The TalTech Estonian Maritime Academy Summer School, "Operational measures to decrease greenhouse gas (GHG) emissions in shipping"

19-23 May, 2025 Tallinn, Estonia

Three-sided Energy Management Strategy of a PV-Wind-Battery Hybrid System with the Electric Vehicle Collaboration

Presenter :

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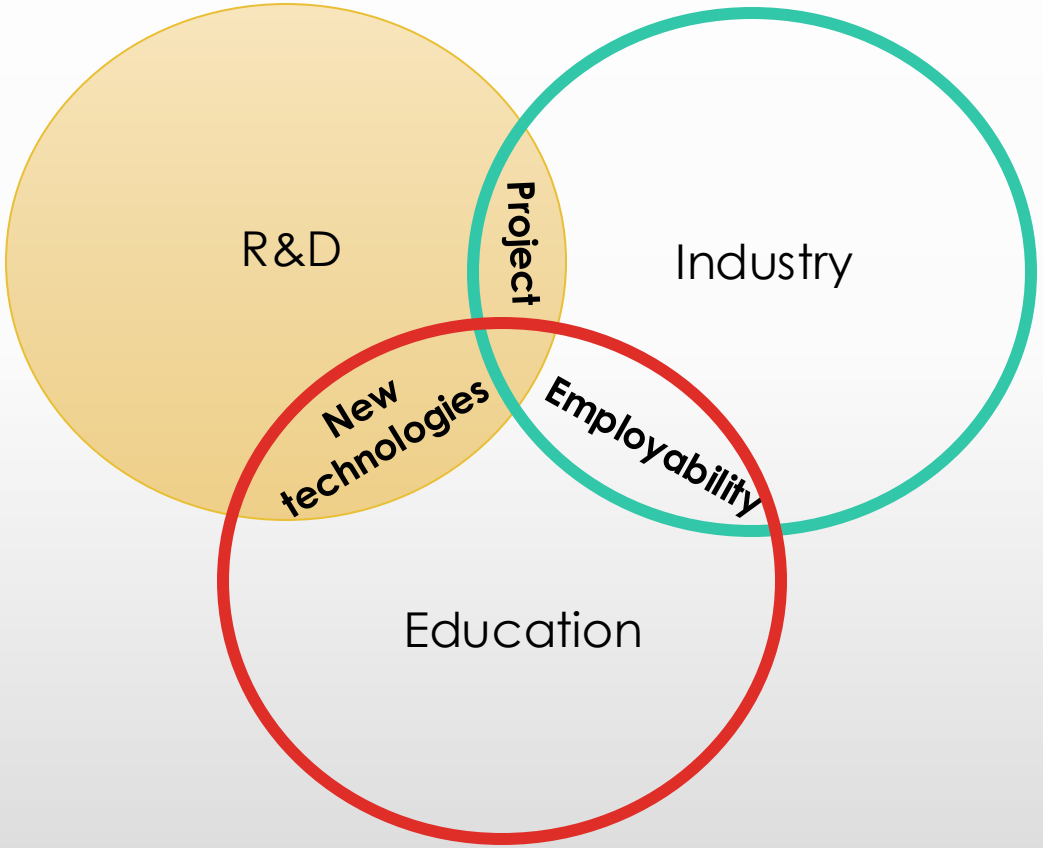
OUR STRATEGY



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- Industrie du futur.
- IoT / IIoT.
- Big data.
- IA / ML .
- Logistique 4.0.
- Connected mobility.
- Energy / energy efficiency.
- Optimisation / maintenance.
- Medical robotics.
- Embedded systems.
- Augmented reality.

CONFERENCE

- JDSI'2016
- INTIS'2017
- IEEE REPS-GIE'2018
- SS IEEE REPS-GIE'2018
- SS IEEE WINCOM'2018
- WiES 2019
- IEEE Systol'2019
- ICACNi'2020
- CCOA-EMSI industrie 4.0 2022
- INTIS'2022
- IEEE ICM 2022
- MASSAI 2023
- TMREES 2025
- IEEE ICECS 2025

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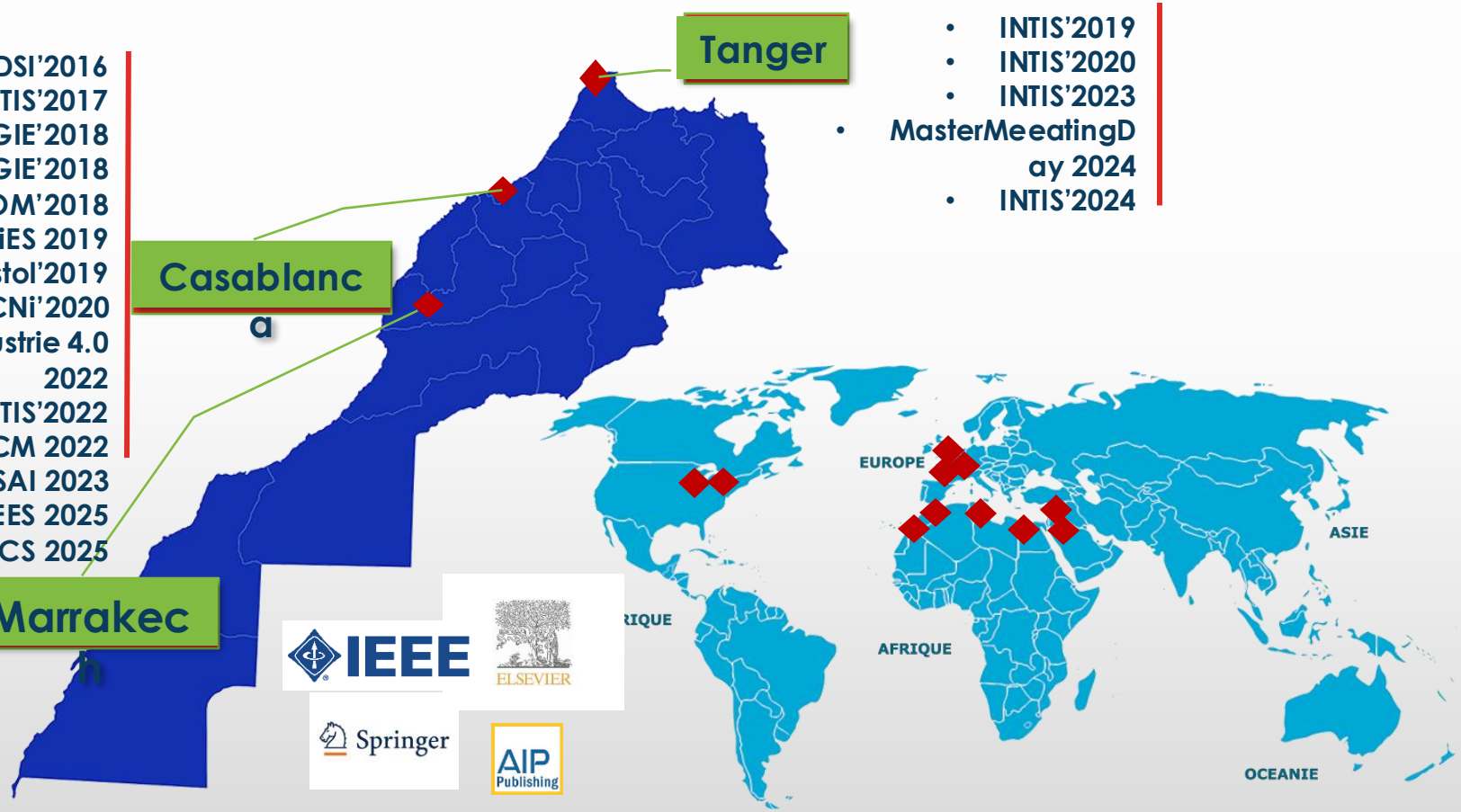
- JDSI' 2017
- ASD' 2018
- INTIS'2018

Marrakech

Tanger

- INTIS'2019
- INTIS'2020
- INTIS'2023
- MasterMeeatingDay 2024
- INTIS'2024



France	IEEE NEWCAS 2017
Liban	29th IEEE ICM 2017
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Canada	FloE 2019
Egypt	31th IEEE ICM 2018
Belgique	FloE 2020
Grèce	TMREES 2020
Grèce	TMREES 2021
Belgique	FloE 2021
France	TMREES 2022
Canada	FloE 2022
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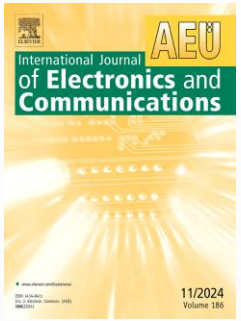
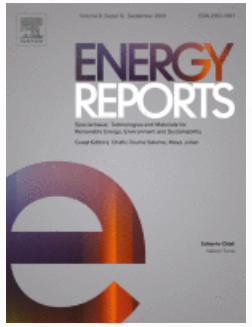
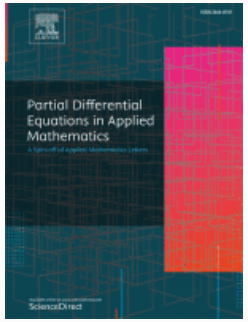
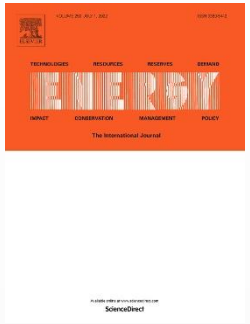
Belgique	FloE 2023
France	TMREES 2024

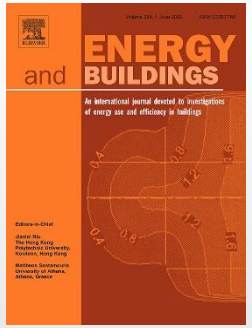
SCIENTIFIC PUBLICATIONS - 2023 / 2025

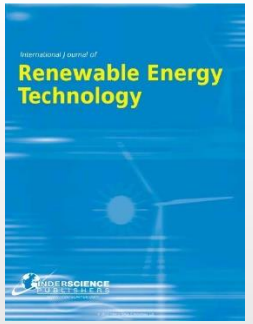


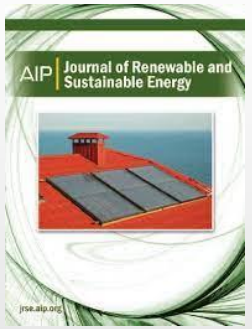


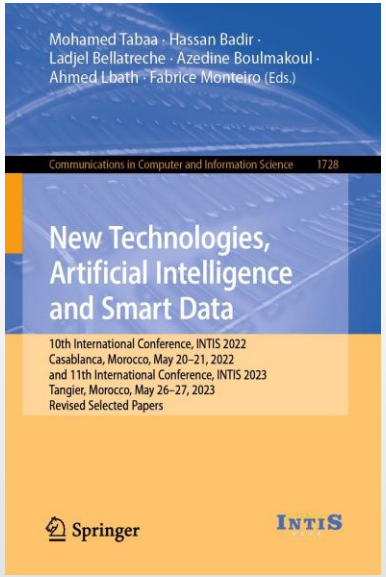












sensors

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IOP Conference Series
Earth and Environmental Science

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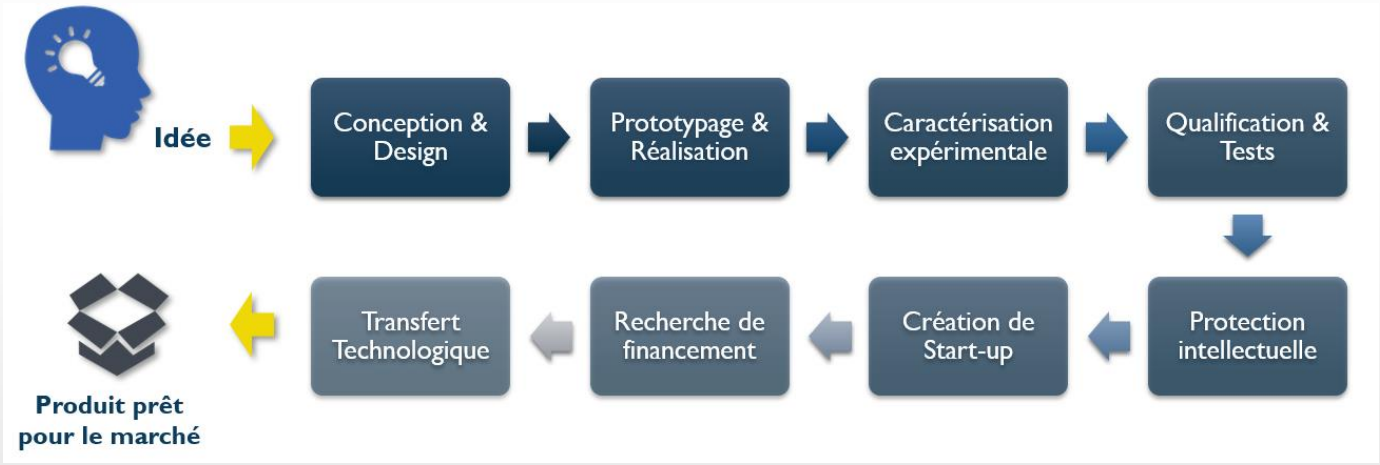
Idée
Conception & Design
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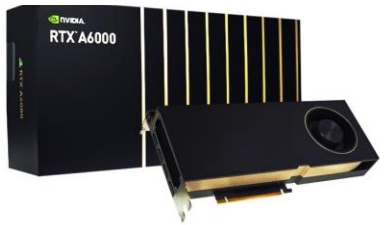
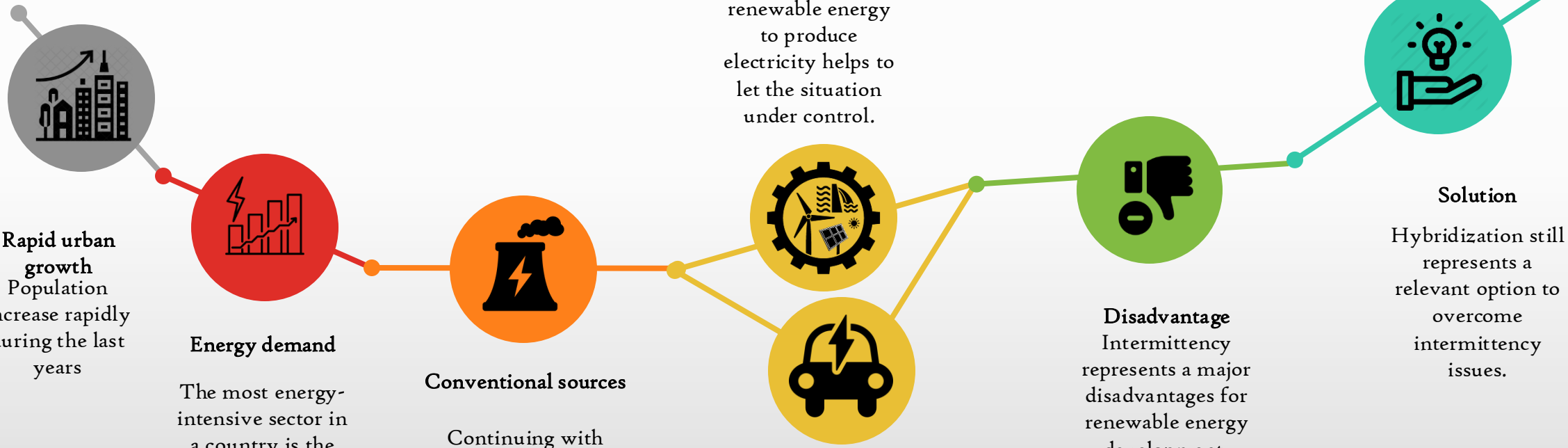


Presentation outline

1. Renewable & Electric vehicle system hybridization
2. Energy storage management system
3. Findings and discussion
4. Conclusions and future works



Rapid urban growth
Population increase rapidly during the last years

Energy demand
The most energy-intensive sector in a country is the residential one

Conventional sources
Continuing with conventional production further intensifies the negative effects, especially the environmental impacts.

Renewable sources
The use of renewable energy to produce electricity helps to let the situation under control.

Electric transportation
The use electric vehicle help with fossil energy consumption

Disadvantage
Intermittency represents a major disadvantages for renewable energy development, especially for system with single source production.

Solution
Hybridization still represents a relevant option to overcome intermittency issues.

Sizing

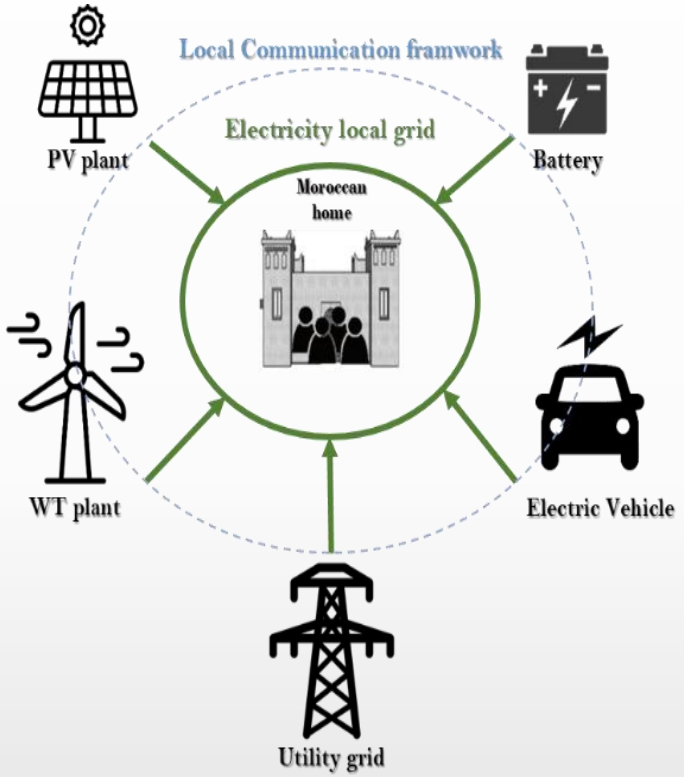
The first step to develop a relevant hybrid renewable energy system

Maximum power point tracking

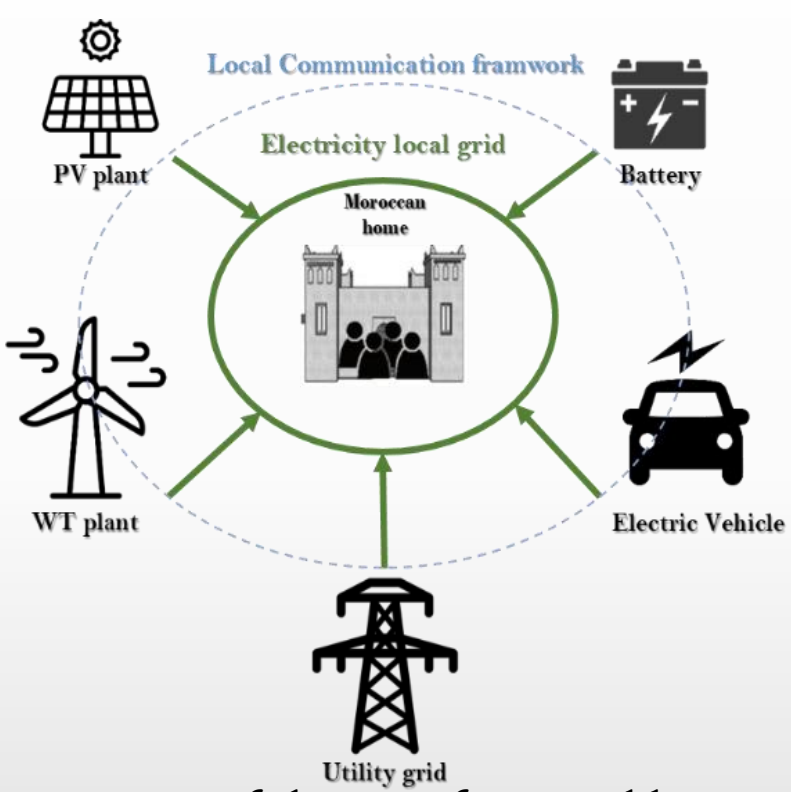
for renewable energies, the operation point is not essentially situated on the maximum power point.

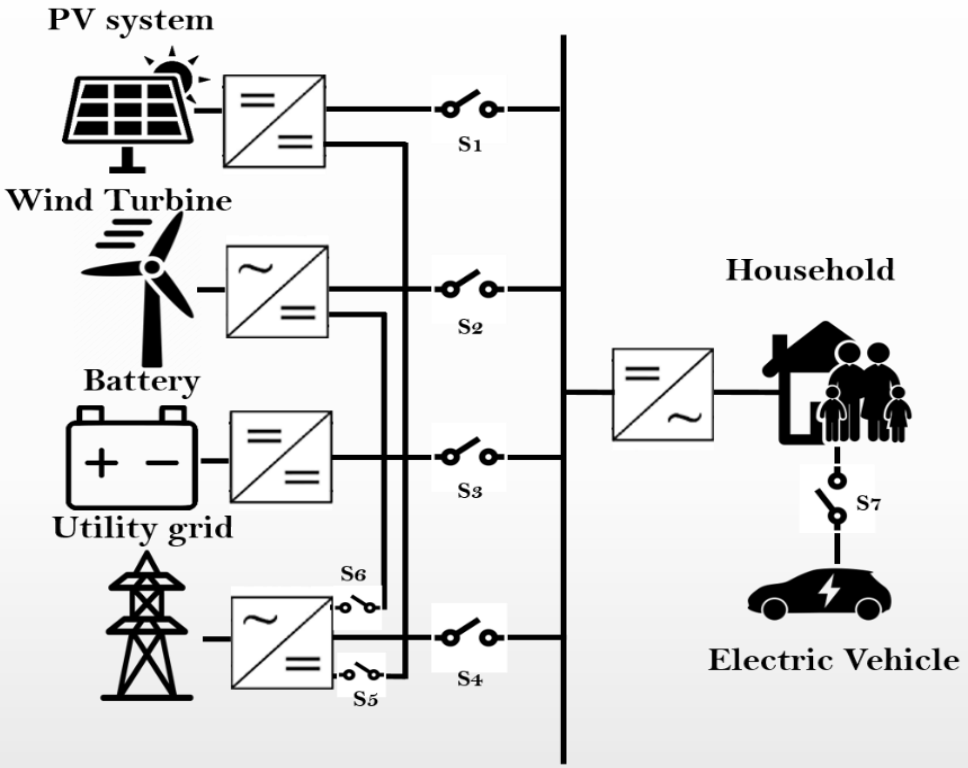
Energy management

The latter is an important aspect because it is strongly influenced by the application and have a direct impact on other aspects.



Combining optimization on two sides, namely: source side and demand side management. With the presence of electric vehicle. The both sides were developed with rule-based method.

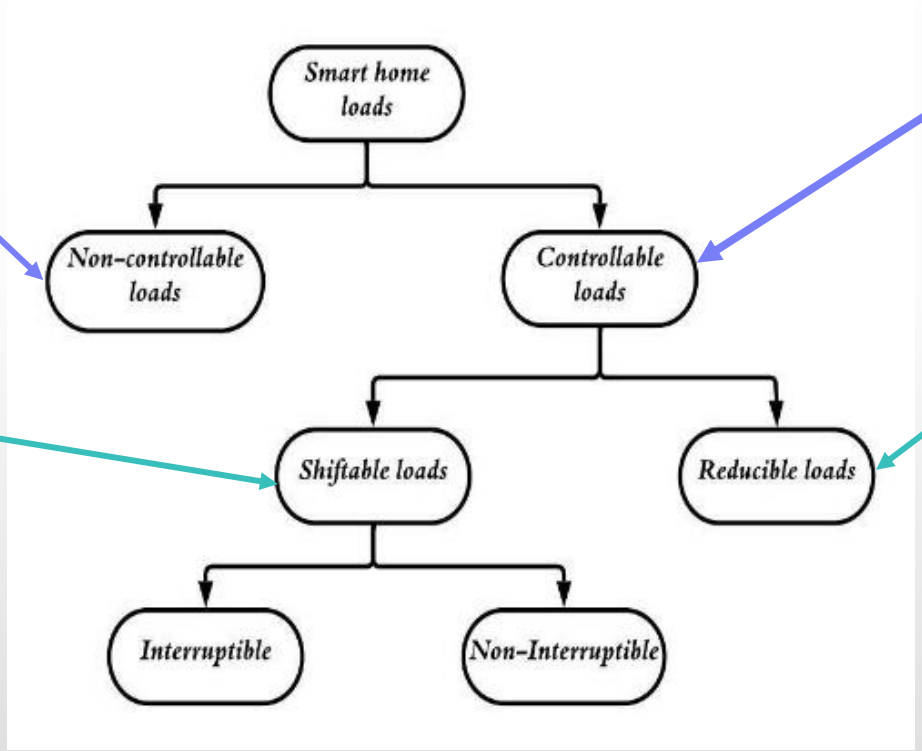




1. The promotion of the use of renewable energy for electricity production.
2. The optimization of the energy made available for a Moroccan household using a HRES.
3. The promotion of the electrical vehicle use for urban mobility.

Loads that influence directly the electricity consumers comfort

Loads the could be managed depending on the energy demand



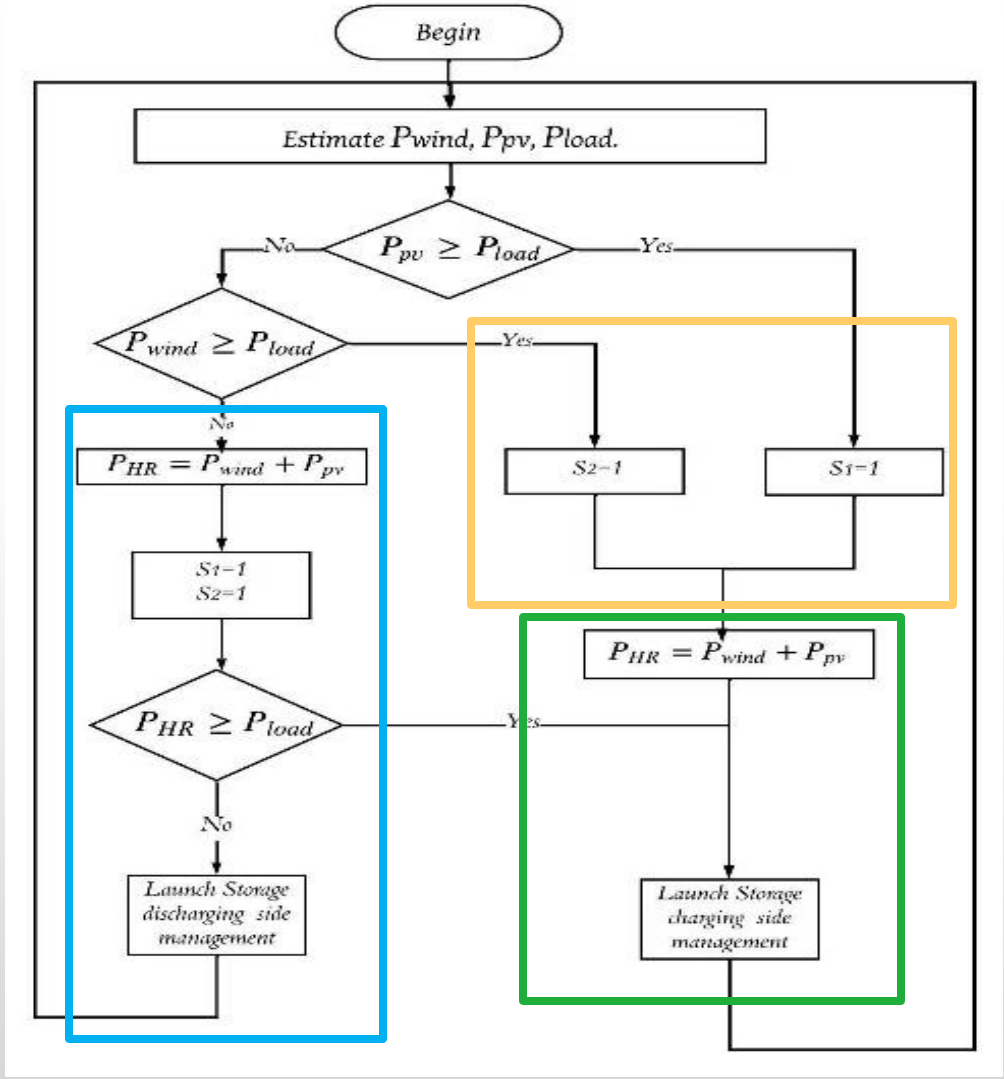
loads that could be turned off during energy deficit

Loads that their power could be reduced to meet the available power production.

Source side energy management algorithm

The system is divided into four main scenarios:

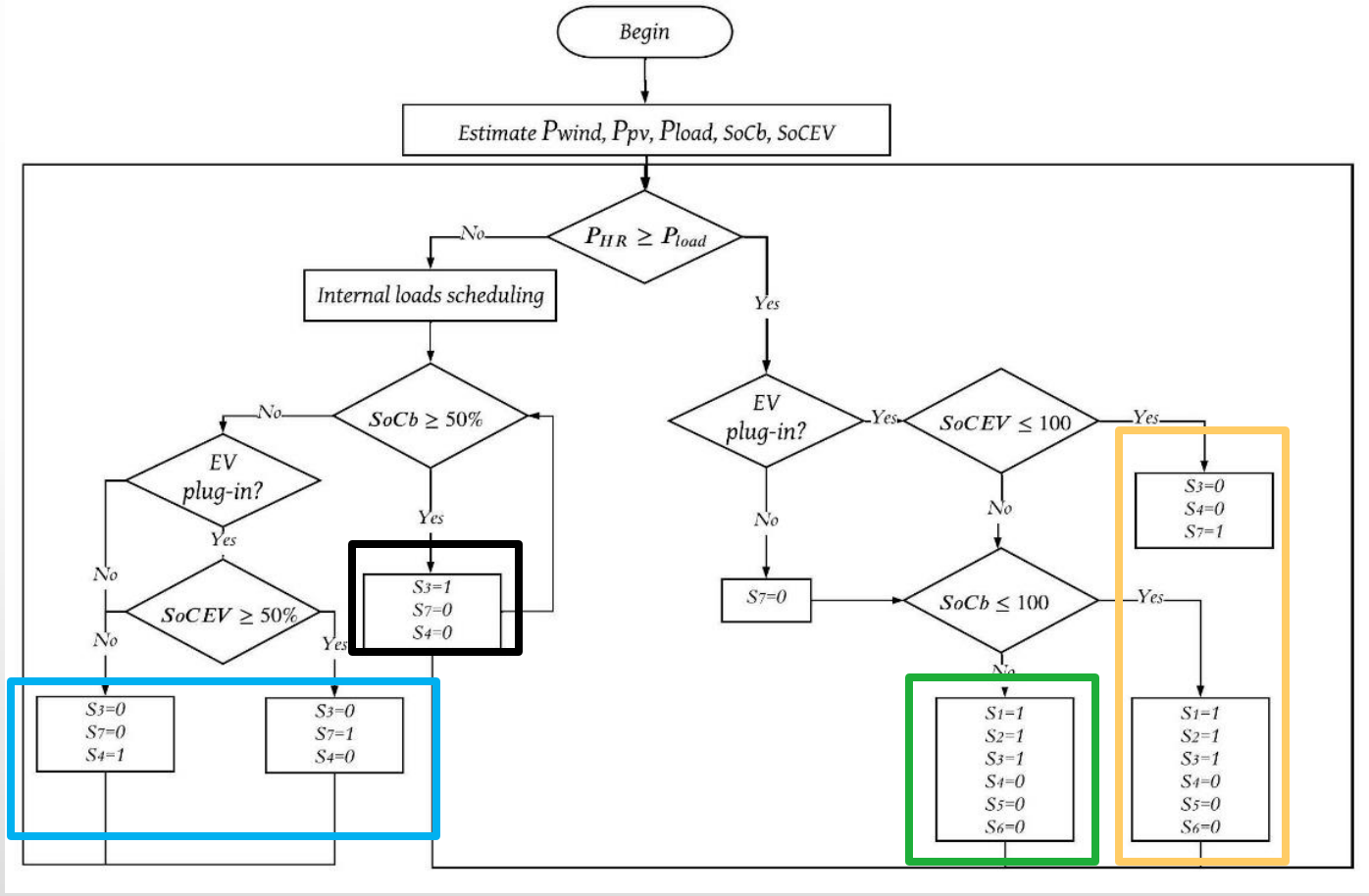
- **Case N°1:** Just one source could cover the consumption;
- **Case N°2:** The hybrid system is not able to ensure the energy demanded by the charge consumption;
- **Case N°3:** The system is during a surplus mode;



Storage energy management algorithm

The system is divided into four main scenarios:

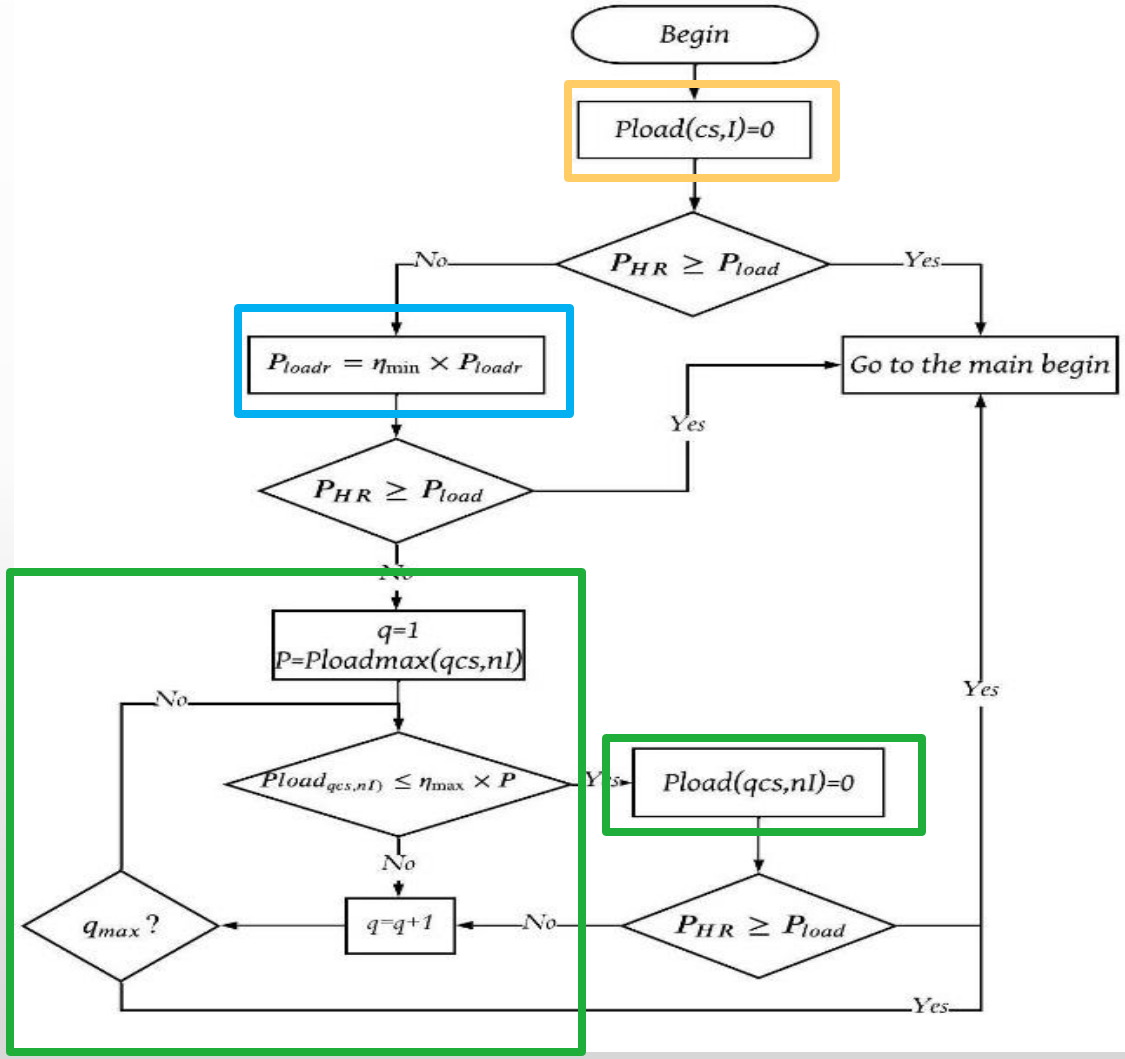
- **Case N°1:** The system is during charging mode (H2V);
- **Case N°2:** The system is during discharging mode (V2H);
- **Case N°3:** The system is during a surplus inject mode;
- **Case N°4:** The system is during a battery restore-powered.



Internal home loads scheduling

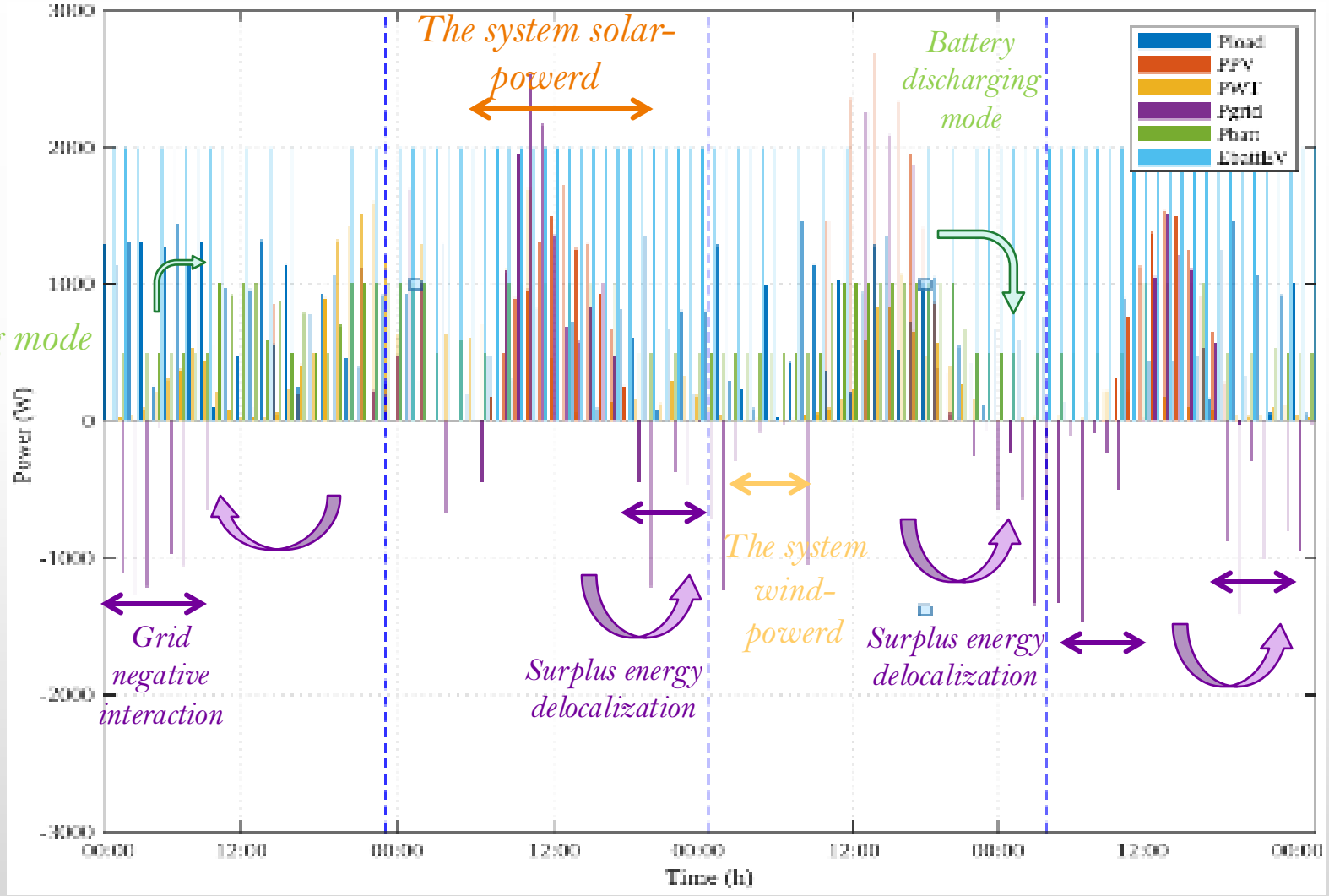
The system is divided into three steps :

- **Step N°1:** The system begins by shifting interruptible loads.
- **Step N°2:** The system decrease reducible loads;
- **Step N°3:** The system starts then shifting non-interruptible loads under specific conditions;



Energy management while launching source side management

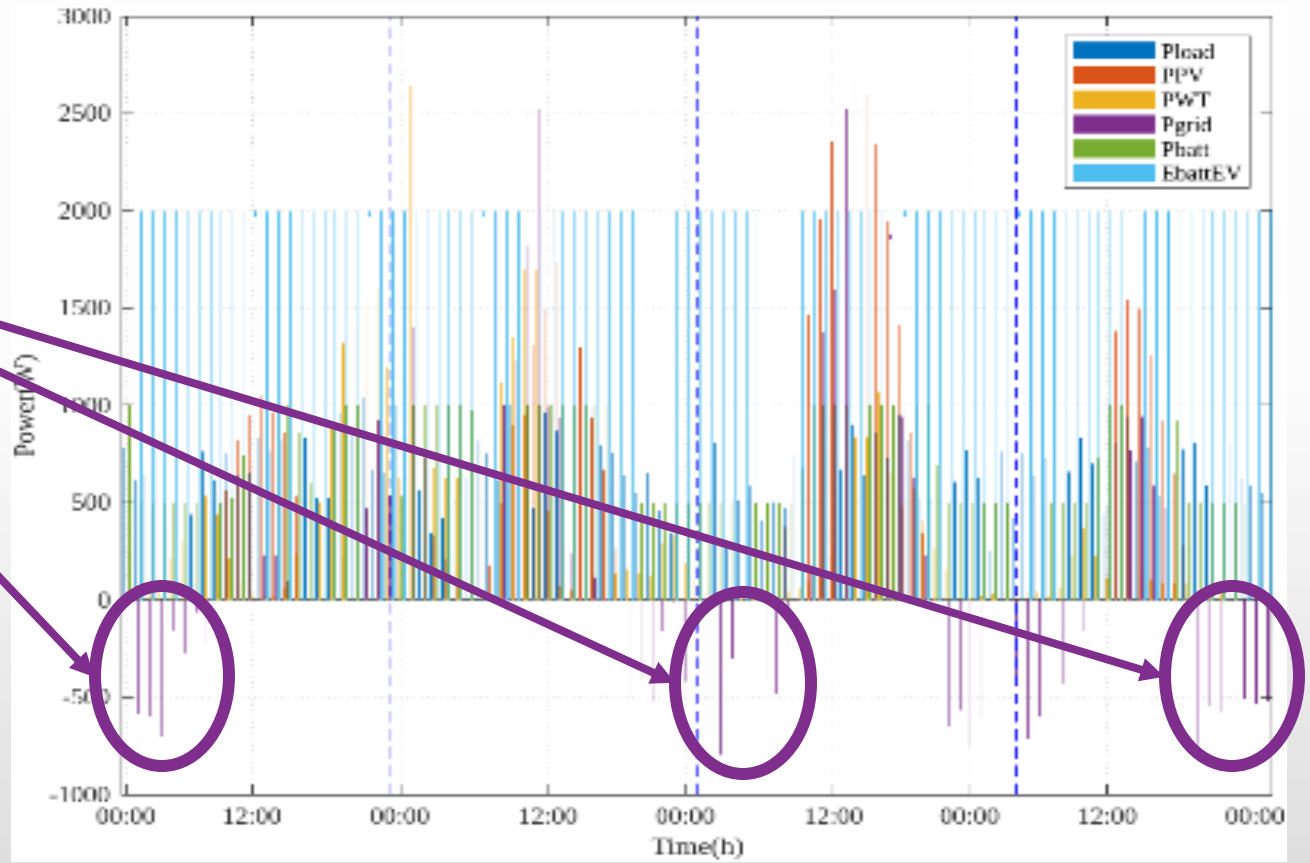
Battery charging mode



Energy management while launching load side management

Grid negative interaction

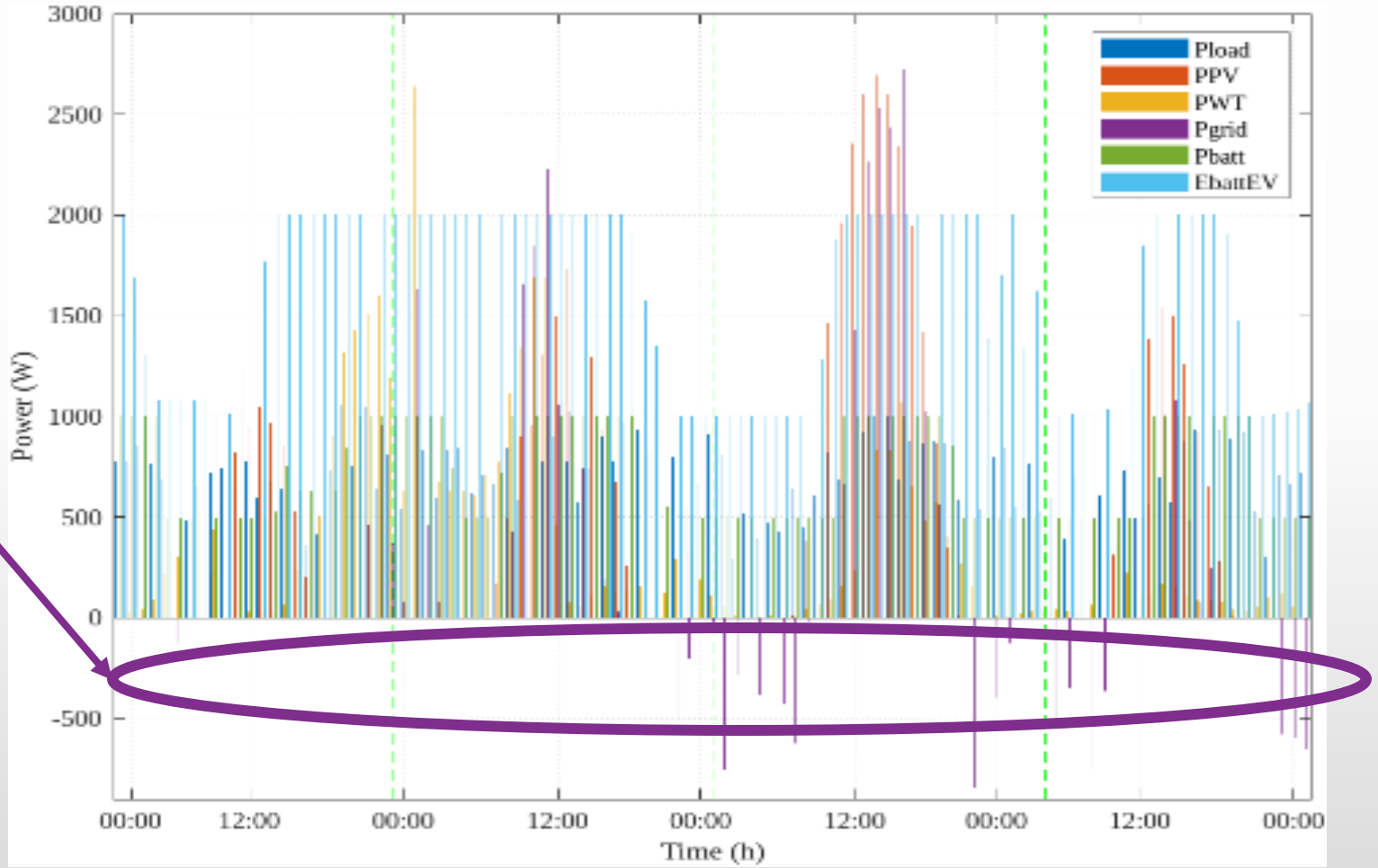
The period where the system consumes or recovers the injected energy to the grid was reduced.

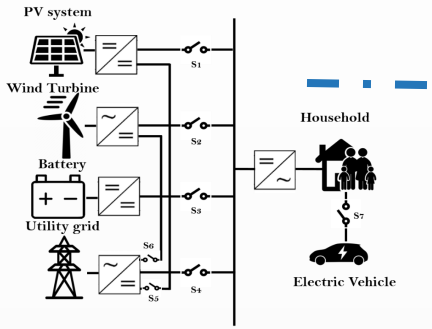


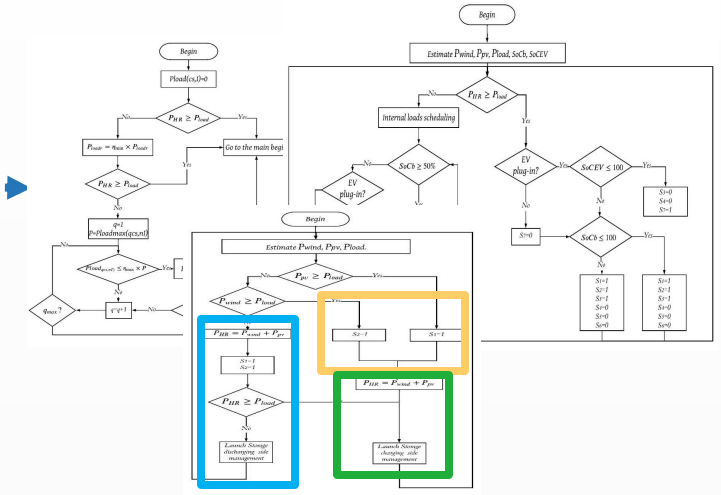
Energy management while launching storage side management with electric vehicle presence

Grid dependence

Critical loads were well served by the presence of the batteries and the electric vehicle.

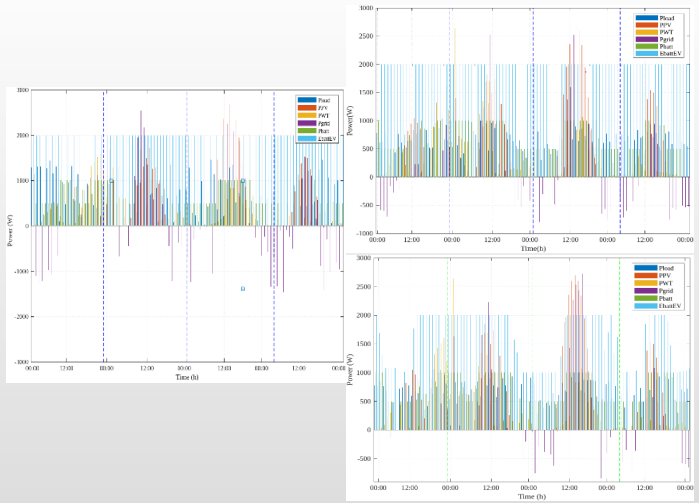






TRNSYS

Meteorological Data- TRNSYS



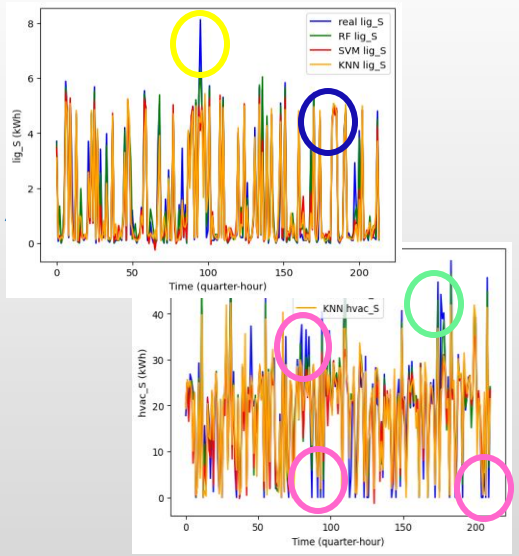
MATLAB SIMULINK

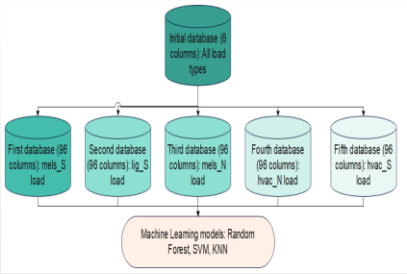
Dynamic Components behavior- MATLAB

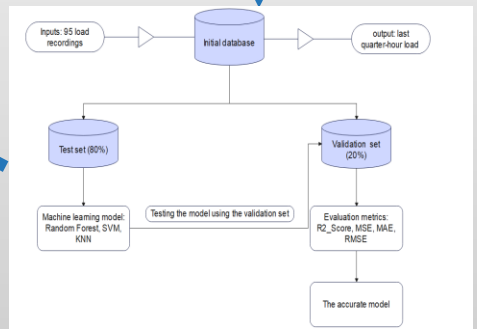
Different loads forecasting

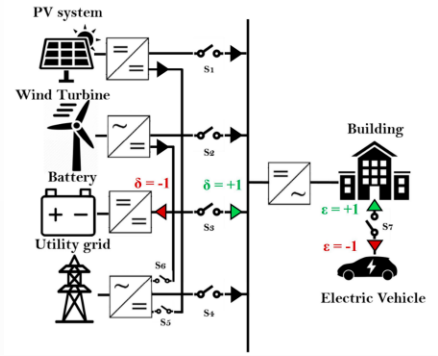
Machine learning Exploitation

Loads types	Random Forest		SVM		KNN	
Mels_S	R2_score	0.9859	R2_score	0.968	R2_score	0.9522
	MSE	0.093	MSE	0.20635	MSE	0.316
	MAE	0.166	MAE	0.257	MAE	0.3221
	RMSE	2.1904	RMSE	0.4542	RMSE	0.5629
Lig_S	R2_score	0.94031	R2_score	0.895	R2_score	0.8775
	MSE	0.2398	MSE	0.42	MSE	0.595
	MAE	0.2529	MAE	0.3596	MAE	0.4921
	RMSE	0.48974	RMSE	0.6481	RMSE	0.7
Mels_N	R2_score	0.9724	R2_score	0.958	R2_score	0.935
	MSE	1.334	MSE	2.98	MSE	3.13
	MAE	0.601	MAE	0.972	MAE	1.078
	RMSE	1.155	RMSE	1.726	RMSE	1.77
Hvac_N	R2_score	0.9074	R2_score	0.837	R2_score	0.822
	MSE	18.69	MSE	32.75	MSE	35.91
	MAE	2.47	MAE	3.45	MAE	3.58
	RMSE	4.324	RMSE	5.72	RMSE	5.99
Hvac_S	R2_score	0.89	R2_score	0.755	R2_score	0.818
	MSE	17.49	MSE	39.11	MSE	29.08
	MAE	2.75	MAE	4.088	MAE	3.8
	RMSE	4.183	RMSE	6.25	RMSE	5.39









$$\min_{P} F(P) = \min_{P} \left\| P_{PV2Bus} + P_{WT2Bus} + \delta P_{Batt} + \varepsilon P_{EV} - P_{Load} - P_{PV2grid} - P_{WT2grid} \right\| \Delta t$$

$$\text{Where} \begin{cases} \delta = -1 \text{ if} (P_{PVMPP} + P_{WTMPP} \geq P_{Load} \&\& SoC(t) < SOC_{max}) \\ \delta = +1 \text{ if} (P_{PVMPP} + P_{WTMPP} \leq P_{Load} \&\& SoC(t) > SOC_{min}) \\ \delta = 0 \text{ if} (P_{PVMPP} + P_{WTMPP} \leq P_{Load} \&\& SoC(t) = SOC_{min}) \,||\, (P_{PVMPP} + P_{WTMPP} \geq P_{Load} \&\& SoC(t) = SOC_{max}) \end{cases}$$

$$\text{And} \begin{cases} \varepsilon = -1 \text{ if} (P_{PVMPP} + P_{WTMPP} \geq P_{Load} \&\& SoC(t) = SOC_{max} \&\& SoCEV(t) < SOCEV_{max}) \\ \varepsilon = +1 \text{ if} (P_{PVMPP} + P_{WTMPP} \leq P_{Load} \&\& SoCEV(t) > SOCEV_{min} \&\& SoC(t) = SOC_{min}) \\ \varepsilon = 0 \text{ if} (P_{PVMPP} + P_{WTMPP} \leq P_{Load} \&\& SoCEV(t) = SOCEV_{min}) \,||\, (P_{PVMPP} + P_{WTMPP} \geq P_{Load} \&\& SoCEV(t) = SOCEV_{max}) \end{cases}$$

$$\text{Subject to} \begin{cases} P_{PV2Bus} + P_{PV2grid} \leq P_{PVMPP} \\ P_{WT2Bus} + P_{WT2grid} \leq P_{WTMPP} \\ 0 \leq E_{Batt} \leq E_{Battmax} (SOC_{max} - SOC(t)) \\ 0 \leq E_{EV} \leq E_{EVmax} (SOCEV_{max} - SOCEV(t)) \\ P_{PV2Bus} \times P_{PV2grid} = 0 \\ P_{WT2Bus} \times P_{WT2grid} = 0 \end{cases}$$

Machine learning Exploitation

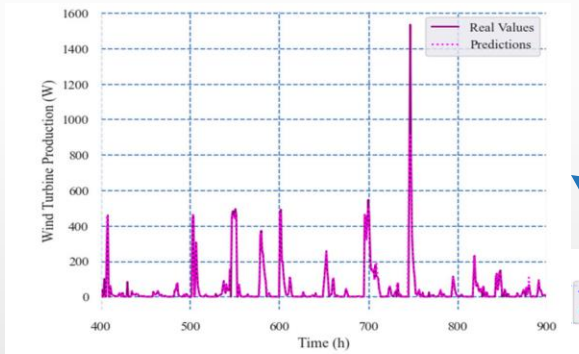


Figure 5. LSTM-regressor prediction for wind turbine power.

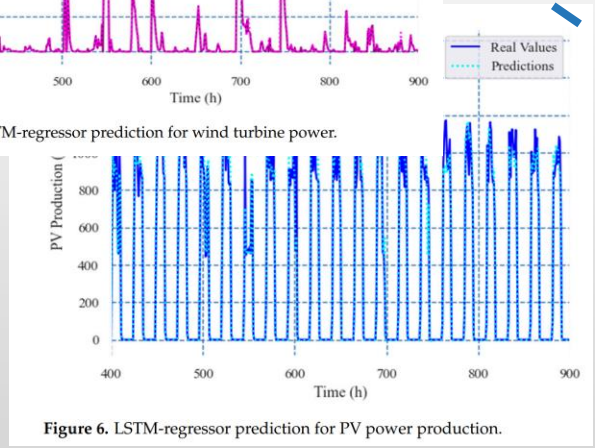


Figure 6. LSTM-regressor prediction for PV power production.

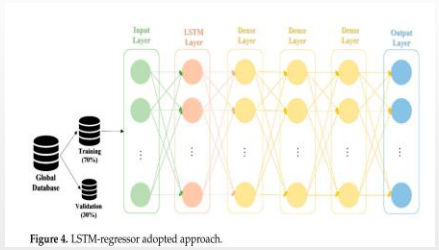
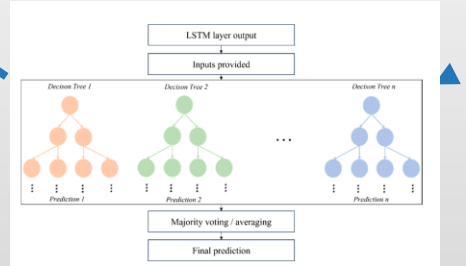
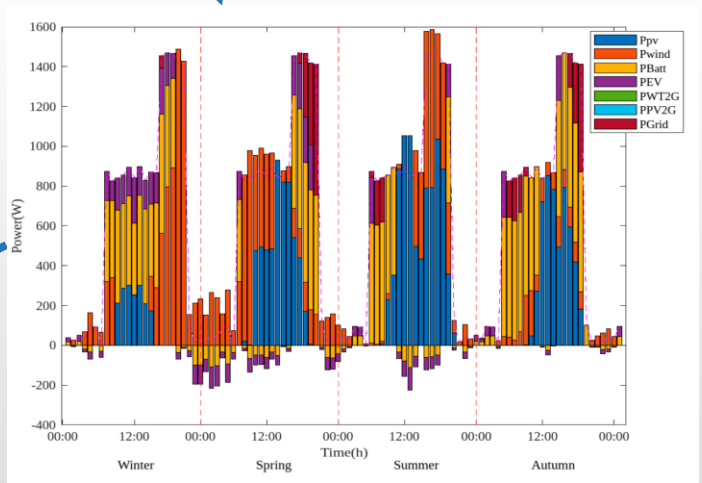


Figure 4. LSTM-regressor adopted approach.

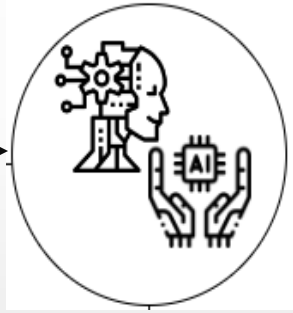




Meterological dataset

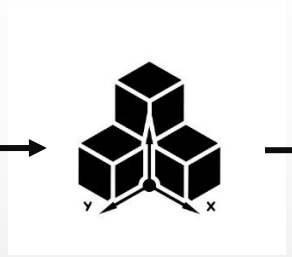
Electrical consumption profile

Energy management system modeling



Potentiel system hybridations simulation

Model reliability through statistical analysis



Defining the optimum hybrid system combination

Recommendations for optimal hybridization sizing

The TalTech Estonian Maritime Academy Summer School, "Operational measures to decrease greenhouse gas (GHG) emissions in shipping"

19-23 May, 2025 Tallinn, Estonia

Thanks for your attention

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