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GOVERNMENT OF INDIA MINISTRY OF POWER

Modelling of Standalone PV-Wind-Battery Hybrid Systems Using Physics-based Battery Models

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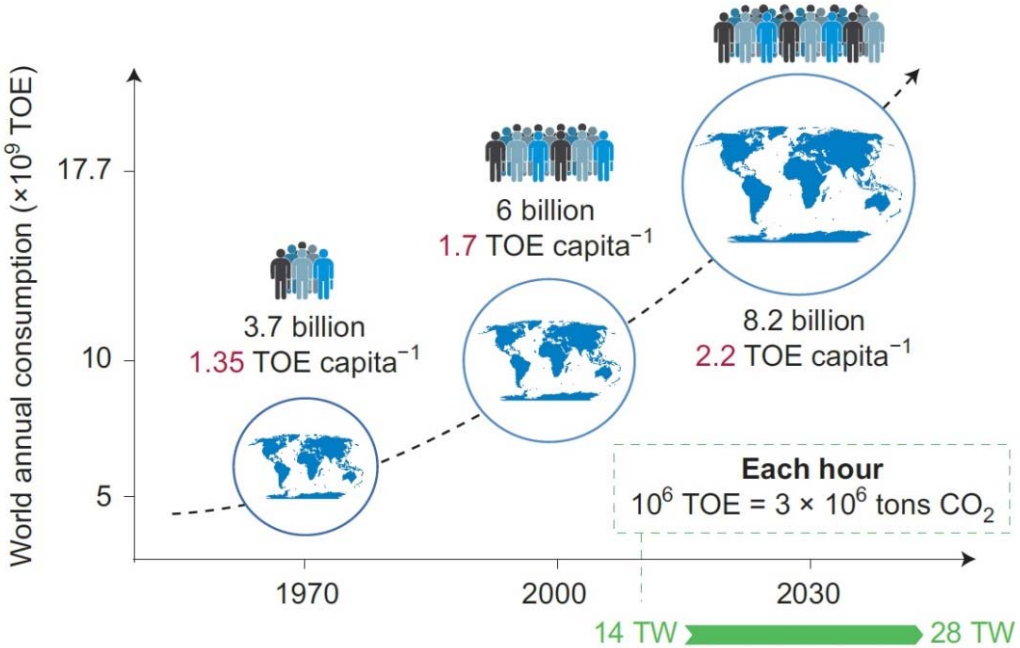
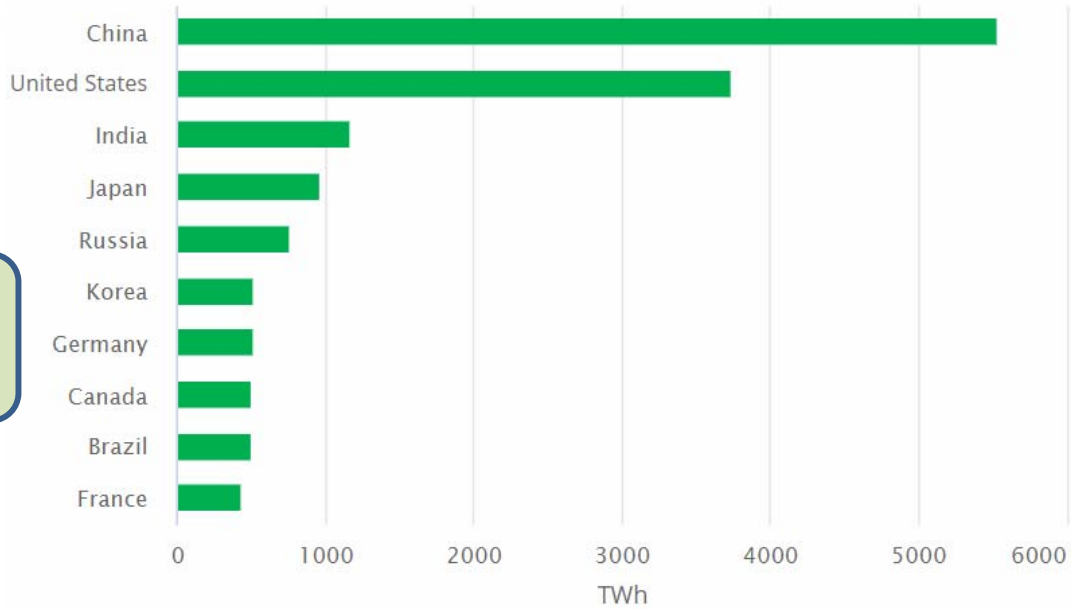
INTRODUCTION The present scenario



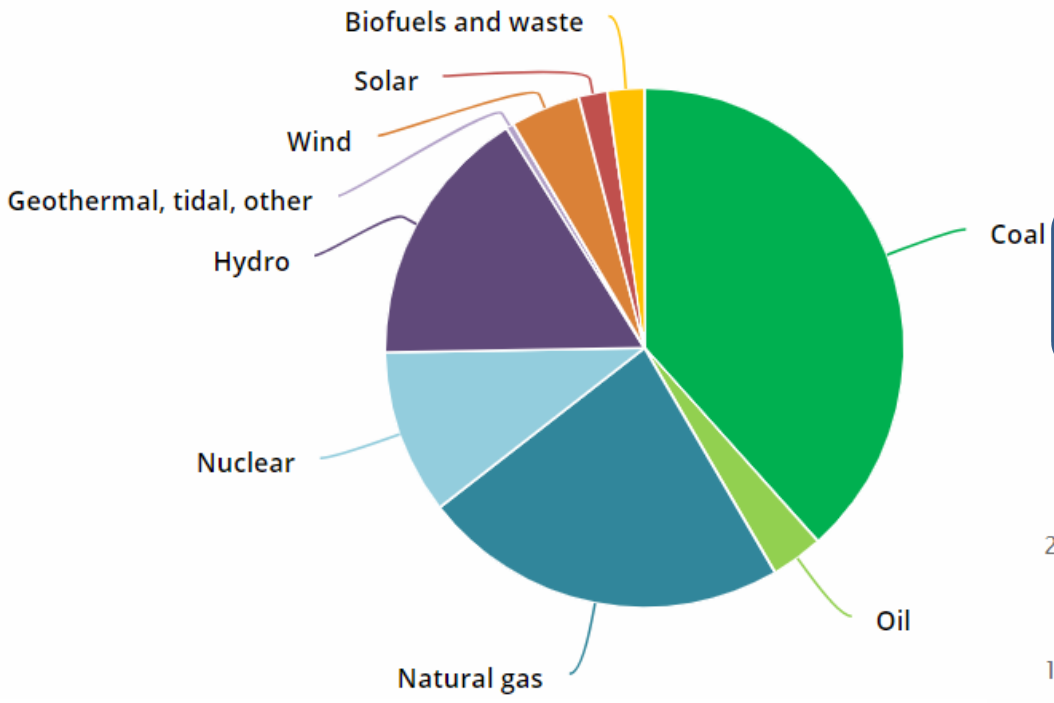
Past, present and forecast of the world's energy needs up to 2050*

Top ten electricity consuming countries**

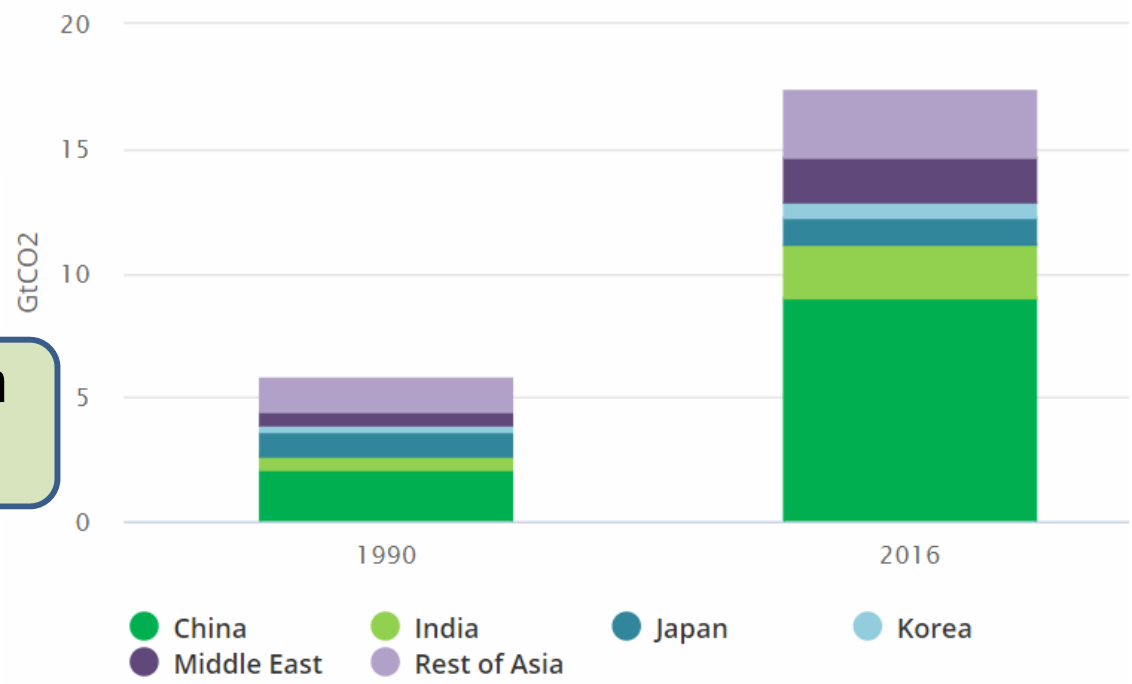


Larcher and Tarascon, Nature Chemistry 2015;7:19-29
***IEA Report*

INTRODUCTION CO_2 emission challenge



World gross electricity production by source*



CO_2 emissions from fuel combustion in Asia*

***IEA Report*

RENEWABLE ENERGY: CHALLENGES

Figure: Renewables energy resources

https://en.wikipedia.org/wiki/Wind_turbine Accessed: 2019-01-31

- Weather dependant
- Quantity and quality of electricity generated
- Unpredictable and inconsistent
- Large capital cost
- Resource location

STANDALONE HYBRID POWER SYSTEM

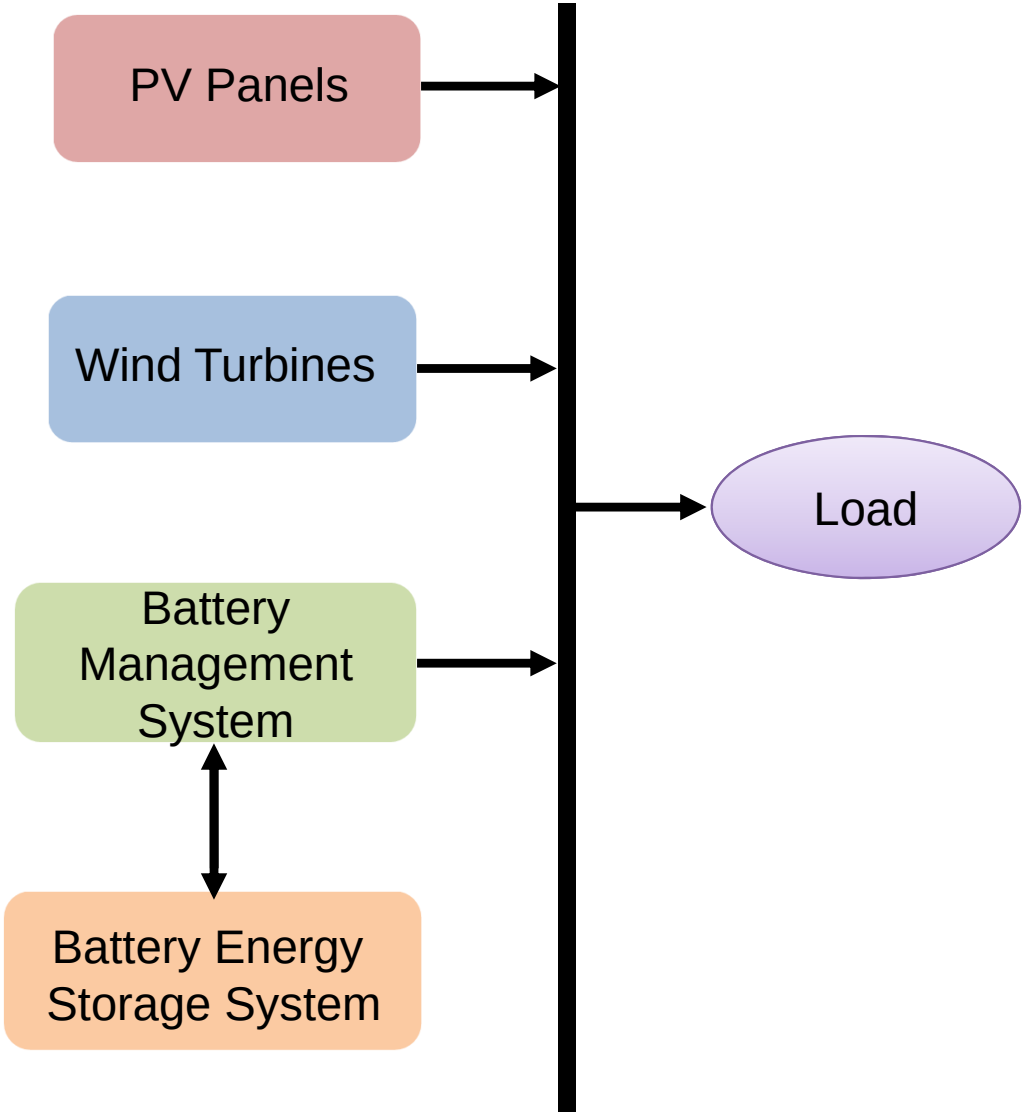


Figure: Schematic of a proposed hybrid system

MOTIVATION

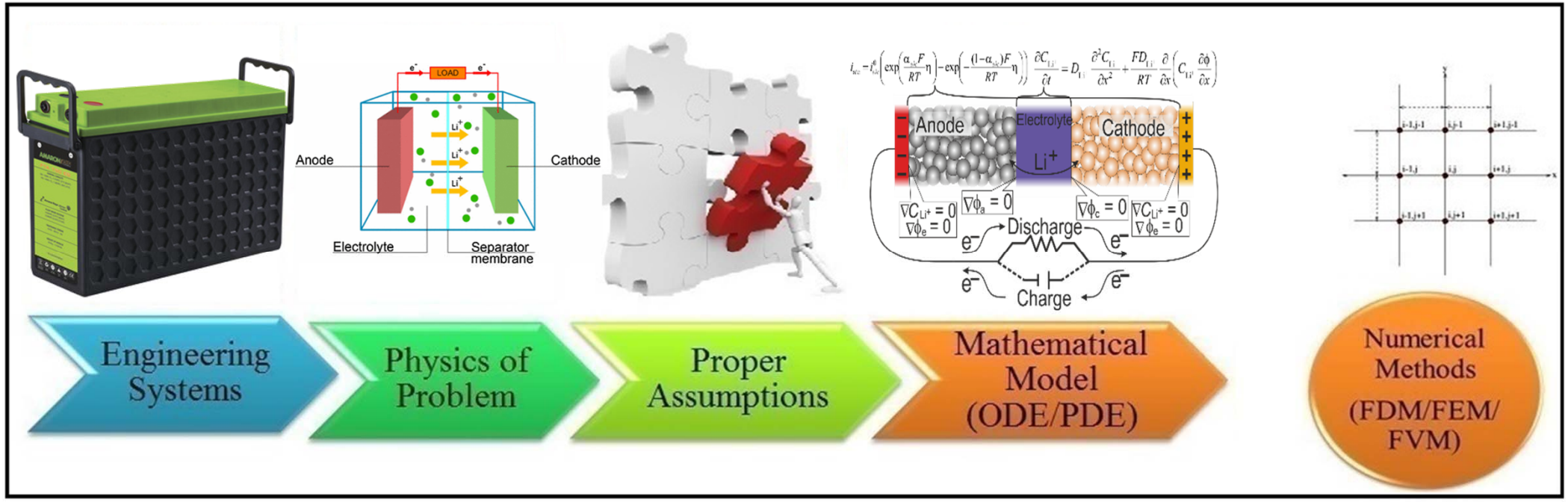
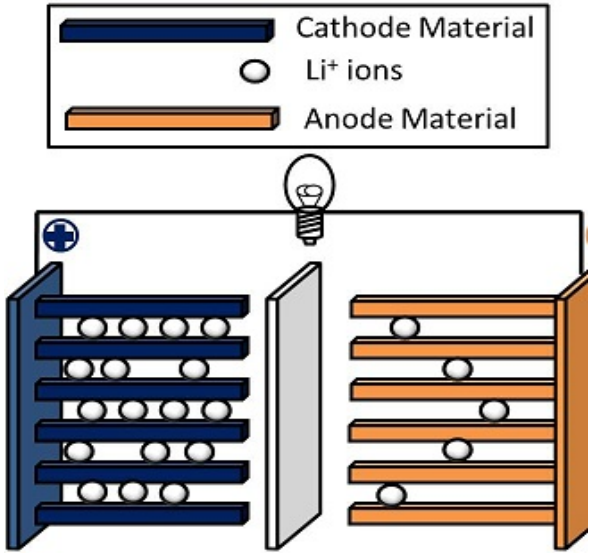


Figure: Process map for numerical simulation



Physics-based models are more accurate than equivalent circuit based models (ECMs)*

*S.K. Rahimian et al., Journal of Power Sources, 2011;196 (20): 8450–8462

https://commons.wikimedia.org/wiki/File:Schematic of a Li-ion battery.jpg. Accessed: 2019-01-31

Li-ION BATTERY MODELLING

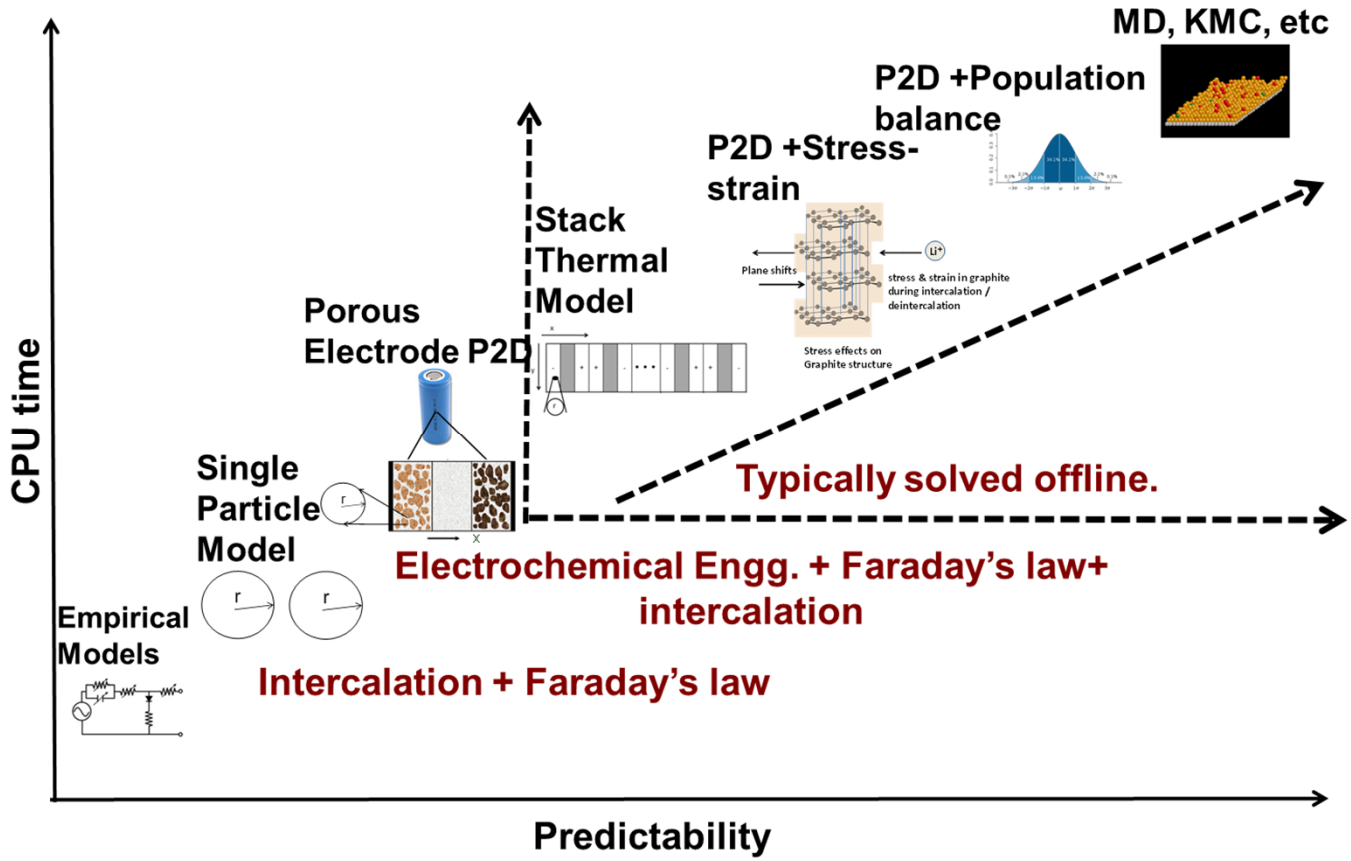


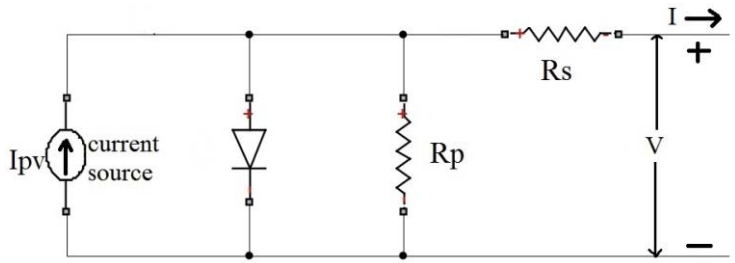
Figure: Battery models Vs computational demands^

- A pseudo-two-dimensional* LiB model & it's discretization using finite volume method**

^Ramadesigan et al., *JES*, 2012;159(3):R31-R45
*M. Doyle et al., JES,1993;140(6):1526–1533
**M. Torchio et al.,JES,2016;163(7):A1192–A1205

POWER BY PV & WIND TURBINE

PV Modelling

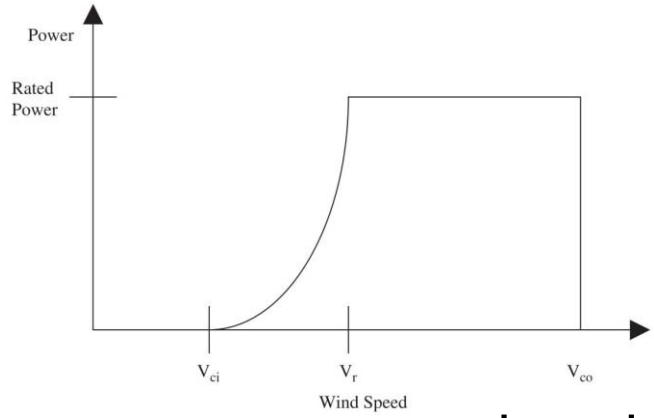


- Single-diode equivalent circuit-based model of a PV cell
- DAE-based MPPT* algorithm is implemented**

$$I(t) = I_{PV}(t) - I_0\left[\exp\left(\frac{V(t)+R_S I(t)}{V_{th}a}\right)-1\right] - \frac{V(t)+R_S I(t)}{R_P}$$

$$\frac{I(t)}{V(t)} = \frac{I_0\left(1-\frac{R_s I(t)}{V(t)}\right)\exp\left(\frac{V(t)+R_S I(t)}{V_t a}\right)}{V_t a} + \frac{1-\frac{R_s I(t)}{V(t)}}{R_P}$$

Wind Turbine Modelling



- The output power produced by the wind turbine

$$P_{wind}(t) = \frac{1}{2}\rho A V_w(t)^3 C_p \eta_{inv}\eta_{mech}$$

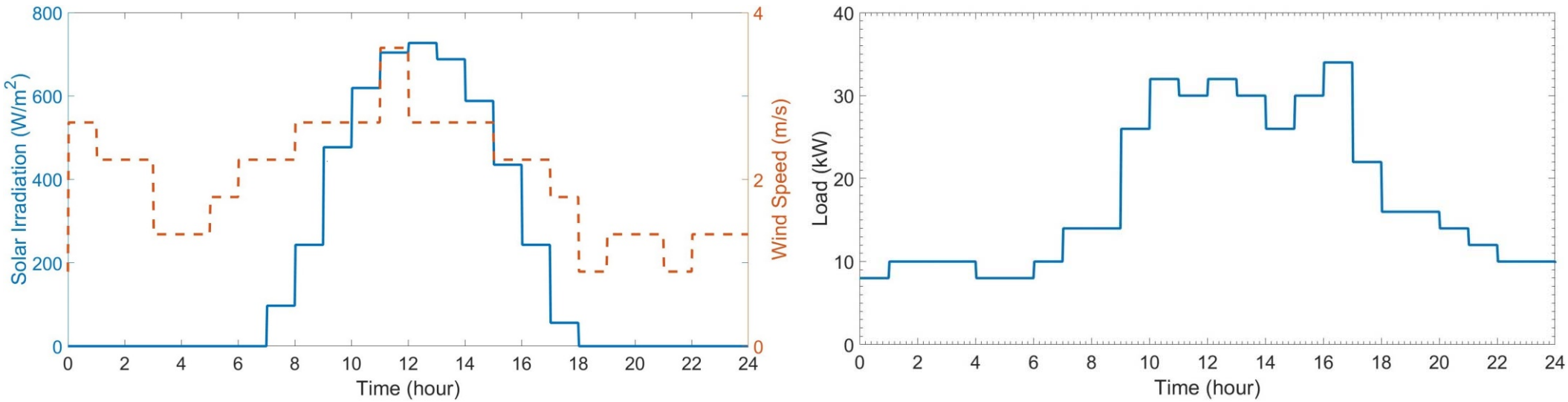
$$P_{wind}(t) = \begin{cases} 0, & V_w(t) < V_{ci} \\ P_{wind}(t), & V_{ci}(t) \le V_w(t) \le V_r \\ P_{rated}, & V_r \le V_w(t) \le V_{co} \\ 0, & V_{co} < V_w(t) \end{cases}$$

**M. Bonkile and V. Ramadesigan, J. Energy Storage,2019, 23:258 – 268
*S.B.Lee et al., JES, 2017,164(11):E3026–E3034

RESULTS

- A remote site at Wardha circle of Nagpur region (20.7453° N, 78.6022° E), located in India

- MATLAB®/SIMULINK environment



(a) (b)

Figure: (a)Hourly average of solar irradiation and wind speed profile; (b)Hourly load variations profile

RESULTS

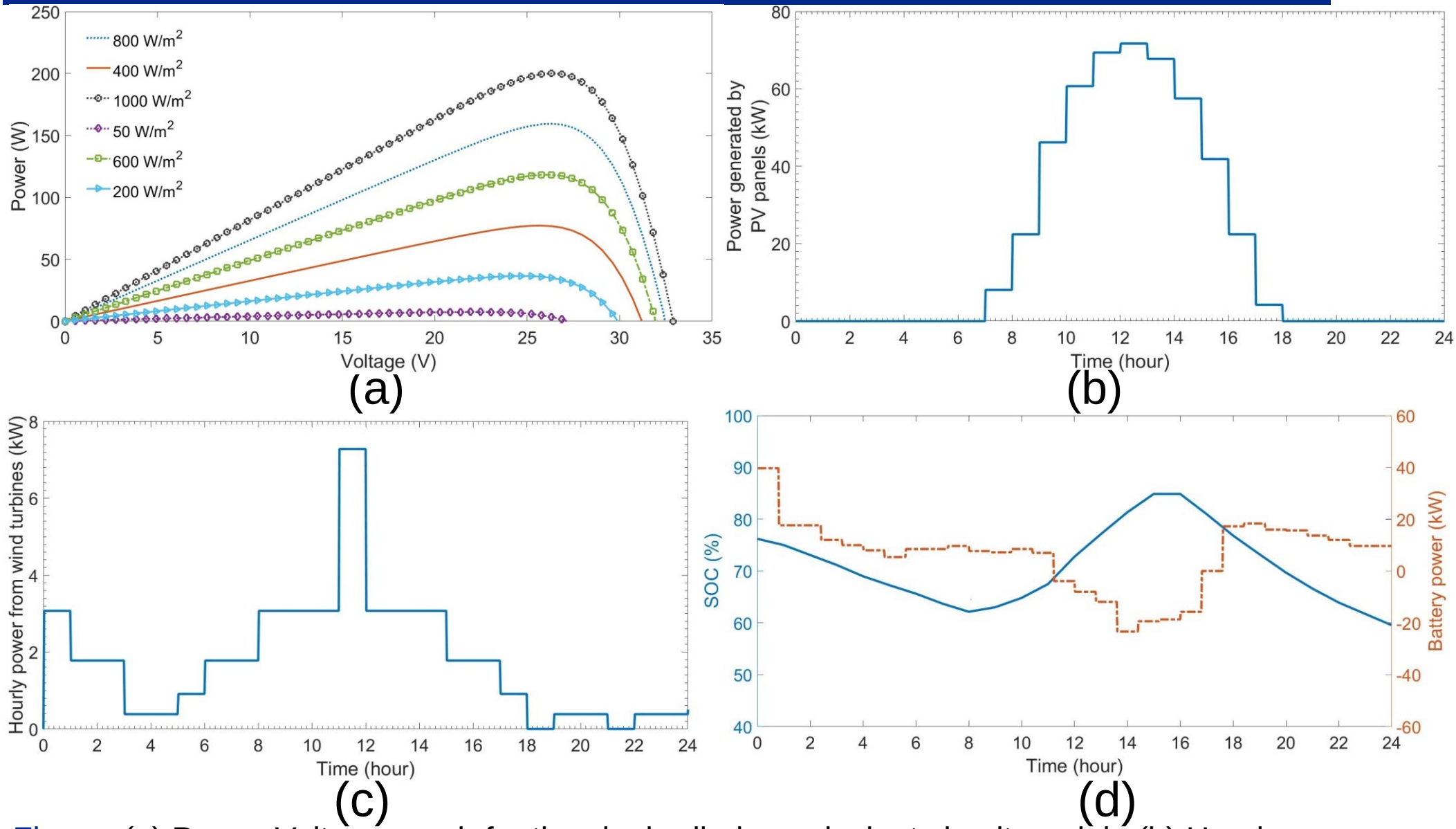
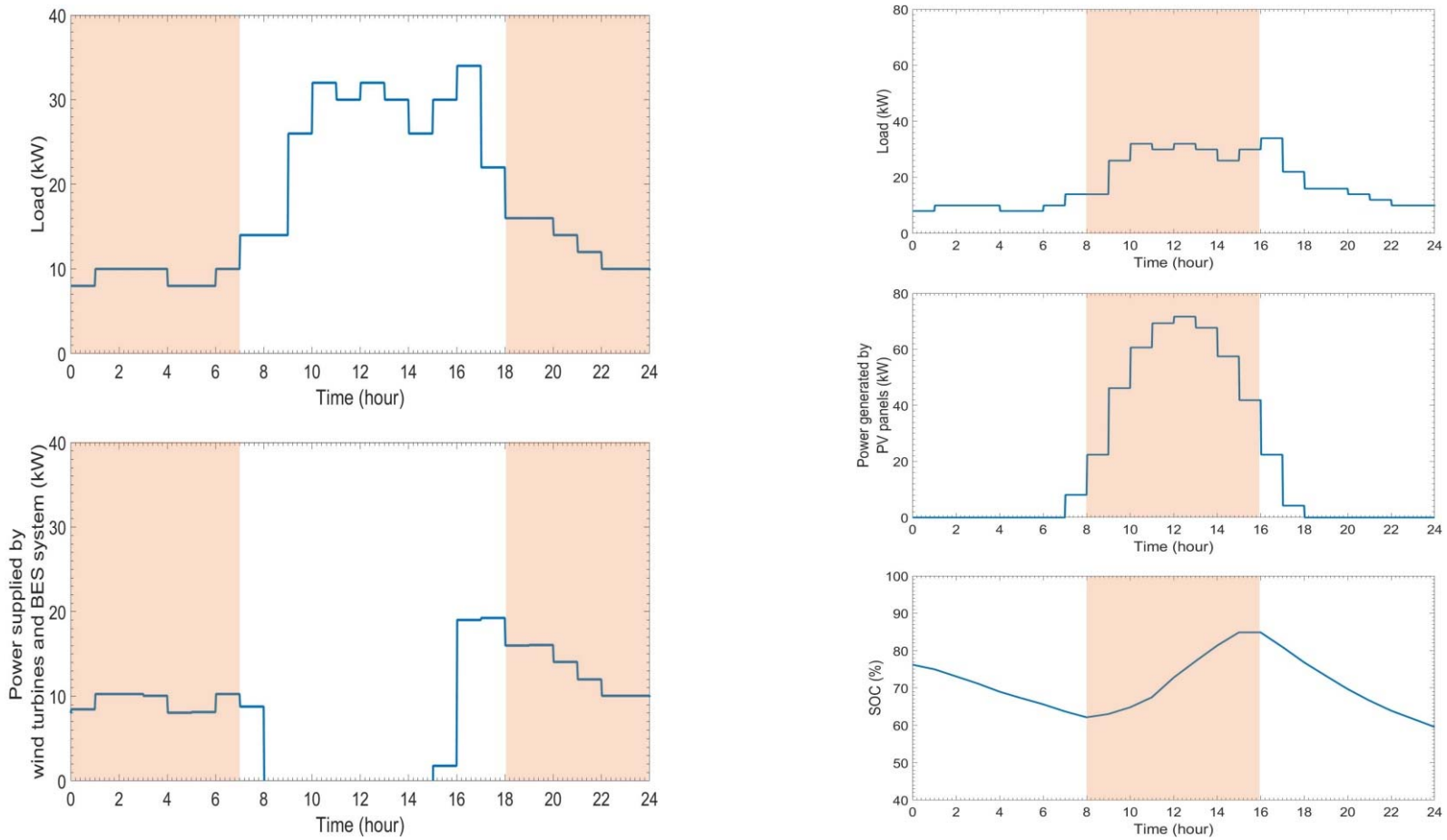


Figure: (a) Power-Voltage graph for the single-diode equivalent circuit model; (b) Hourly power generated by PV panels; (c) Hourly power generated by wind turbines; (d) Battery SOC & power

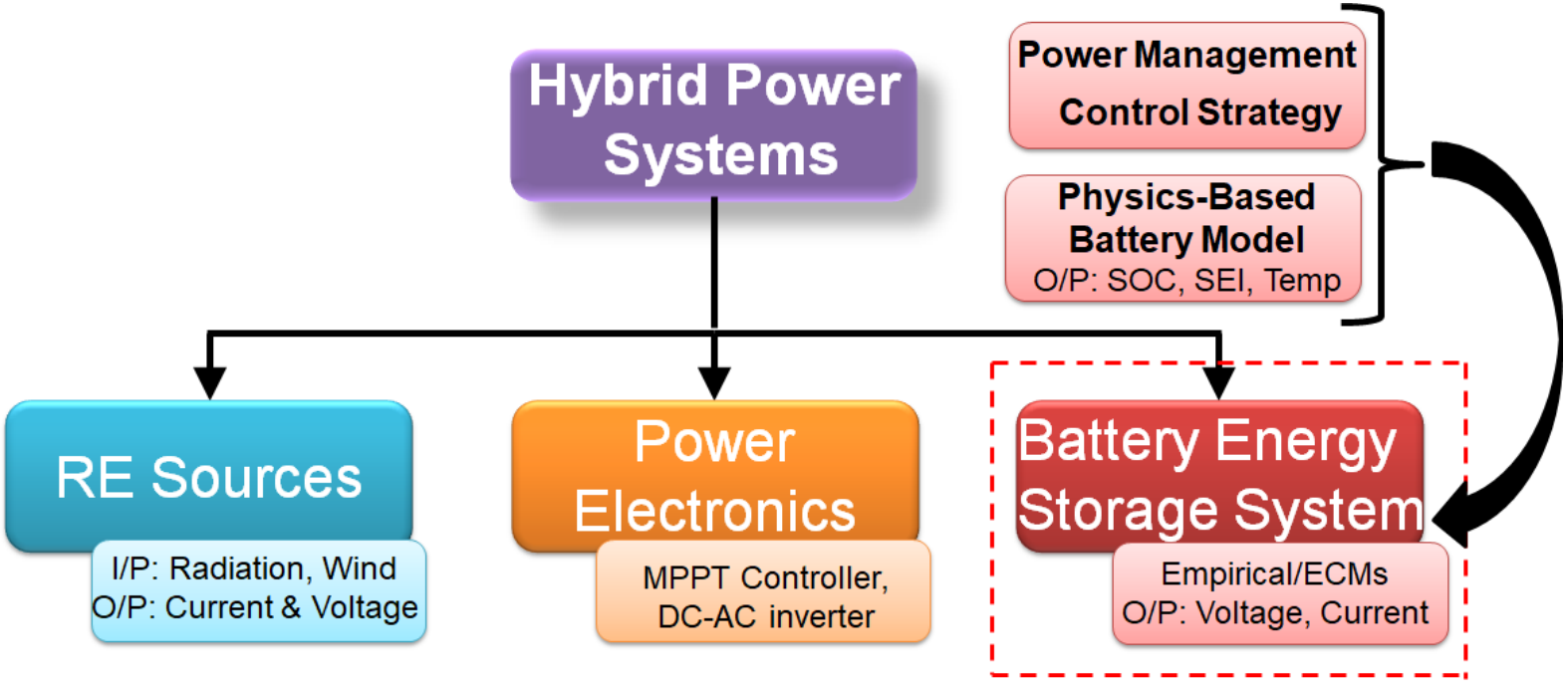
RESULTS



(a) (b)

Figure: (a) Power supplied by wind turbines and BES during no sunshine hours; (b) Battery charging during sunshine hours

CONCLUSIONS



Physics-based battery model representing the transport and kinetic processes inside the LiB is implemented instead of the typically used ECM

THANK YOU