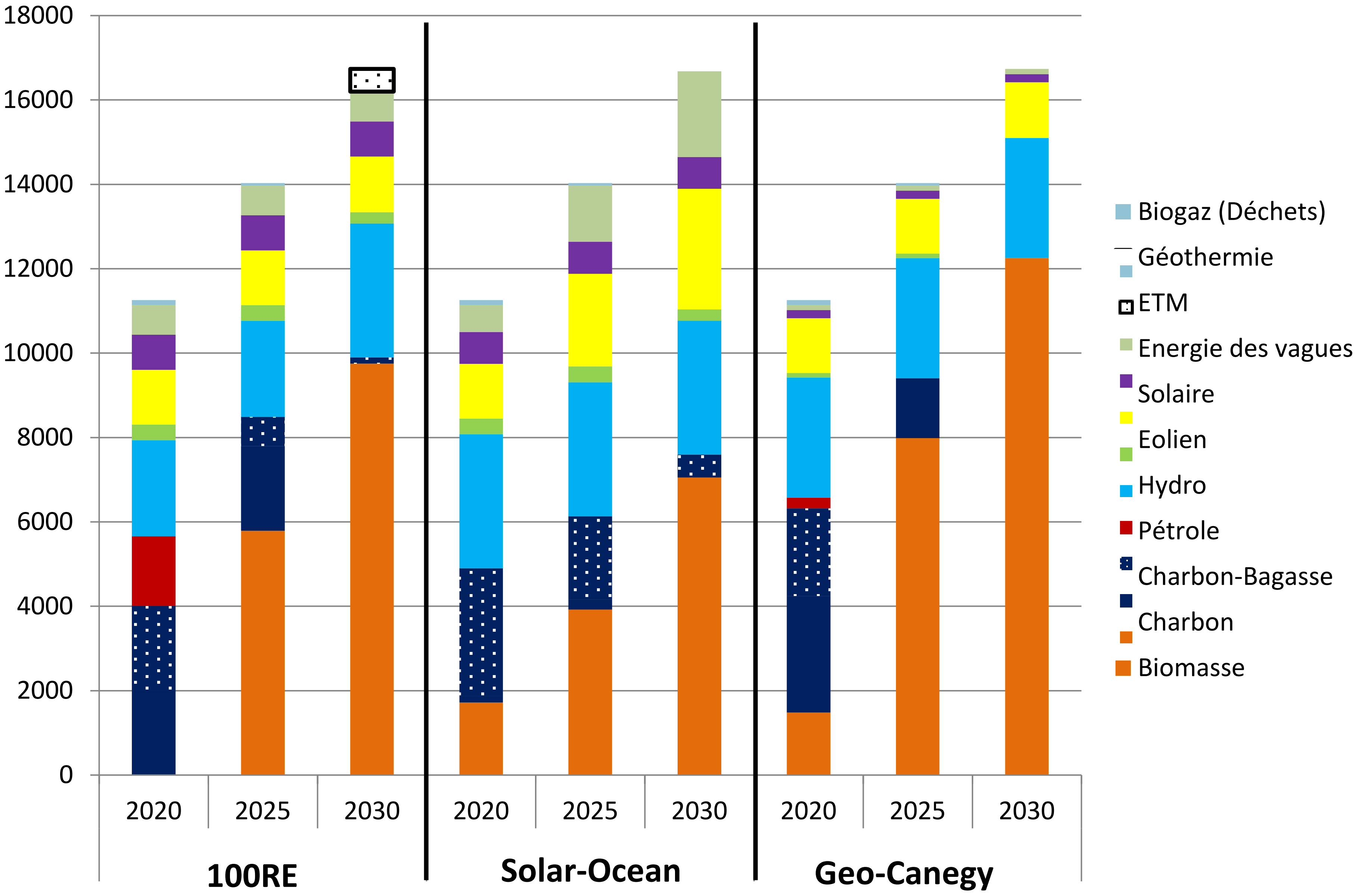
- Thermal Power Plants (76%)
  - 476 MW
  - Coal, oil, bagasse
- Hydropower (20%)
  - Dam: 109.4 MW
  - Run of river: 11.6 MW
- Other installations (4%)
  - Wind power: 16.8 MW
  - Solar: 10 MW
  - Municipal waste: 2 MW

# Scenarios specification: Autonomy objective by 2030

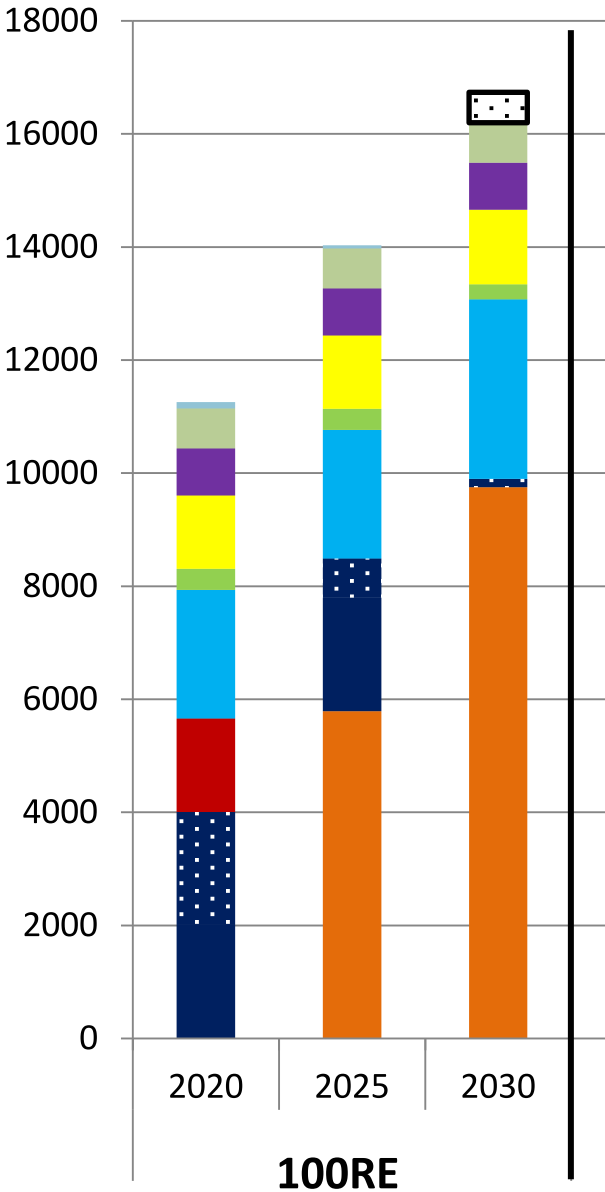
Examine the change in the current production pattern in order to move toward a 100% renewable mix by 2030

| Scenarios | | | | |
|---|---|---|---|---|
| | **Business As Usual (BAU)** | **AUTONOMY – 100%RE** | | |
| **Specificities** | No specific energy policy is assumed | **No more fossil fuel**, induced by strong policy | | |
| | | **100RE** | **Solar-Ocean** | **Geo-Canegy** |
| | | 300 MW solar in 2020 | Photovoltaic (700 MW) and ocean energy (150 MW) system are largely developed | Geothermal energy and 100% sugarcane to energy |
| **Exogenous demand evolution** | Median scenario of EDF | Scenario Energy Demand Control (EDC) and Electric Cars (EC) | | |

# Electricity production (TJ): Modification of the current production modes to tend towards a system able to answer energy challenges



# Electricity production (TJ): 100% renewables




**100 RE Scenario**

- Fossil fuel consumption decrease: from 2020, 50% of electricity is produced from renewable energies

- Geothermal energy (from 2015, site of Salazie)

- Wind, Solar and Ocean energies

- High development of biomass from 2025 2030: it represents more than 50%

- End of oil after 2020

- End of coal after 2025

# Electricity production (TJ): Solar and ocean energy support

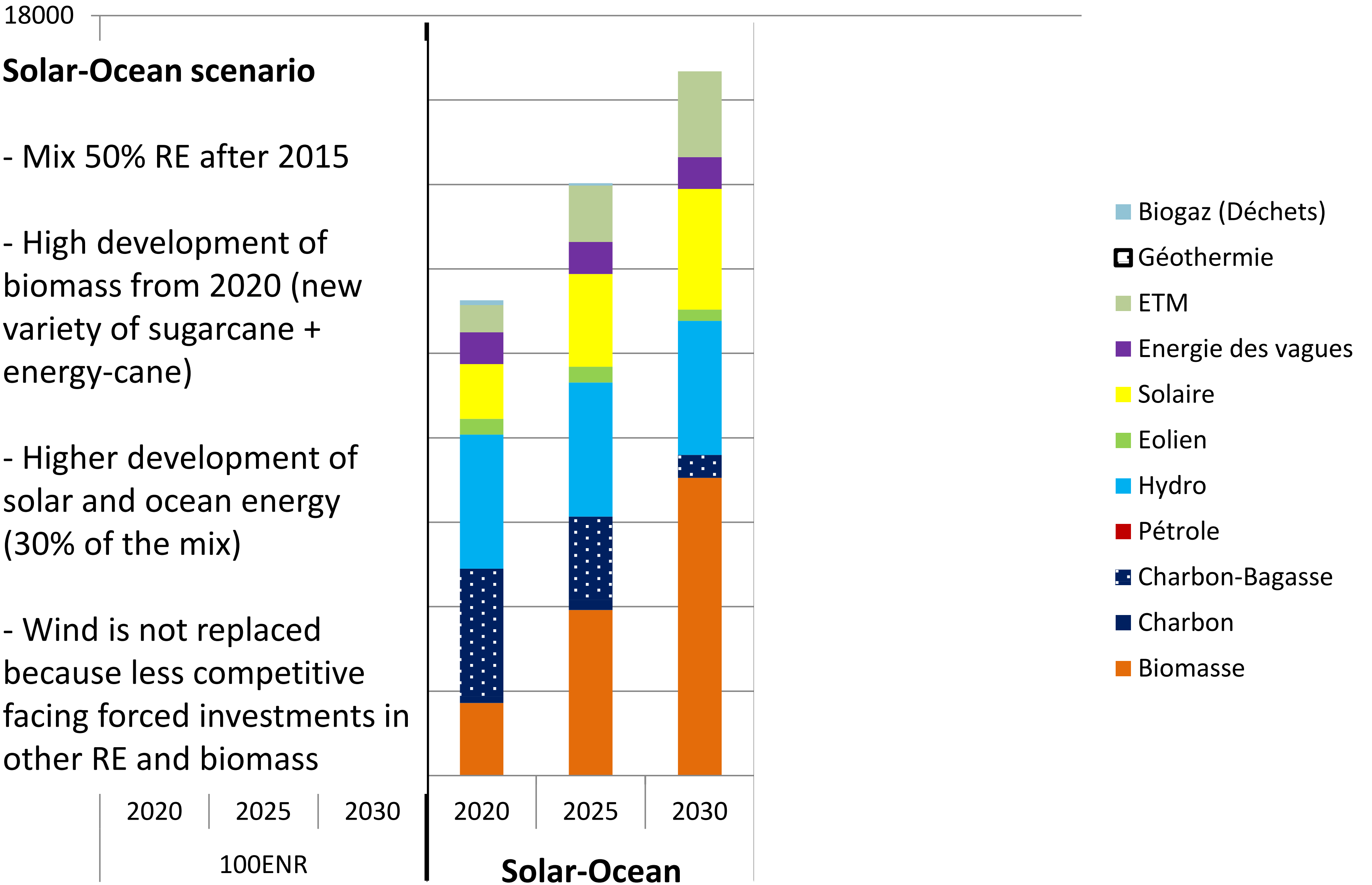
**Solar-Ocean scenario**

- Mix 50% RE after 2015

- High development of biomass from 2020 (new variety of sugarcane + energy-cane)

- Higher development of solar and ocean energy (30% of the mix)

- Wind is not replaced because less competitive facing forced investments in other RE and biomass



# Electricity production (TJ): Geothermal + bioenergy support

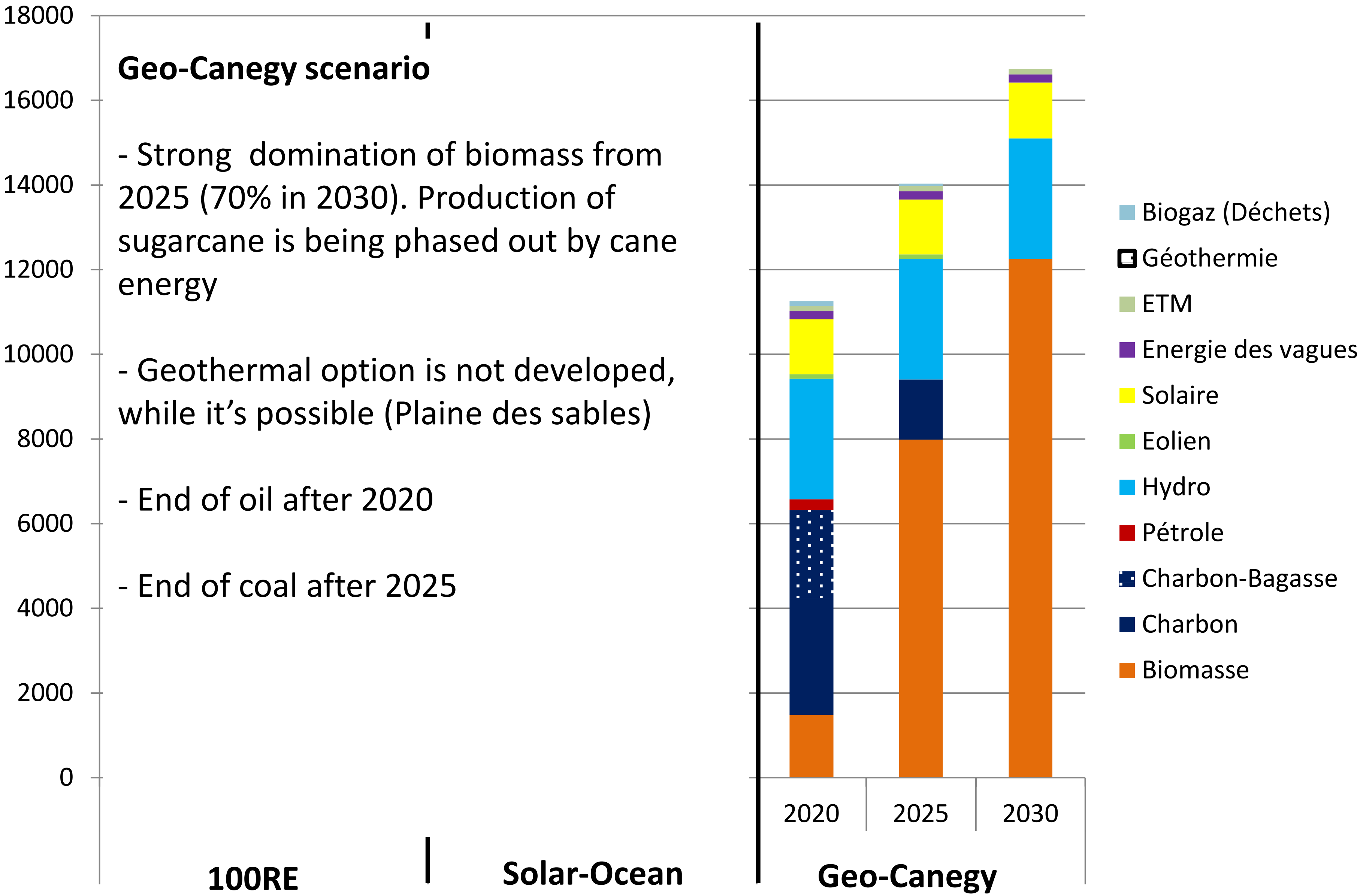
**Geo-Canegy scenario**

- Strong domination of biomass from 2025 (70% in 2030). Production of sugarcane is being phased out by cane energy

- Geothermal option is not developed, while it's possible (Plaine des sables)

- End of oil after 2020

- End of coal after 2025



# 100% renewable pathways by 2030

| Energy | | 100RE | Solar-Ocean | Geo-Canegy |
|---|---|---|---|---|
| **Fossil Energies** | **Coal** | <50% from 2020 | <50% from 2015 | <50% from 2015 |
| | **Oil** | | | |
| **Renewable Energies** | **Solar** | Peak in 25% - 2020 (17%) | Strong dvt from 2020 (30%) | Peak in 14% - 2020 (10%) |
| | **OTE** | | | |
| | **Wind** | Almost Disappear (1,6%) | Almost Disappear (1,6%) | Disappear in 2025 |
| | **Biomass** | > 50% in 2030 | Dvt from 2020 (40%) | Strong domination from 2025 (73%) |
| | **Geothermal** | Appear in 2030 | - | No Appear |
| **System cost (objective function variation compare to BAU** | | **+15%** | **+24%** | **+8%** |

# The challenges of an energy transition and territorial autonomy

- Modes of electricity production in the face of energy challenges
  - Which modes to favor?
  - When to invest?
  - Energy policy design (Incentives)

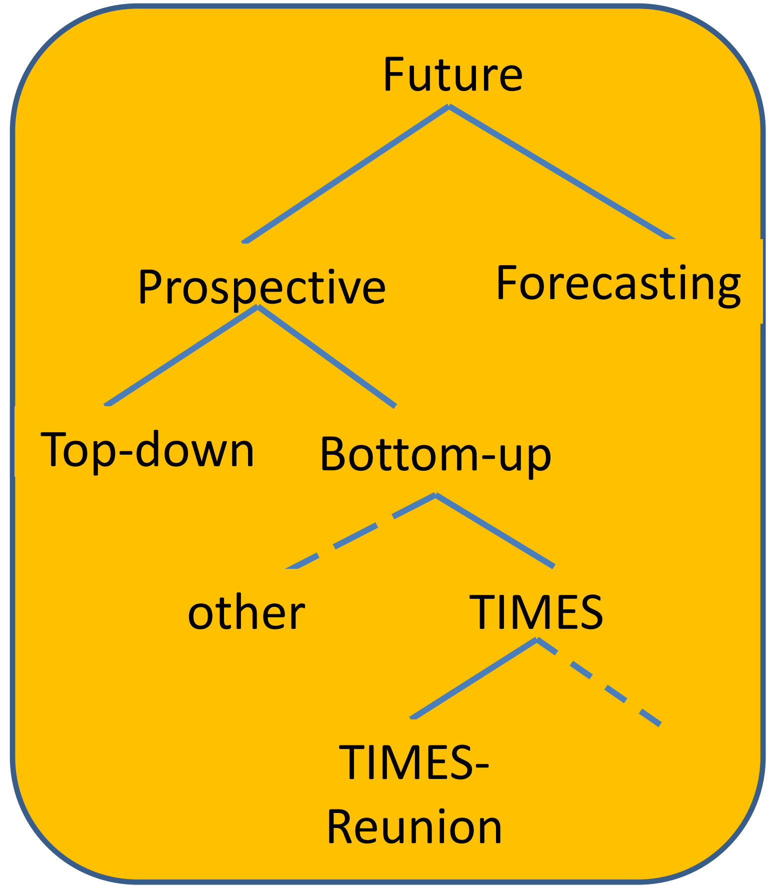
- Massive use of biomass
  - What potential of biomass? Sustainable use.
  - What types of biomass? Future of the sectors (sugar sector)
  - What expansion of waste-to-energy projects?

- Strong participation of renewable energies and in particular of variable production

- Energy transition have a cost but the potential of renewable energies is important
- Solar and marine energies are not the most cost effective option
- The development of biomass is economically more interesting

# Thanks for your attention!

- **Does NOT plan le future**
- Bottom-up technological model
- System representation
  => Very disaggregated where the various technological processes are explicitly represented
- Model structure: reference energetic system
  – Technology database of whole system (extract., production transformation, exchange, use)
  – Technical-economics parameter for each technology (cost, efficiency, life cycle, gas emissions, etc.)



# Les technologies utilisées
## (Paramètres issues de RES 2020)

| Ressources | Technologies | Capacité d'une unité (MW) |
|---|---|---|
| Fioul lourd | Turbines vapeur | 10 à 80 |
| | Moteurs diesel (au Port) | $3 \times 18,3$ |
| | Turbines diesel | 10 à 80 |
| Fioul domestique | TAC | 10 à 80 |
| Charbon | Turbines vapeur | 20 à 80 |
| | IGCC (gazéification) | 20 à 80 |
| Charbon / Bagasse / Canne fibre | Turbines vapeur | 20 à 80 |
| Bagasse / Canne fibre | Turbines vapeur | 20 à 80 |
| Biomasse | Turbines vapeur | 20 à 80 |
| | IGCC | 20 à 80 |
| Hydroélectricité | Fil de l'eau | $\leq 5$ |
| | Barrages | 5 à 30 |
| Éolien | *Onshore* | – |
| Solaire | Toitures PV | – |
| | Champs PV | – |
| | Thermodynamique à concentration | 5 à 80 |
| Géothermie | Turbines vapeur | 5 à 40 |
| | Roches chaudes sèches | 5 à 20 |
| Énergies marines | Houlomotrice | 3 à 60 |
| | Énergie thermique des mers | 1 à 55 |

*Source: DROUINEAU, 2012*

# Renewable potentials

| Energy sources | 2008 | Potentials |
|---|---|---|
| Biomass | 260 GWh* | 400 GWh* |
| Hydro | 121 MW<br>553 GWh* | 177 MW (by 2012)<br>268 MW (after) |
| Wind | 16.8 MW | 50 MW |
| Solar PV | 10 MW | 160 MW |
| Ocean thermal energy | | 10 MW in 2020<br>100 MW in 2030 |
| Wave energy | | 30 MW |
| Geothermy | | 30 MW |
| Storage capacity | | 1 MW in 2009<br>10 MW |

# Demand evolution

| Scénario | 2008 | 2010 | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|---|---|
| **Médian** | | | | | | |
| Electricité livrée (GWh) | 2546 | 2710 | 3110 | 3500 | 3805 | 4100 |
| Electricité consommée (GWh) | 2318 | 2467 | 2831 | 3187 | 3464 | 3732 |
| TCAM (%) | | 3,2 | 2,8 | 2,4 | 1,7 | 1,5 |
| Puissance de pointe (MW) | 408 | 445 | 520 | 595 | 670 | 750 |
| TCAM – puissance (%) | | 4,4 | 3,2 | 2,7 | 2,4 | 2,3 |
| **MDE - Renforcée** | | | | | | |
| Electricité livrée (GWh) | 2546 | 2705 | 3020 | 3130 | 3200 | 3248 |
| Electricité consommée (GWh) | 2318 | 2463 | 2750 | 2850 | 2913 | 2957 |
| TCAM (%) | | 3,1 | 2,2 | 0,7 | 0,4 | 0,3 |
| Puissance de pointe (MW) | 408 | 435 | 480 | 521 | 560 | 596 |
| TCAM – puissance (%) | | 3,3 | 2 | 1,7 | 1,5 | 1,3 |
| **Véhicules électriques** | | | | | | |
| Electricité livrée (GWh) | | | | 0 | | 1400 |

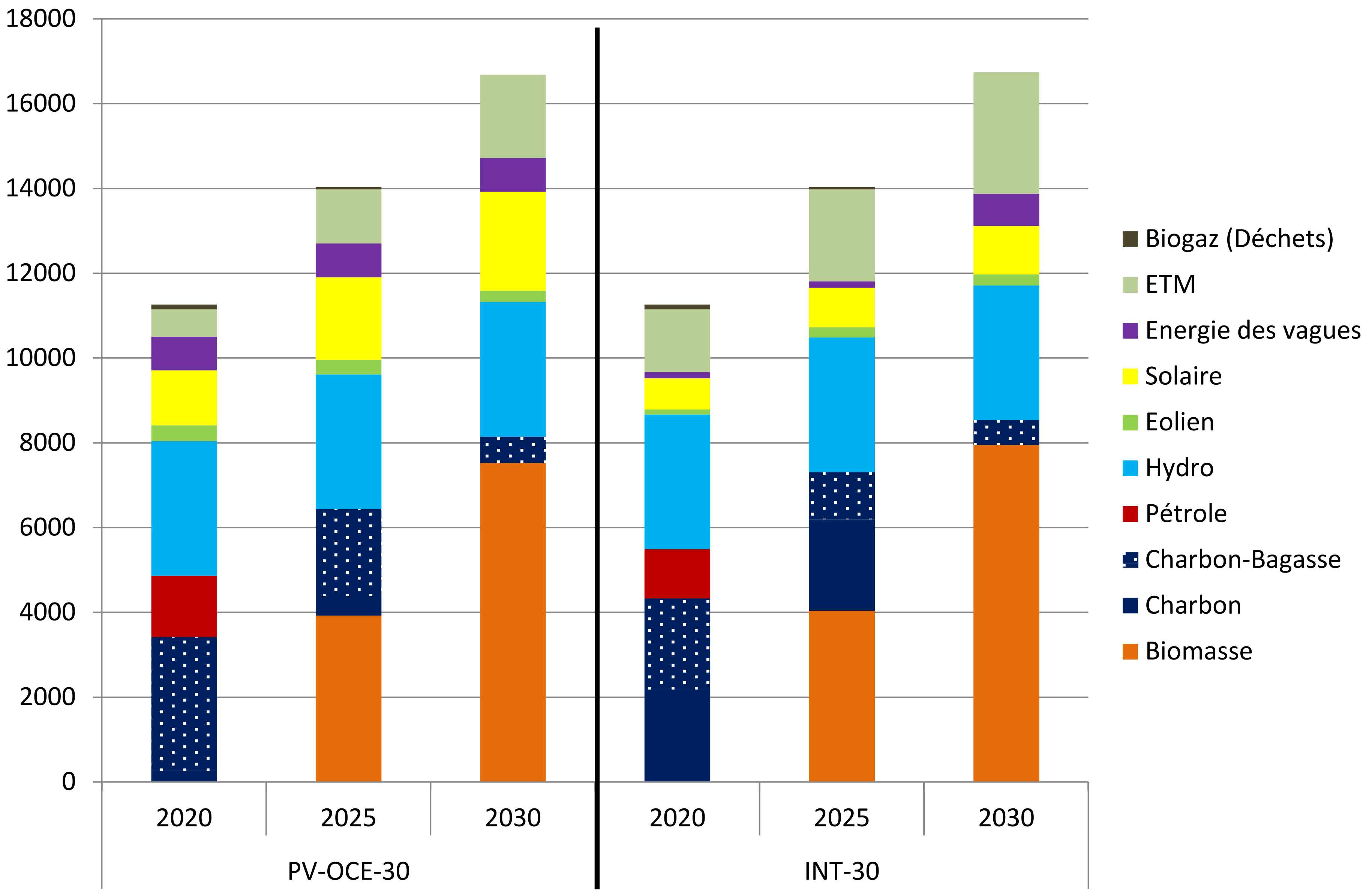
*Source: DROUINEAU, 2012*

# Gestion de l’intermittence

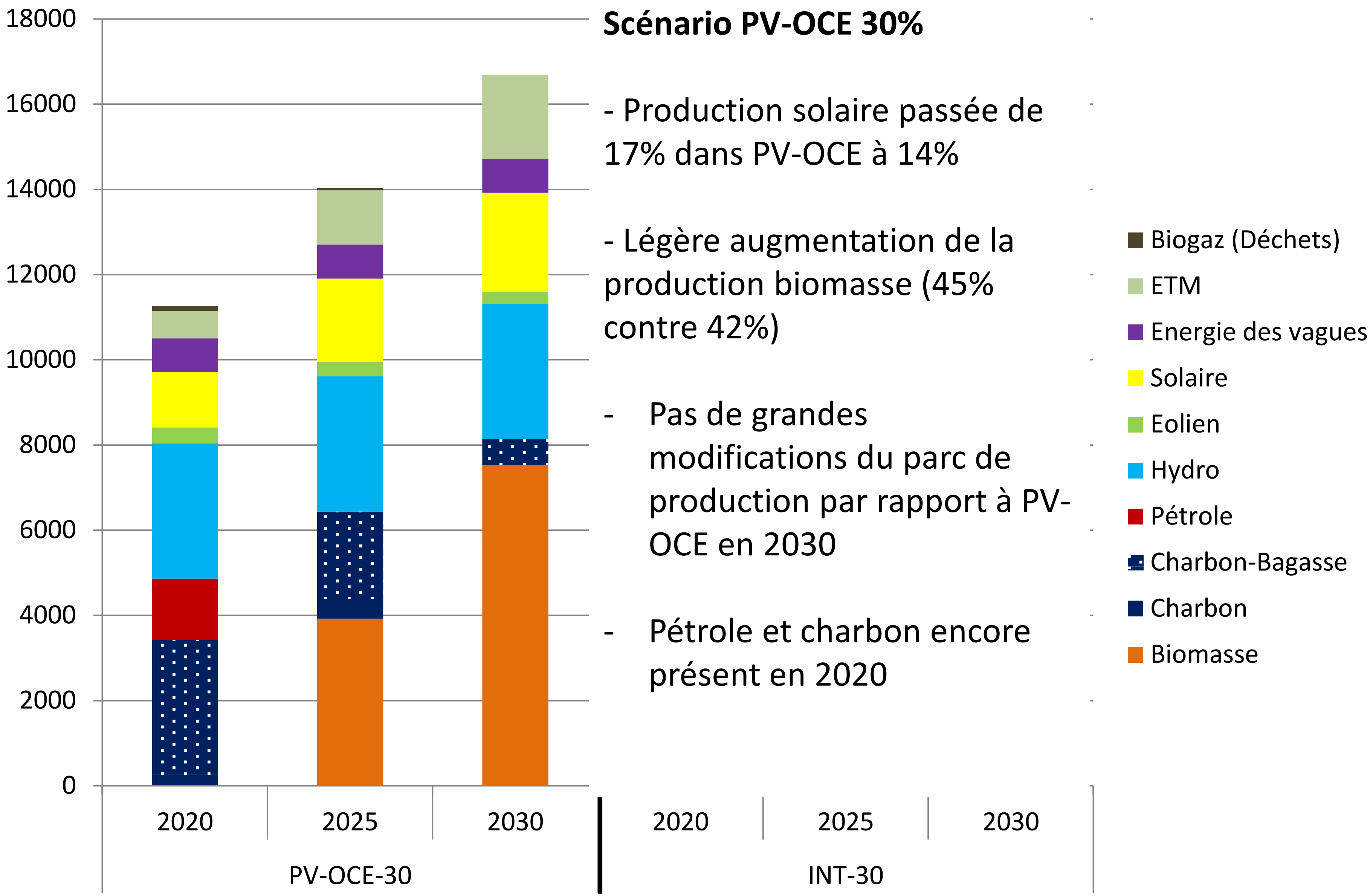
| Scénarios | Spécificités | | |
|---|---|---|---|
| 100ENR | Potentiels EnR Max | 100% EnR | Déploiement solaire minimal dès 2020 – 300 MW |
| PV-OCE | | | Plus de solaire (700 MW) et d’énergie marine (150 MW) |
| Rupture | | | Plus de géothermie et 100% canne-énergie |
| **PV-OCE 30%** | | | PV-OCE + Règle des 30 % d’exploitation du système électrique |
| **INT 30%** | | | Règle des 30 % + contrainte solaire plus cohérente avec la règle d’exploitation (175 MW en 2020 et 260 en 2030, selon EDF) |

*Dans les deux scénarios, développement élevé des énergies marines conservé (≥100 MW pour ETM et ≥ 50 MW pour Energie des vagues)*

# Production d'électricité (TJ) : Gestion de l'intermittence



# Production d’électricité (TJ) : Gestion de l’intermittence




**Scénario PV-OCE 30%**

- Production solaire passée de 17% dans PV-OCE à 14%

- Légère augmentation de la production biomasse (45% contre 42%)

- Pas de grandes modifications du parc de production par rapport à PV-OCE en 2030

- Pétrole et charbon encore présent en 2020

# Production d'électricité (TJ) : Gestion de l'intermittence

**Scénario INT-30**

- Production solaire représentant 7% et celle de la biomasse près de 48%

- Mix électrique plus impacté en raison de la limitation du solaire

- Recours plus important au centrale thermique : charbon et biomasse

- Développement plus important de ETM

- Pétrole en 2020

- Charbon en 2025