Smart Energy Systems Lab

Invited Talk at AIT- Austrian Institute of Technology [IEEE PES Austria Chapter], Vienna, Austria, 13-Jun-2024

Resilient Energy and Transportation Infrastructures

Hossam A.Gabbar, Professor, PhD, P.Eng., Fellow IET (FIET)
Distinguished Lecturer IEEE NPSS
Director, Smart Energy Systems Lab
Ontario Tech University

Acknowledgement to members at Smart Energy Systems Lab, Ontario Tech University

OntarioTech UNIVERSITY

Oshawa, Durham Region, Ontario, Canada

Talk Summary

- Energy Transitioning
- Smart Energy Grids for Marine and Waterfront Applications
- Resilient Interconnected Infrastructures
- Fast Charging for Marine and Waterfront Applications
- Nuclear-Renewable Hybrid Energy Systems for Marine and Waterfront Applications
- Smart Energy Networks

Energy Transitioning

- Task-1: Analysis of Energy Grids for a Given Region or Application
- Task-2: Low-Carbon Energy Transition Scenario Assessment
- Task-3: Integrated Hybrid Energy Modeling and Simulation
- Task-4: Supply Side Design and Control Strategies for Smart Energy Grids

- Track-5: Smart Energy for Water Networks
- Track-4: Smart Energy for Transportation Infrastructures
- Track-3: Thermal Grids and Storage Technologies
- Track-2: Gas and Hydrogen Grids and Storage Technologies
- Track-1: Electricity Grids and Storage Technologies

- Module-6: Energy Transitioning Projects for Communities
- Module-5: Transactive Energy, Performance, and LCC
- Module-4: Smart Sensors, Monitoring, Diagnosis, Data Centers
- Module-3: AI, Optimization, Data Analytics
- Module-2: Energy Computational Modeling and Simulation
- Module-1: Energy Transitioning Scenario Modeling

- Task-8: Energy Transition Planning, Technology Deployment and Business Modeling
- Task-7: Data Analytics of Smart Energy Grids Energy Operation with Co-Simulation
- Task-6: Optimization of Smart Energy Grids Design and Control
- Task-5: Demand Side Design and Control Strategies for Smart Energy Grids

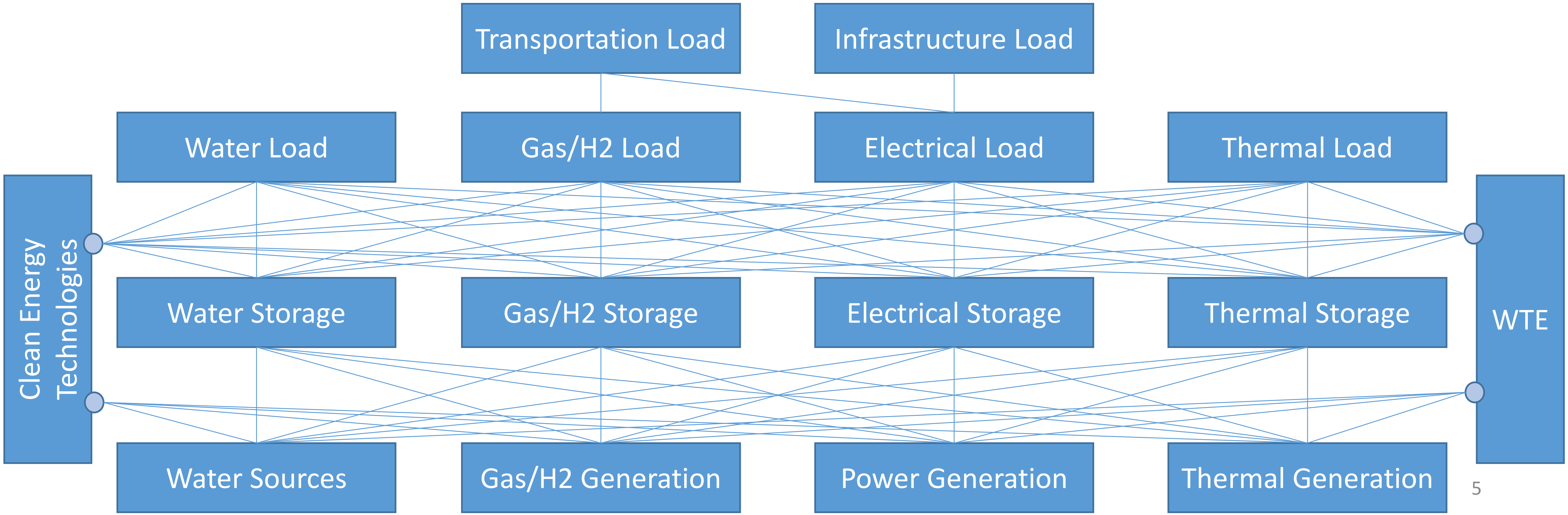
Energy Transitioning

Policies, Procedures, and Regulations

Region, Application, and Integration

Business Models and Management Scheme Strategies

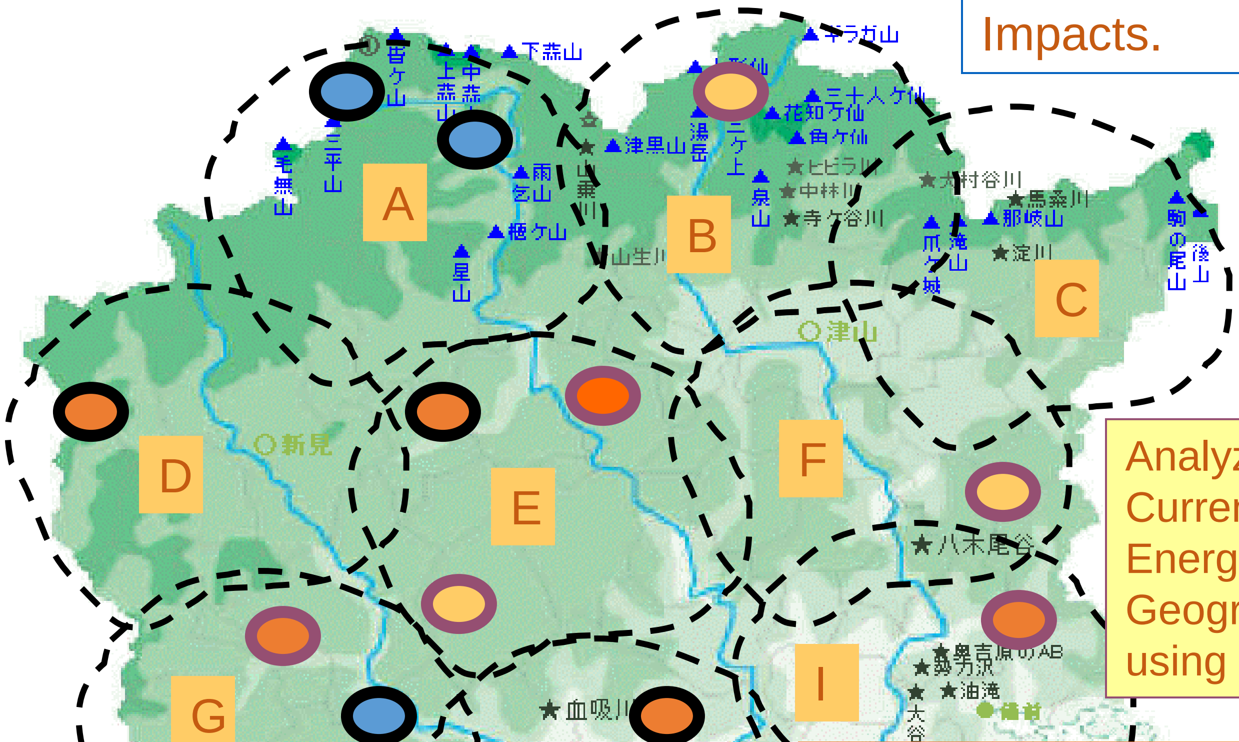
Control Strategies



Hybrid Energy Infrastructures – Marine and Waterfront Regions

Classify Energy Use & Supply as per Amounts / Risks / Environmental Impacts.

- Hydro Power Plants
- Wind Mill
- Solar
- Thermal Power Plants
- Nuclear Power Plants



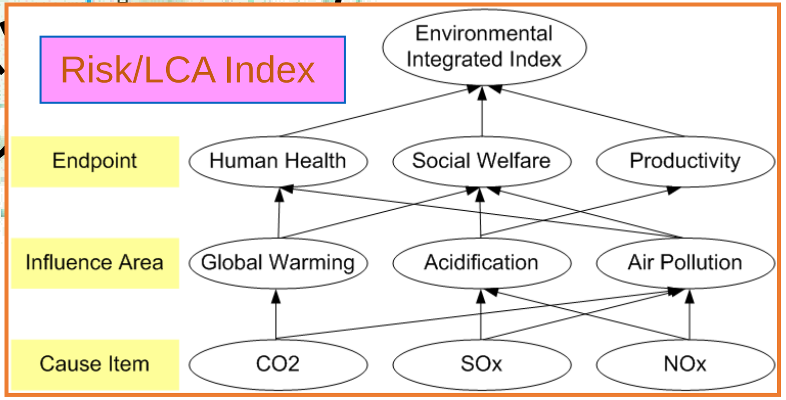
Fuel Cells

Ocean/Tide Plants

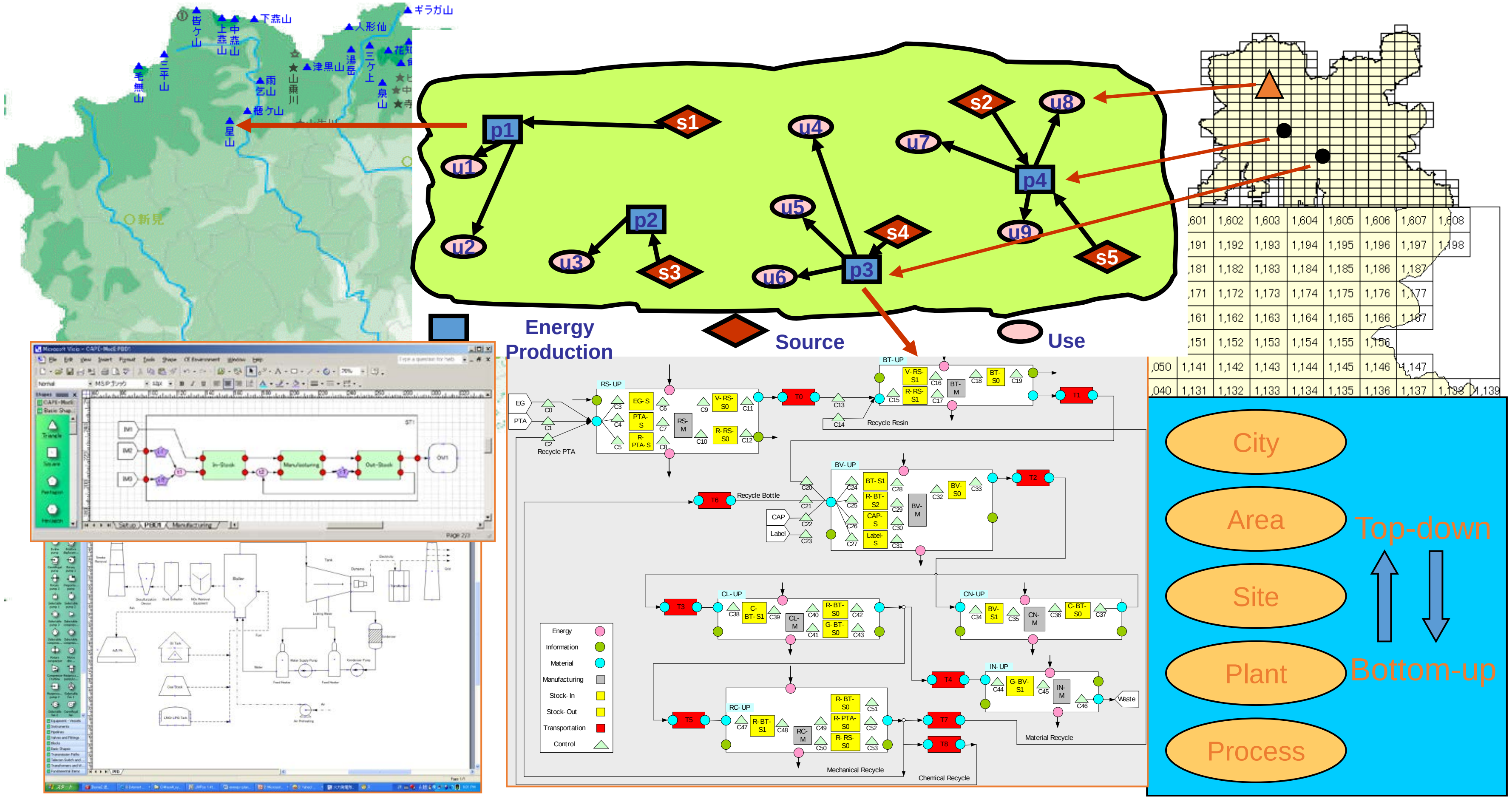
…

Analyze and Evaluate Current & Future Energy Needs in each Geographical Area using LCA/LCC Index

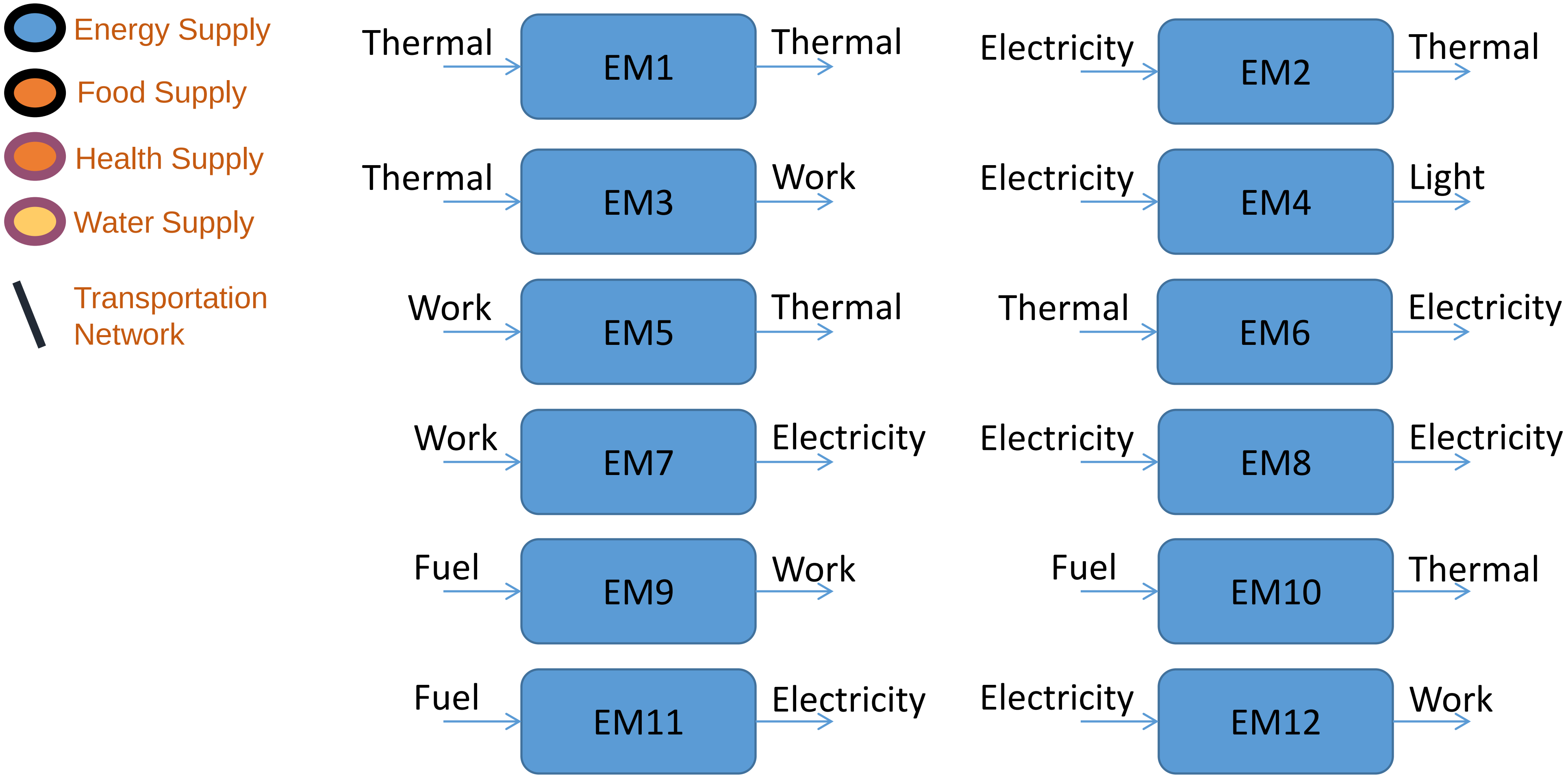
Clustering, Data Mining for Optimized Energy Production/Supply Chain



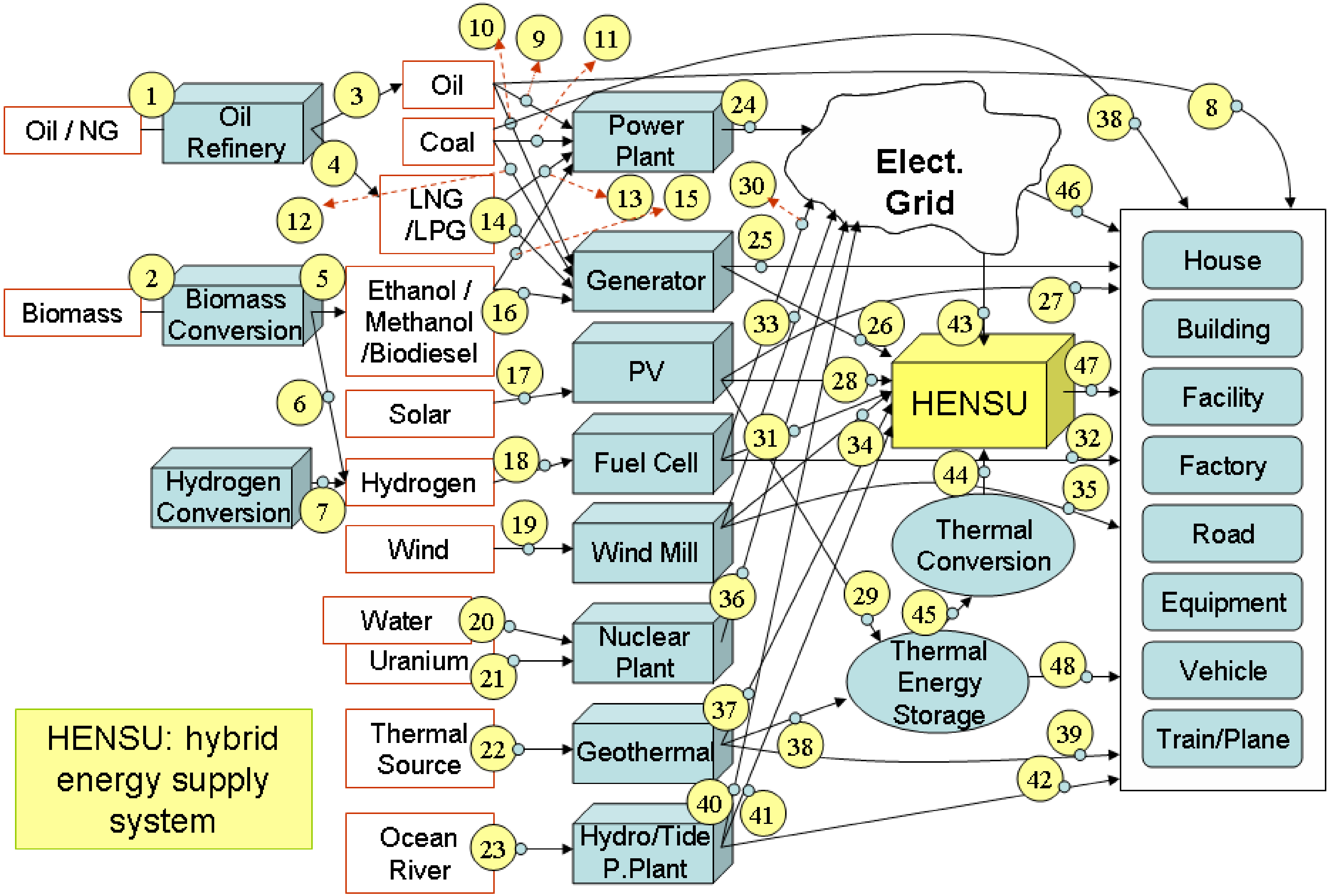
Planning of Resilient Energy-Water-Food-Health-Transportation Infrastructures – Marine and Waterfront Regions



Energy Conversion Technologies

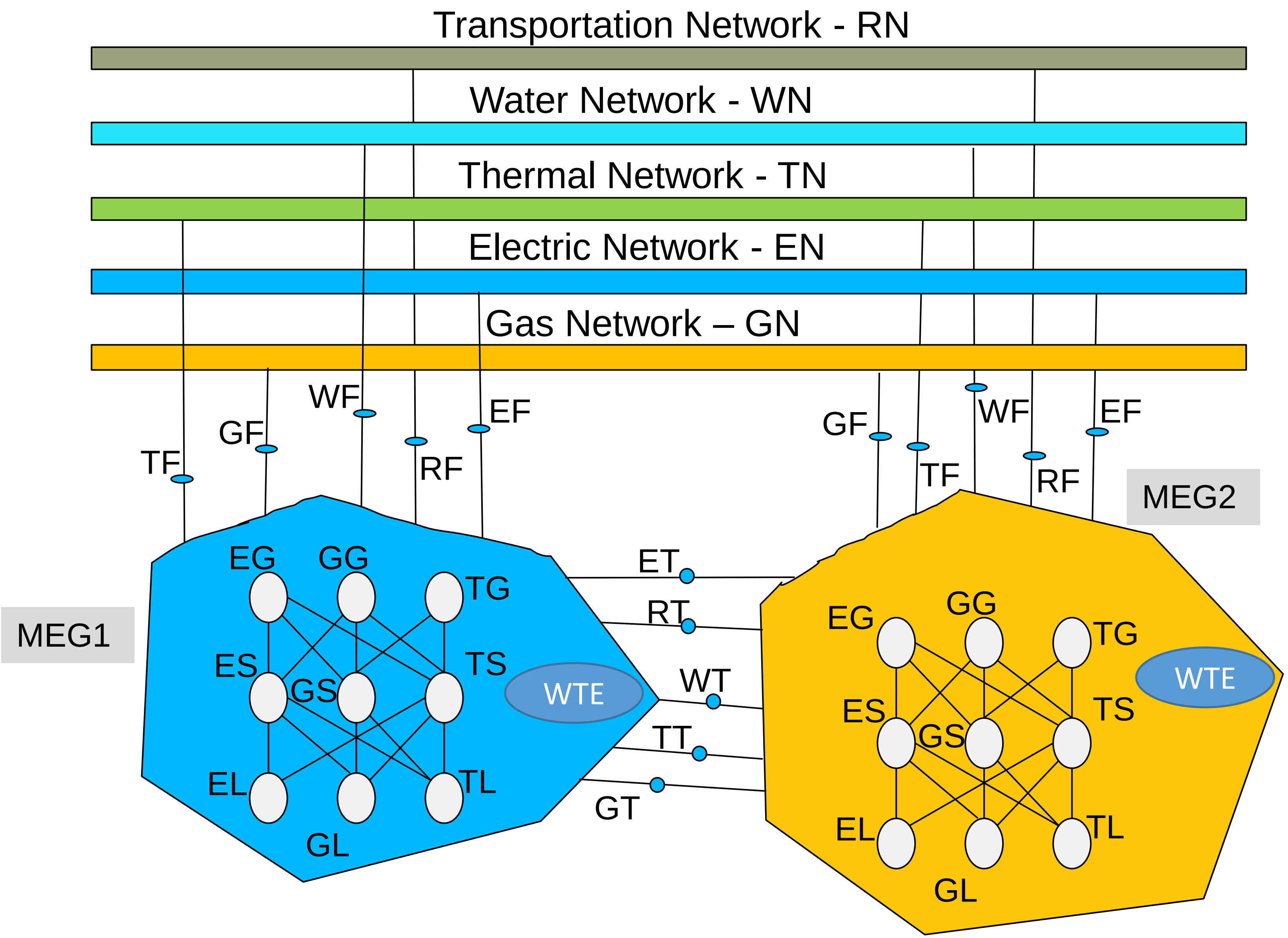


Smart Energy Grid Superstructure

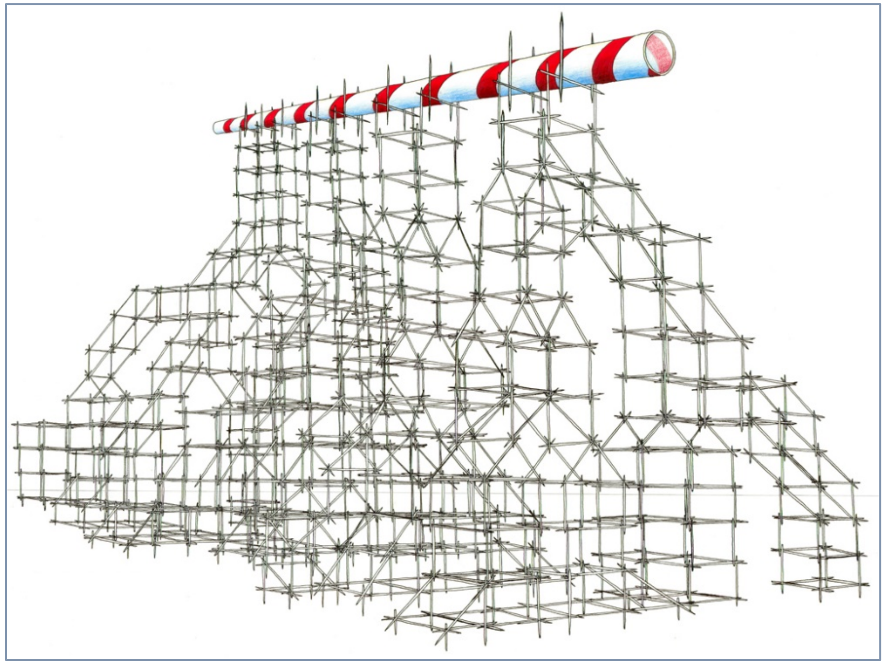


HENSU: hybrid energy supply system

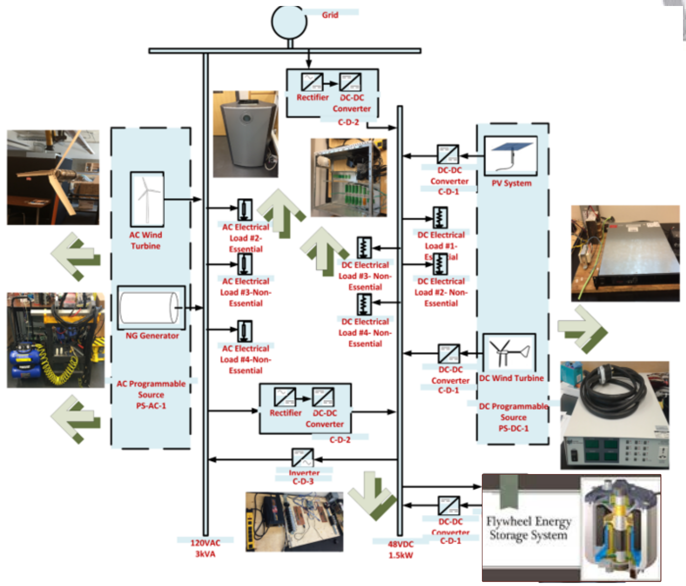
Interconnected Micro Energy Grids

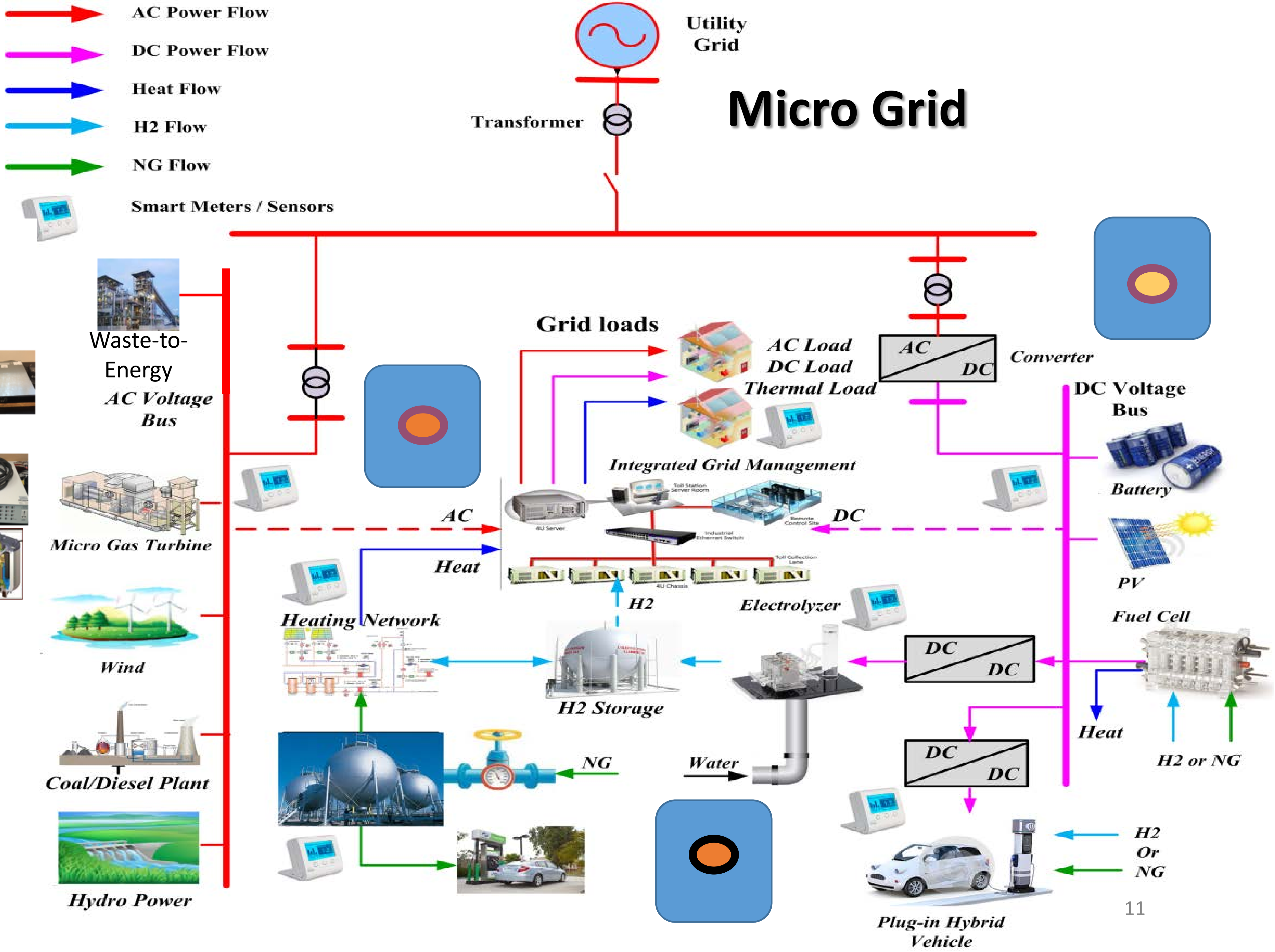


Adaptive Interconnected Micro Energy Grid Superstructure



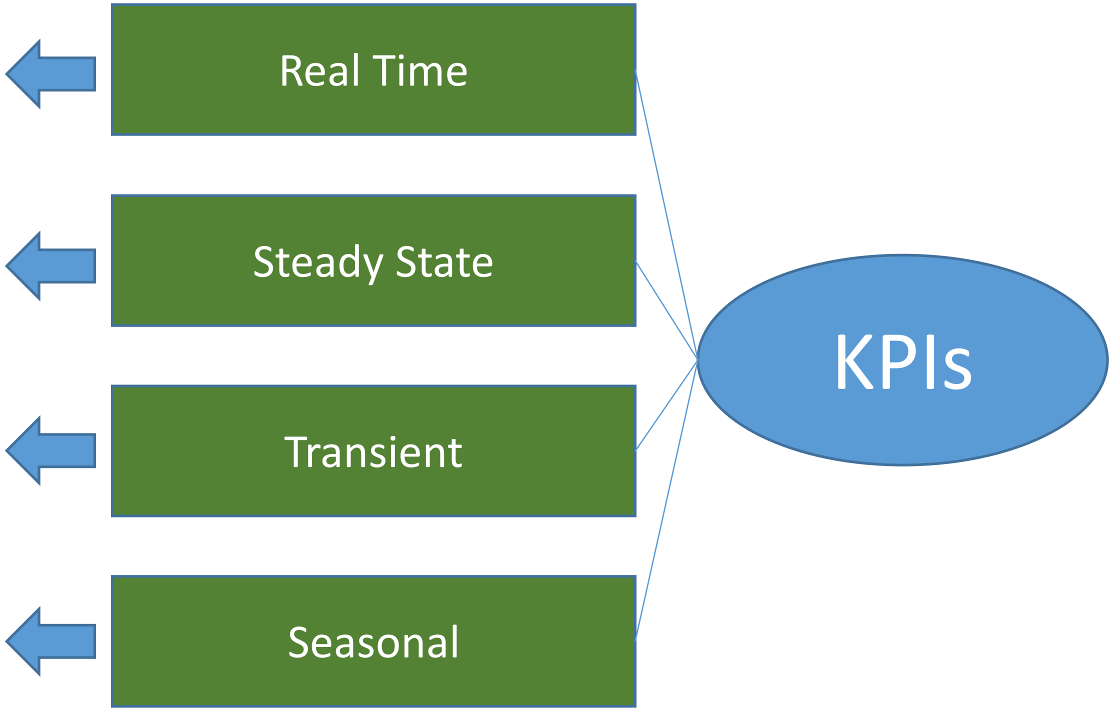
MEG Demonstration at UOIT





Performance Modeling

- Quality
- Reliability
- Safety
- Security
- Resiliency
- Economy
- Technical
- Environmental
- Human Interface
- Social / Cultural
- Regulation Compliance



KPI Modeling

- EWFHT (Generation / Storage / Loads)
- KPI Modeling
  - Socio-cultural
  - Economic
  - Environmental
  - Reliability / Safety / Security
  - Technical

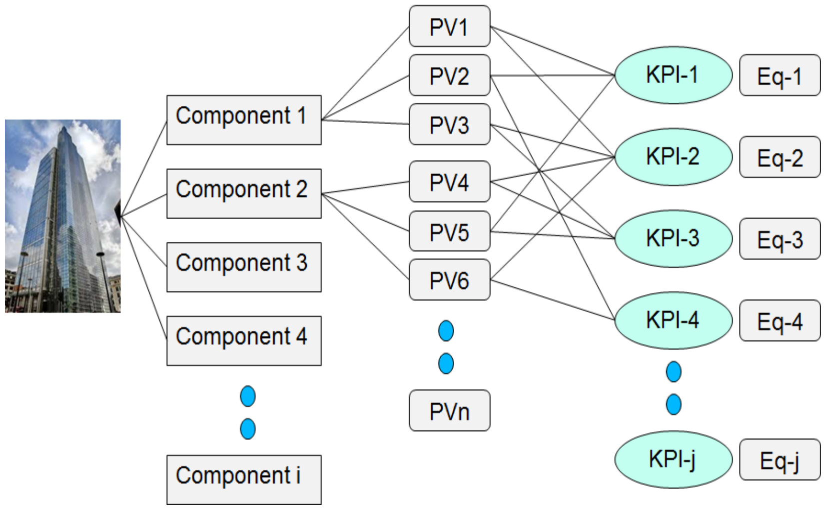
Socio-Cultural
- Public Acceptance
- Diversity of Supply

Economic
- Capital Cost
- Replacement Cost
- Operational Cost
- Payback Period
- Life Cycle

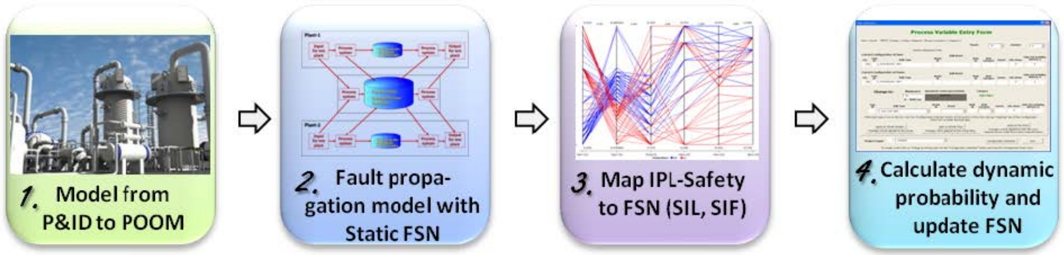
Environmental
- Greenhouse Gas Emissions
- Pollutant Emissions
- Noise
- Waste

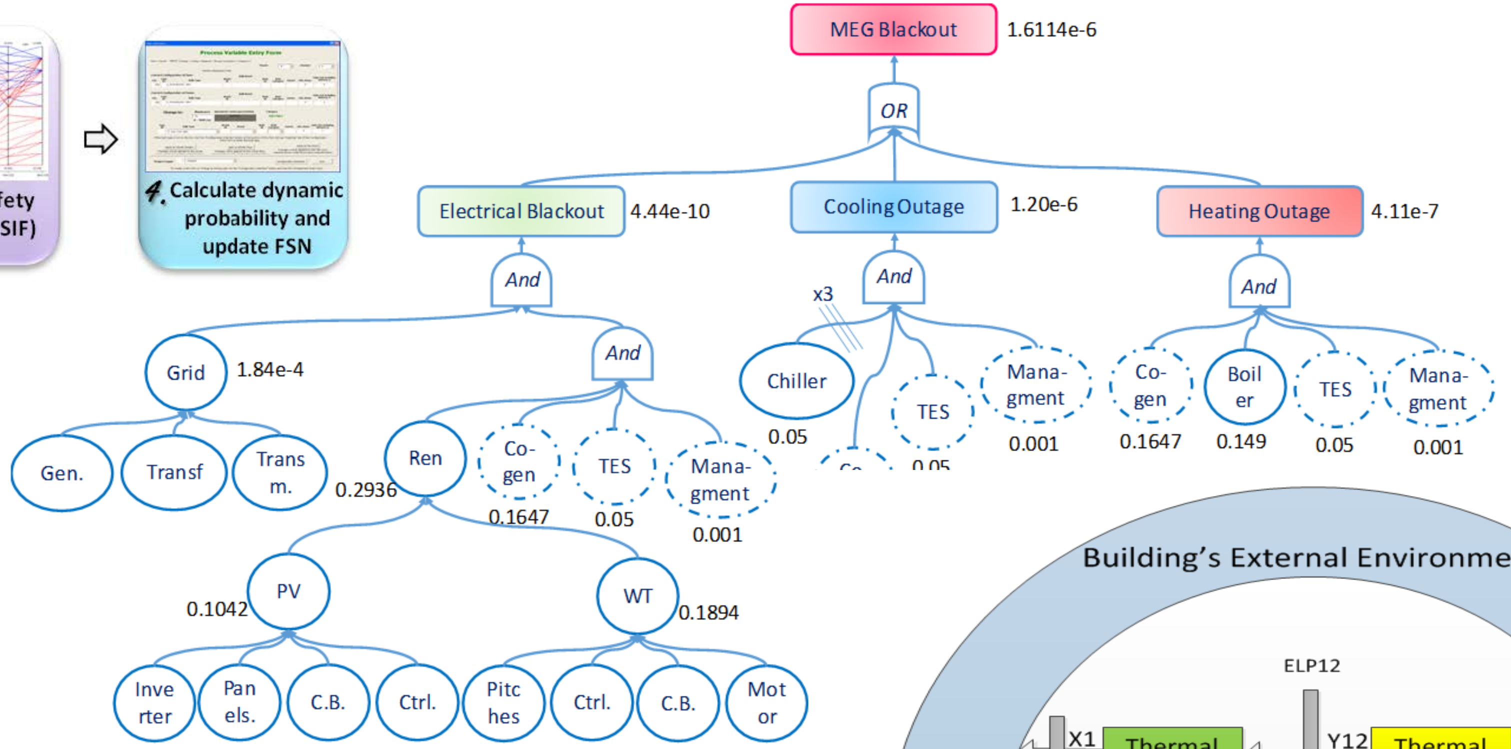
Reliability
- System average interruption distribution index (SAIDI)
- System average interruption frequency index (SAIFI)
- Average service availability index (ASAI)
- Expected energy not served (EENS)
- Customer average interruption duration index (CAIDI)
- Average energy not supplied (AENS)

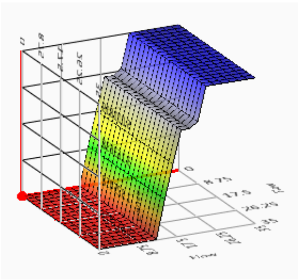
Technical
- Power Balance
- Power Losses
- Total Harmonic Distortion
- Capacity Factor
- Load Factor
- Microgrid Supply, Load, Reliability, Availability
- Electric Grid Dependence

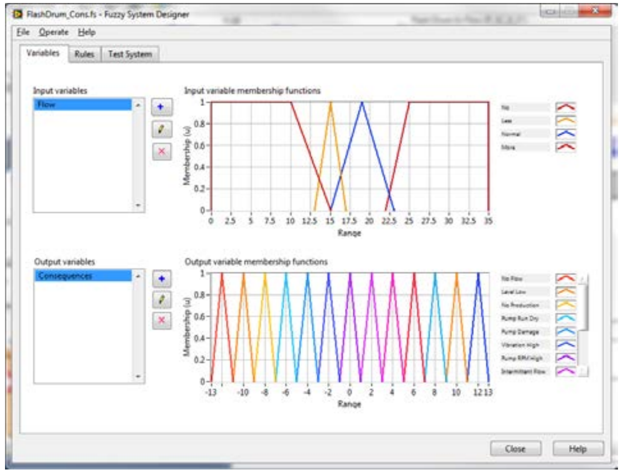


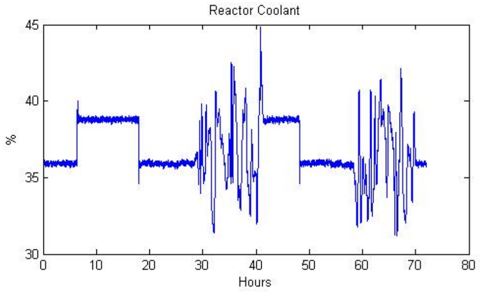
Risk-based Energy Systems

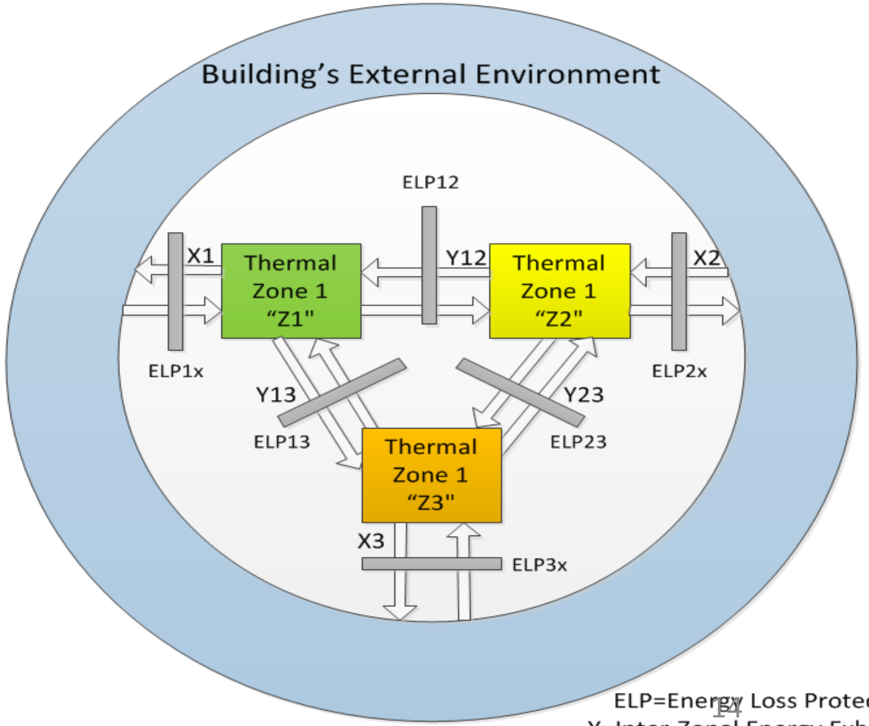








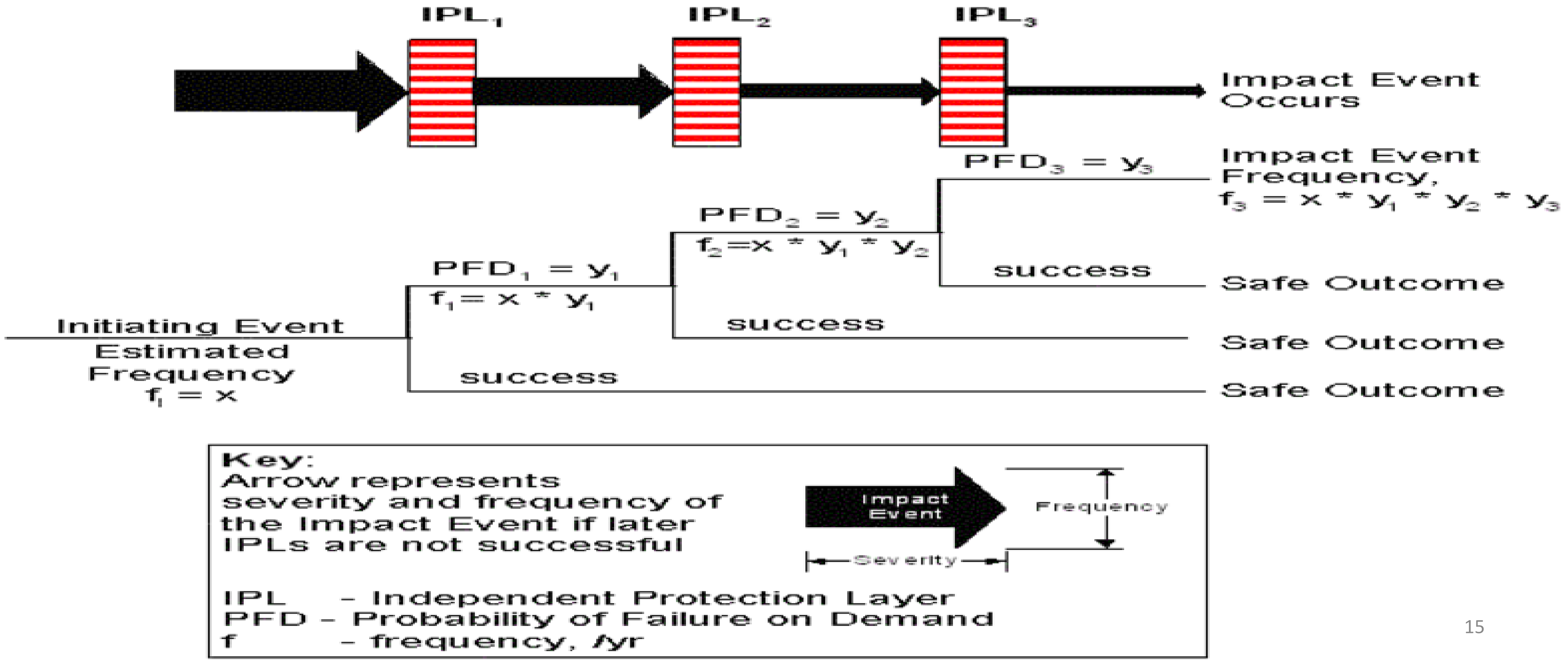




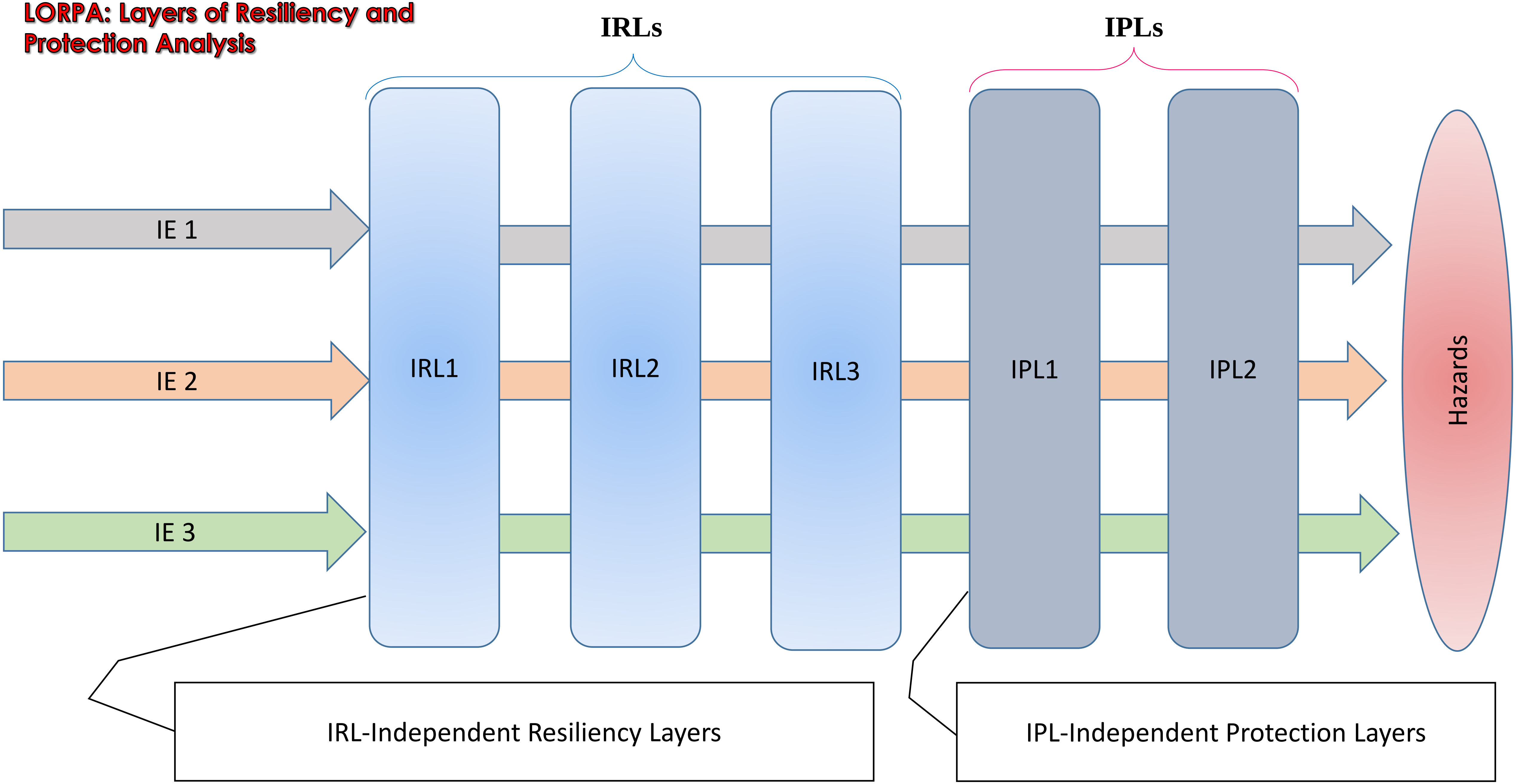
ELP=Energy Loss Protection
Y=Inter-Zonal Energy Exhcnge
X=Energy Exchange with external Environment

LOPA (Layer of Protection Analysis)

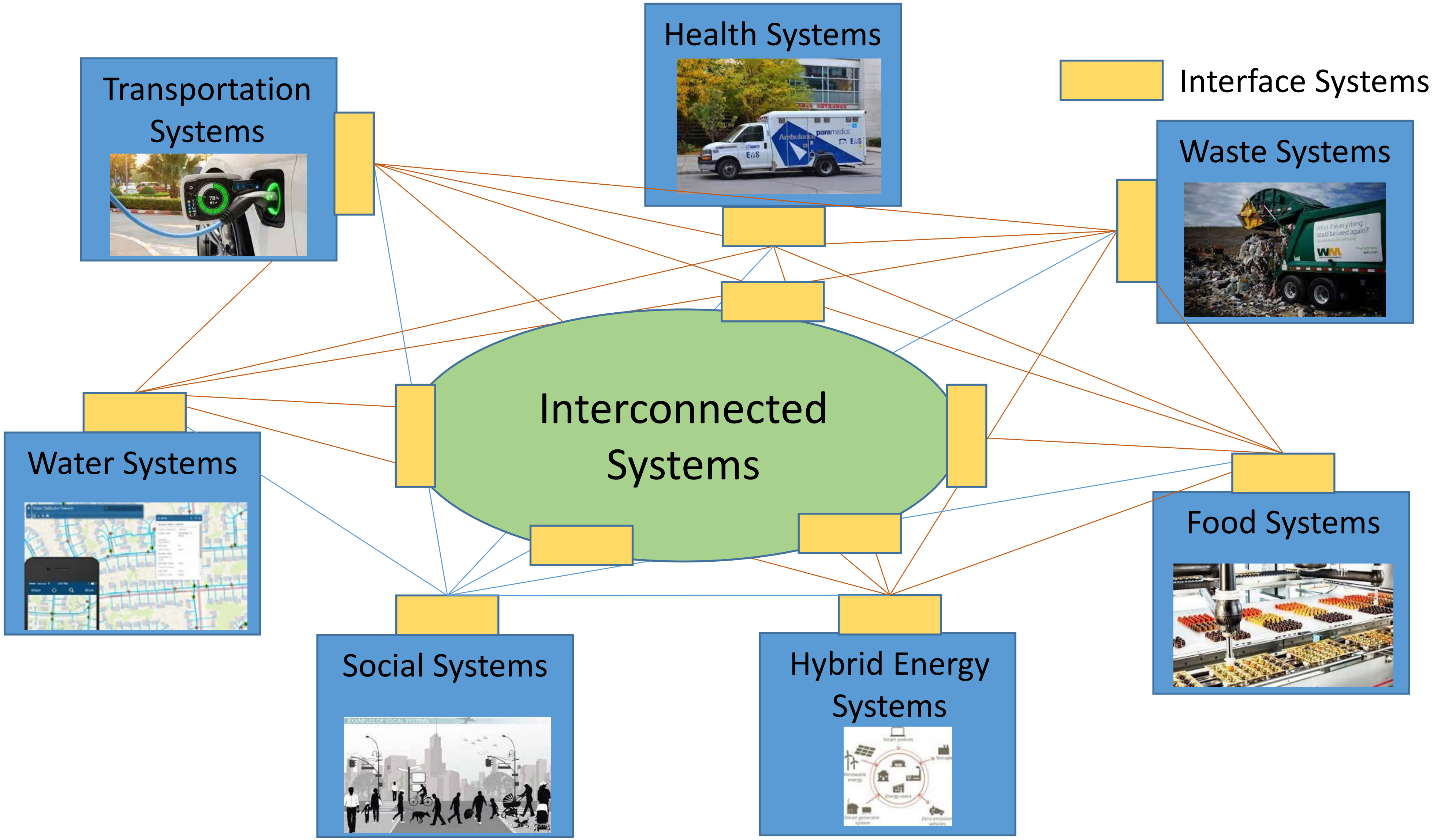
- **LOPA Definition:** is to determine if there are sufficient layers of protection against the consequences of an accident scenario (can the risk be tolerated?).



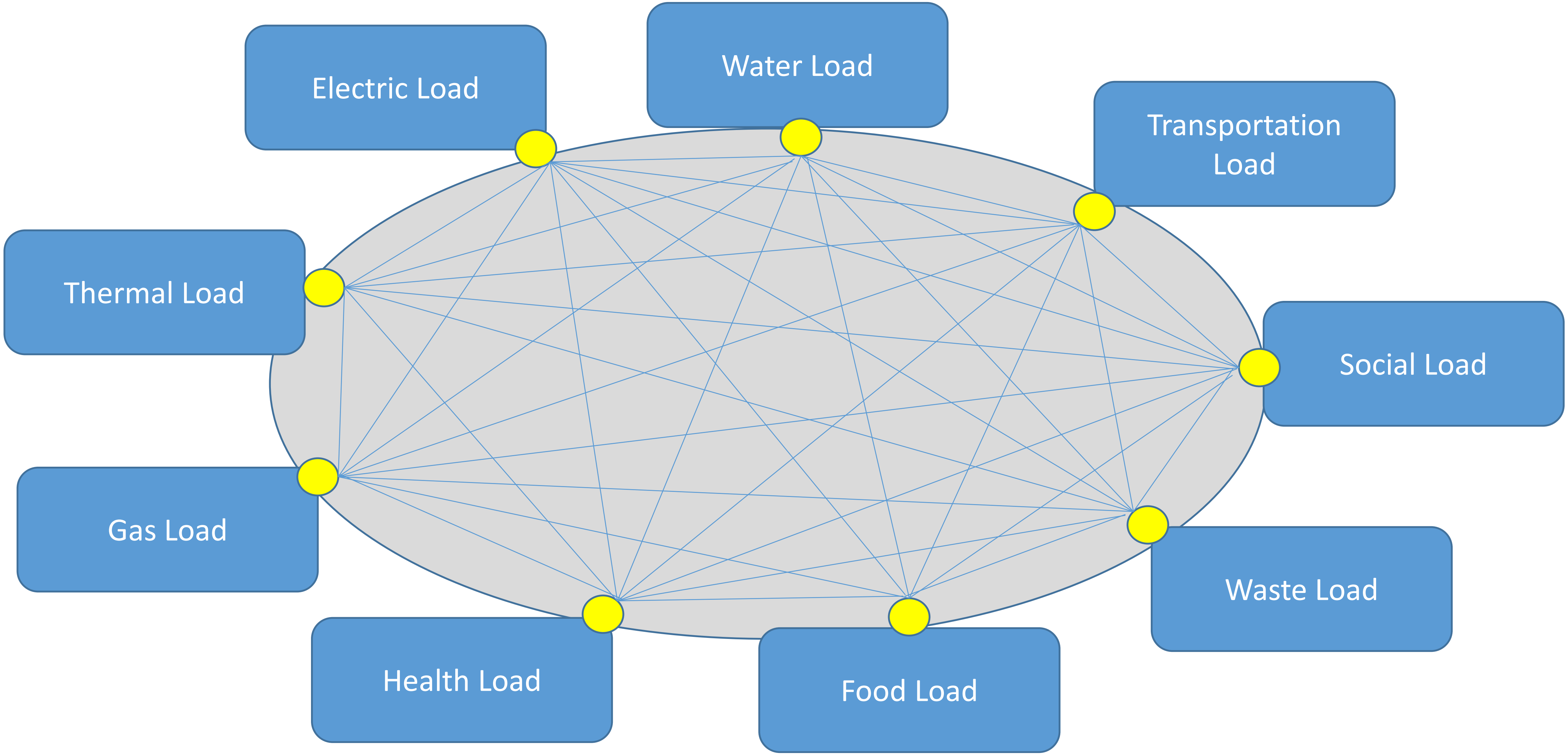
LORPA: Layers of Resiliency and Protection Analysis



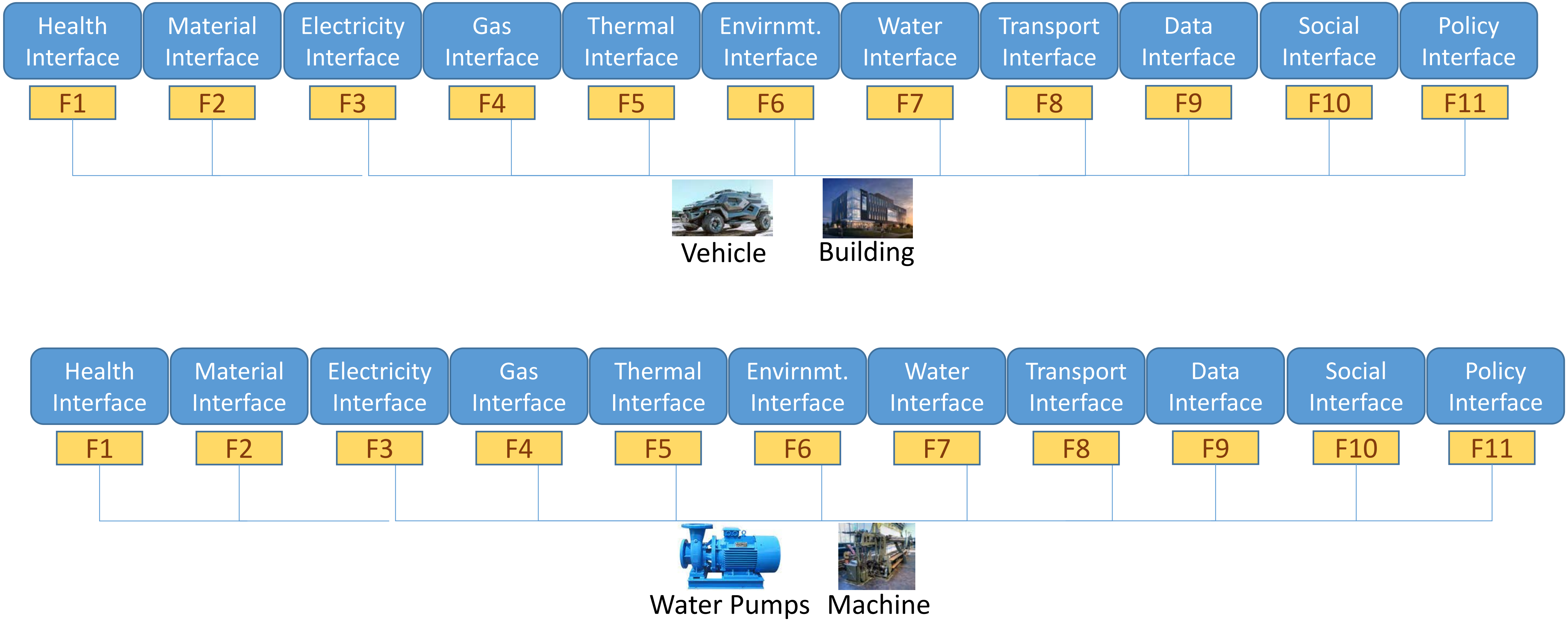
Interconnected Infrastructures



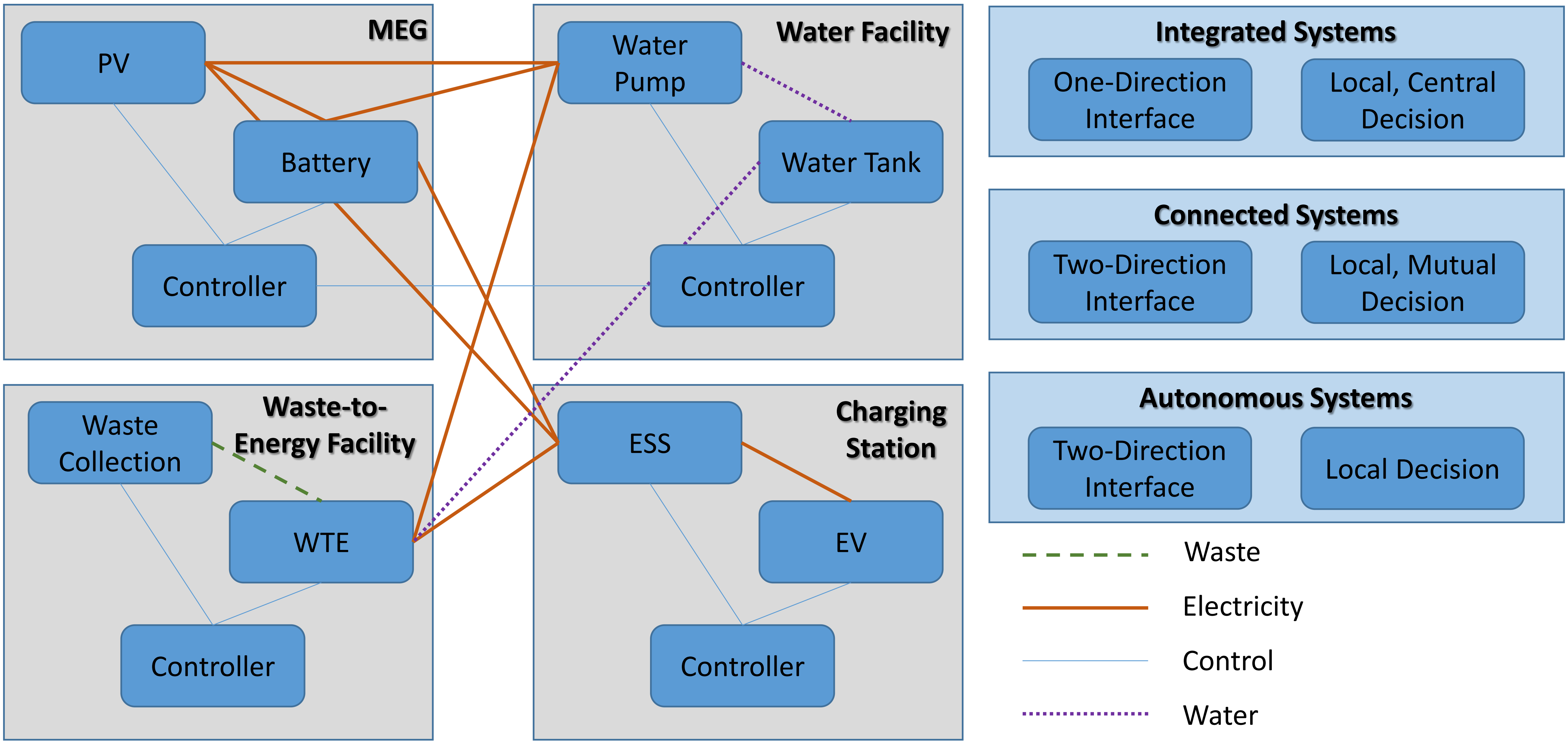
Energy Loads Coupling with Interconnected Infrastructures



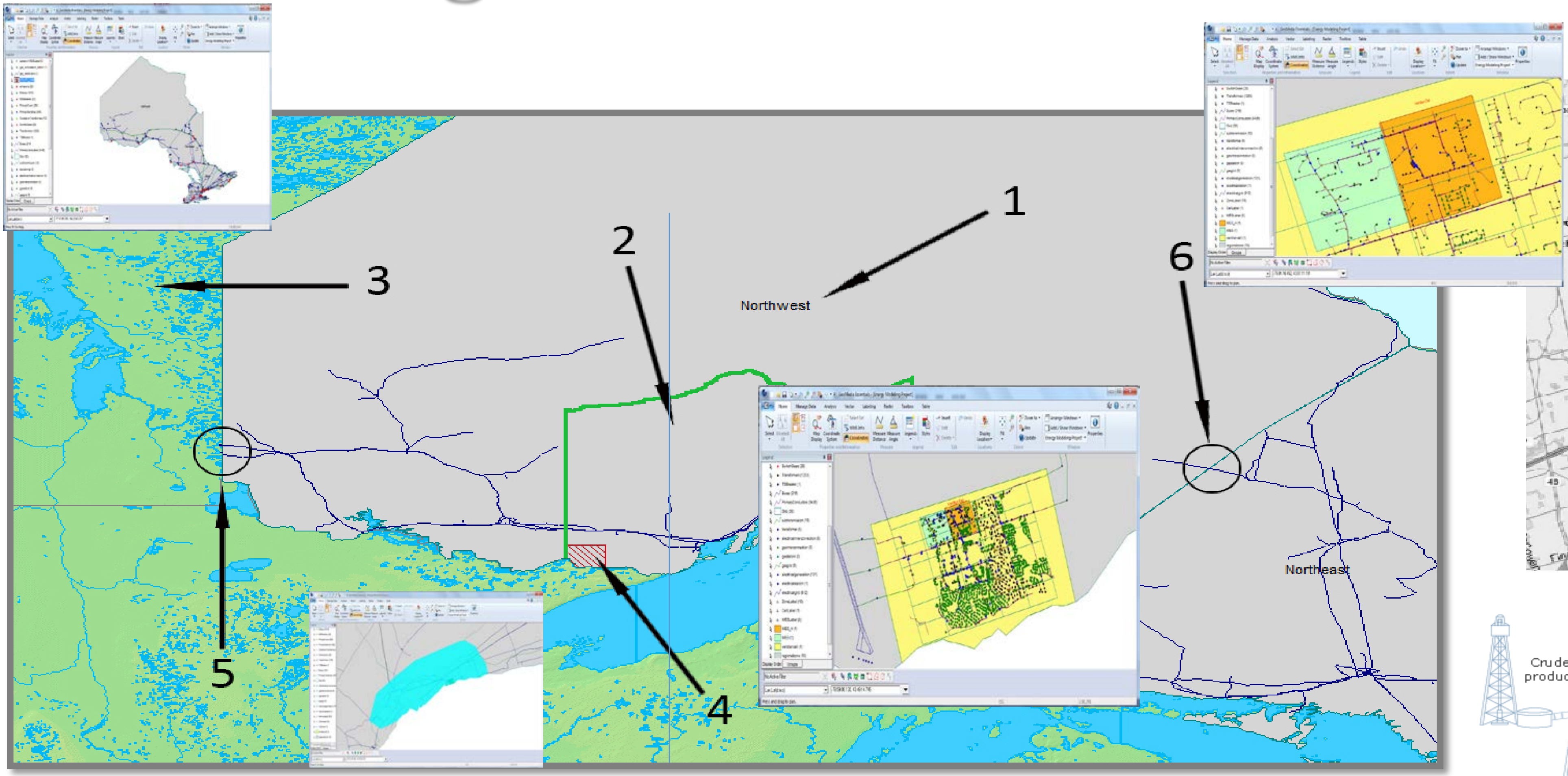
Interface Design for Interconnected Systems, Application on Energy-Water-Transportation Networks



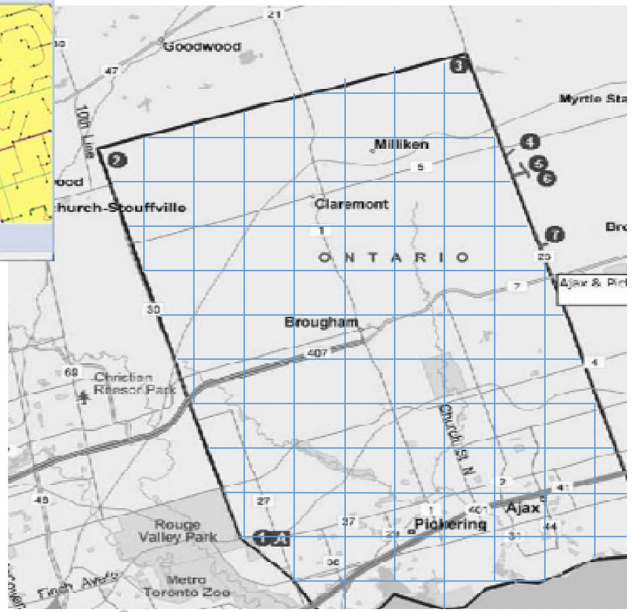
Integrated, Connected, and Autonomous Systems

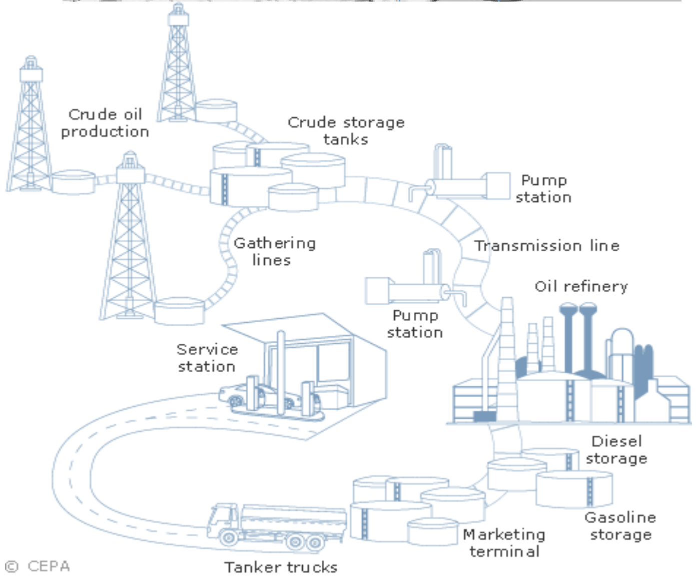


Regional Gas-Power MEG Planning



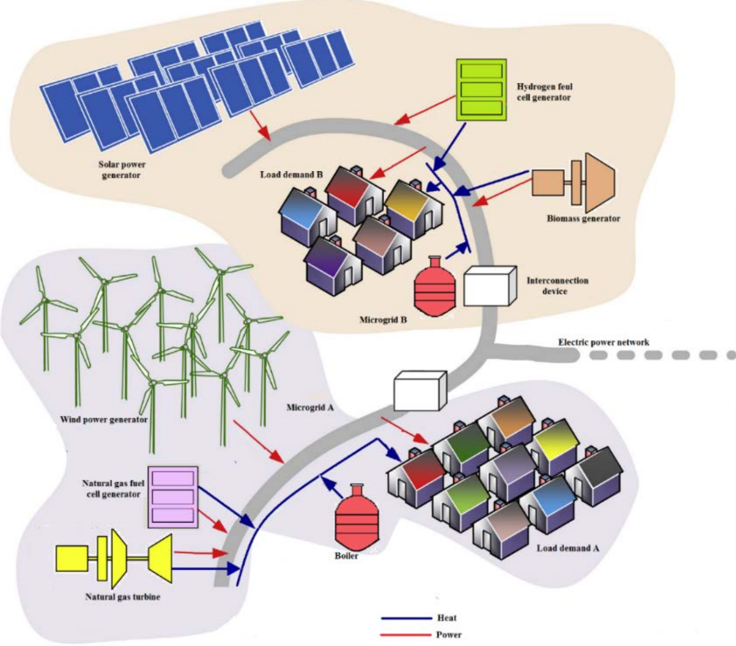
Region Cell Arrangement



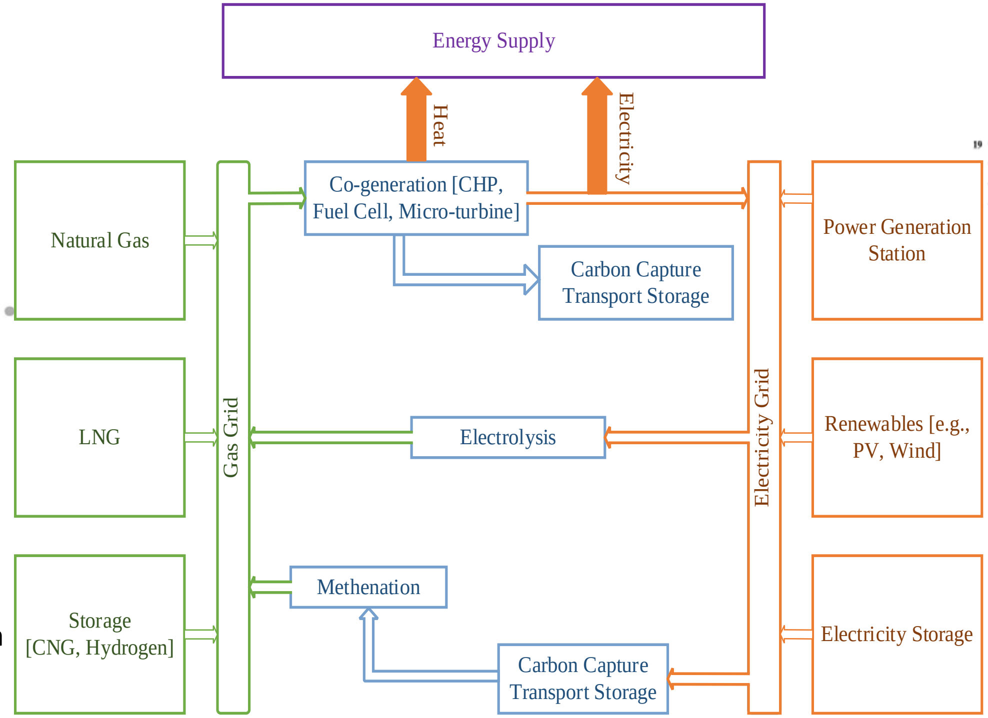


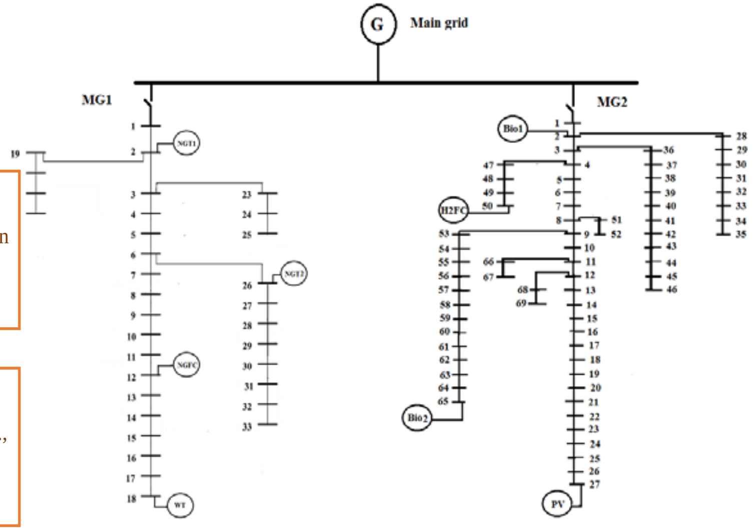
1. Regional Zone
2. Sub-regional Zone
3. Extra-regional Zone
4. Cell
5. Interconnection
6. Interface

Evaluation and Optimization of Interconnected Micro Energy Grids with Gas-Power, CHP, and Renewable Technologies

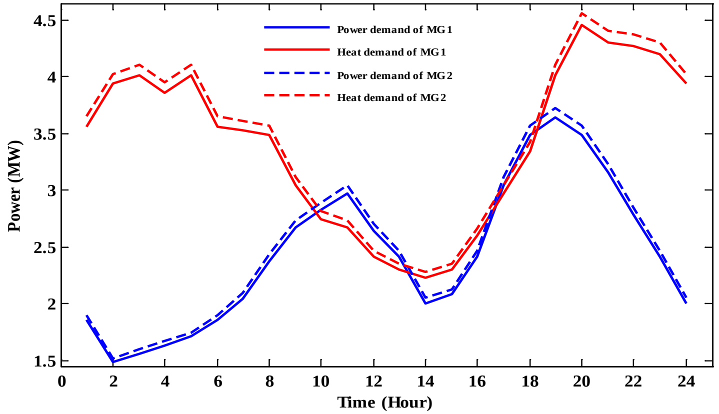


Energy flow schematic of interconnected-MEGs system

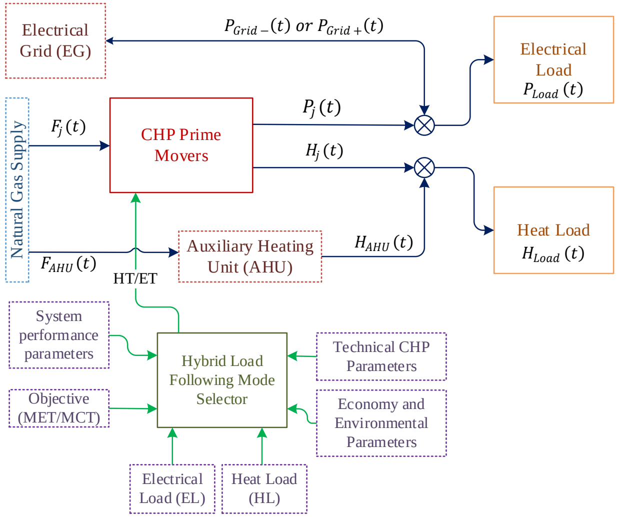




Structure of network with two MEGs



Typical heat and electricity demand for MEG1 & 2

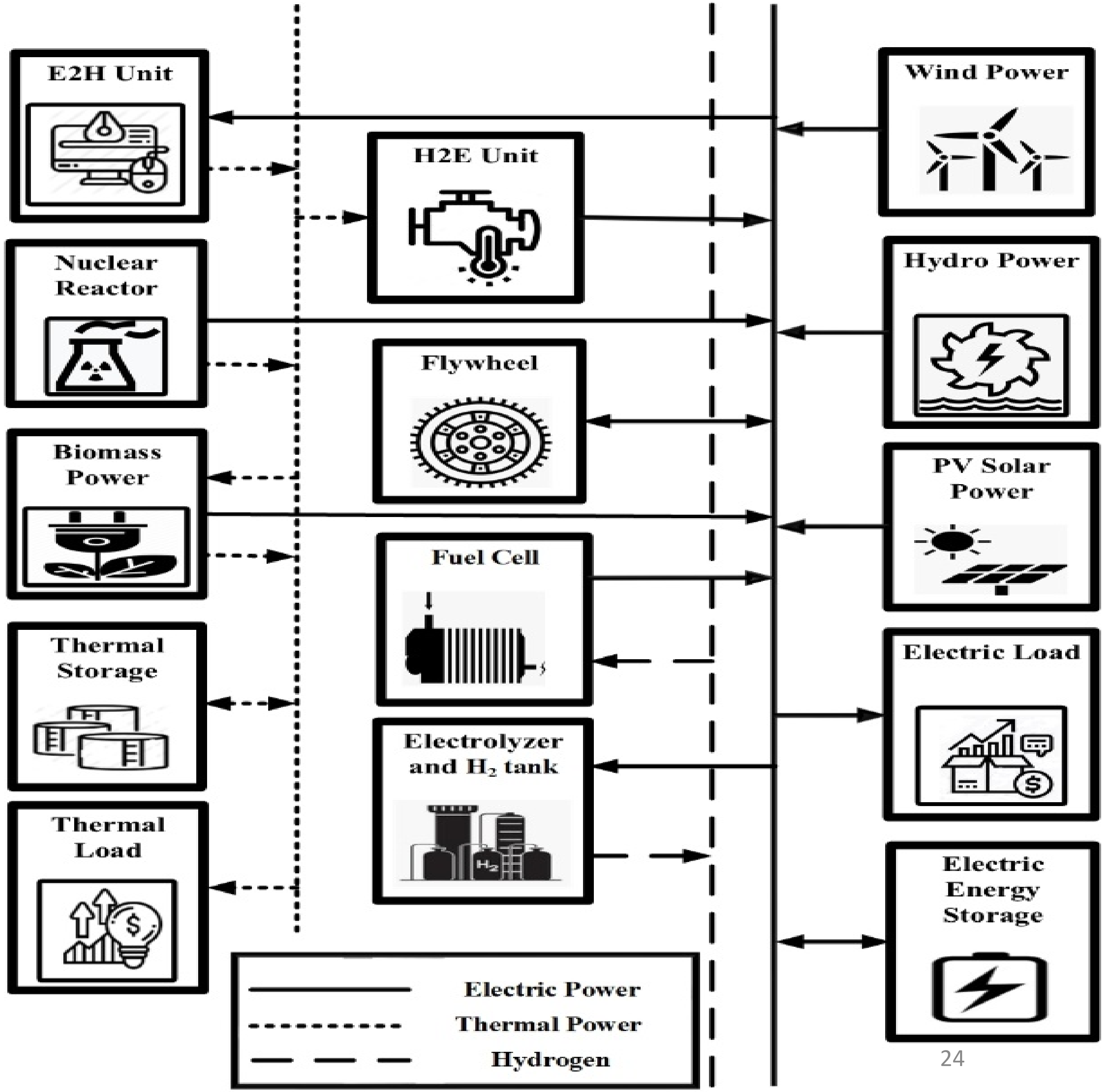


- CHP system with optimal prime mover, it is found that:
  - Return on investment of the system could be as high as **13%**
  - Minimum payback period found is **7.8** years
  - Maximum possible CO_2 emission saving is **15%**
  - Maximum NOx savings found is **61%**

Mobile Microgrid Trailer

MOBISMART
MOBILE OFF-GRID POWER & STORAGE

Multiple Resources and Multiple Products-based Coupling



iii)

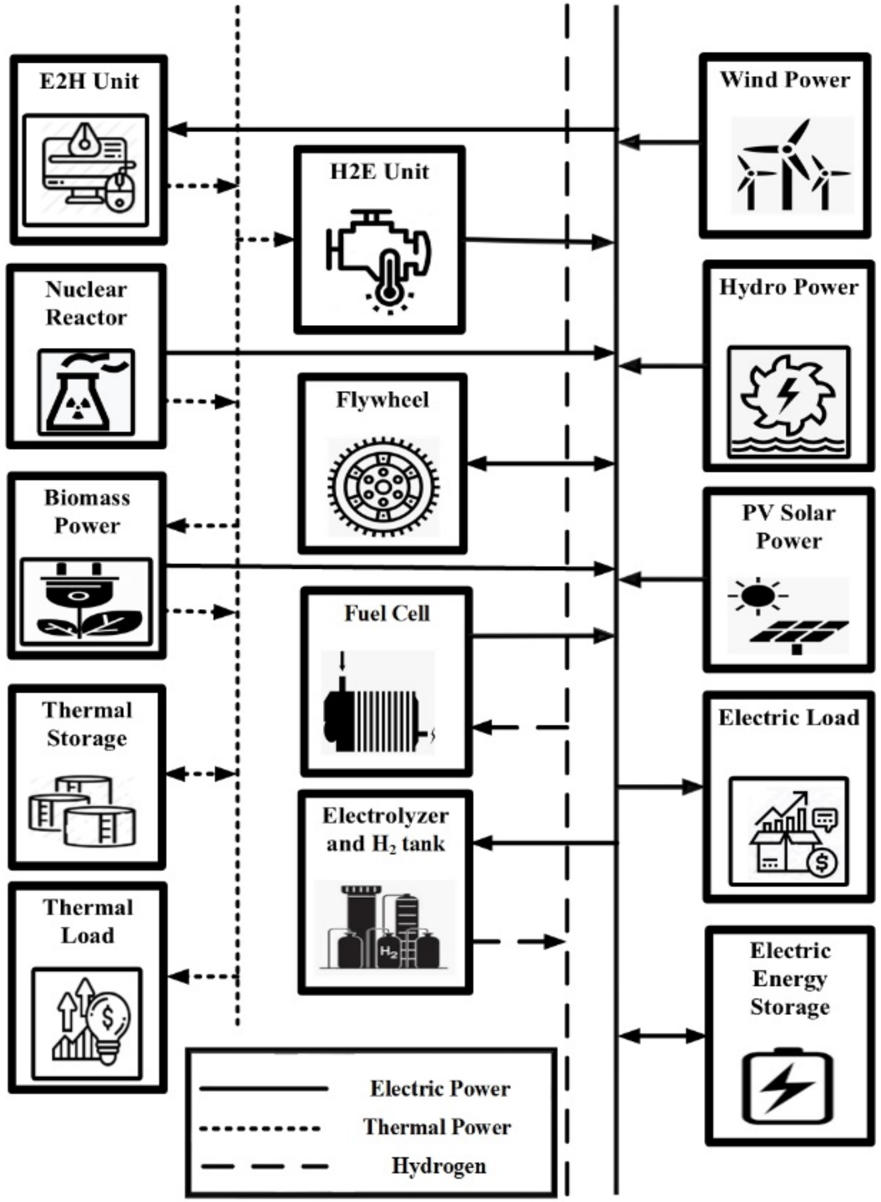


Fig: Multiple Resources and Multiple Products-based Coupling

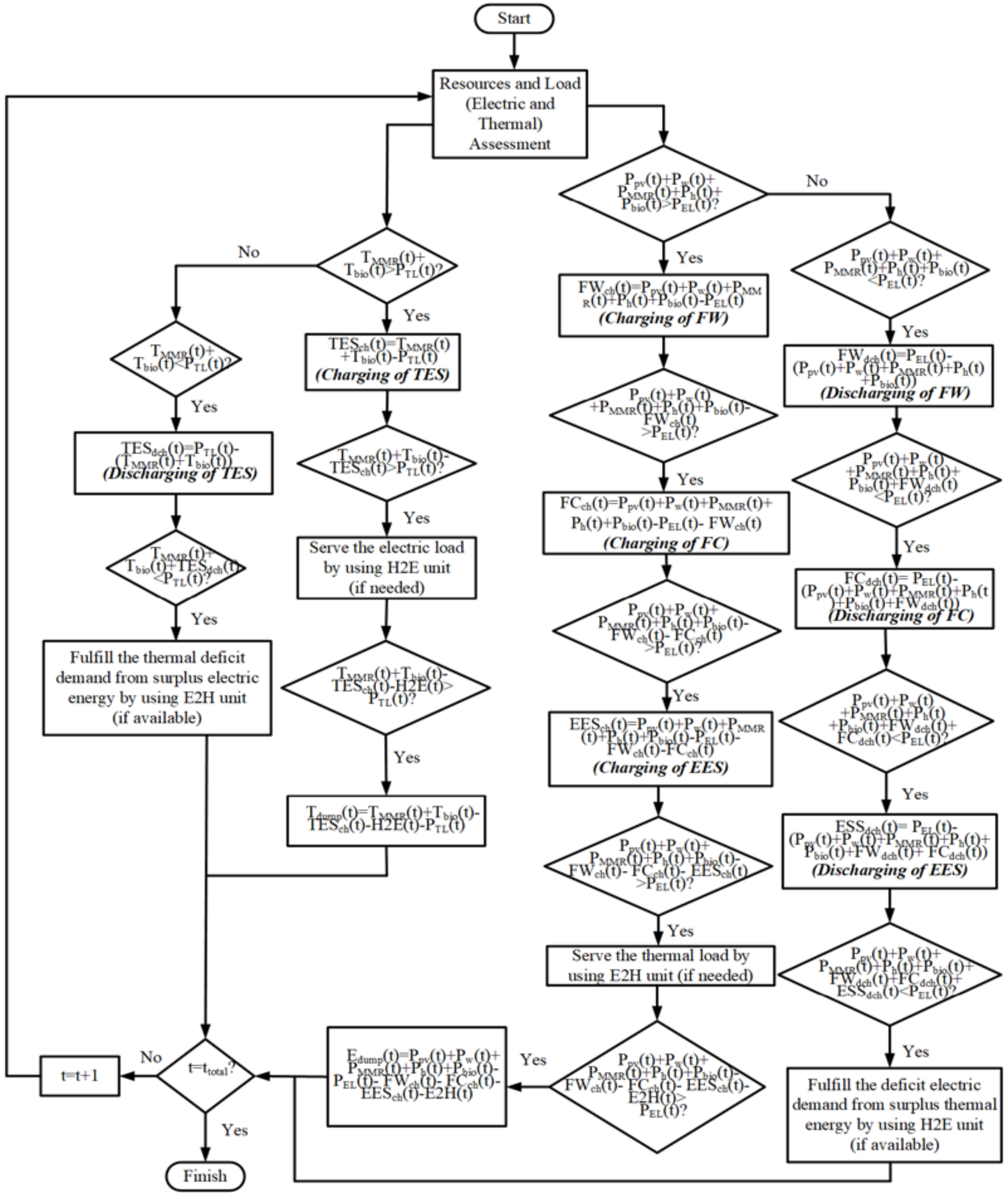
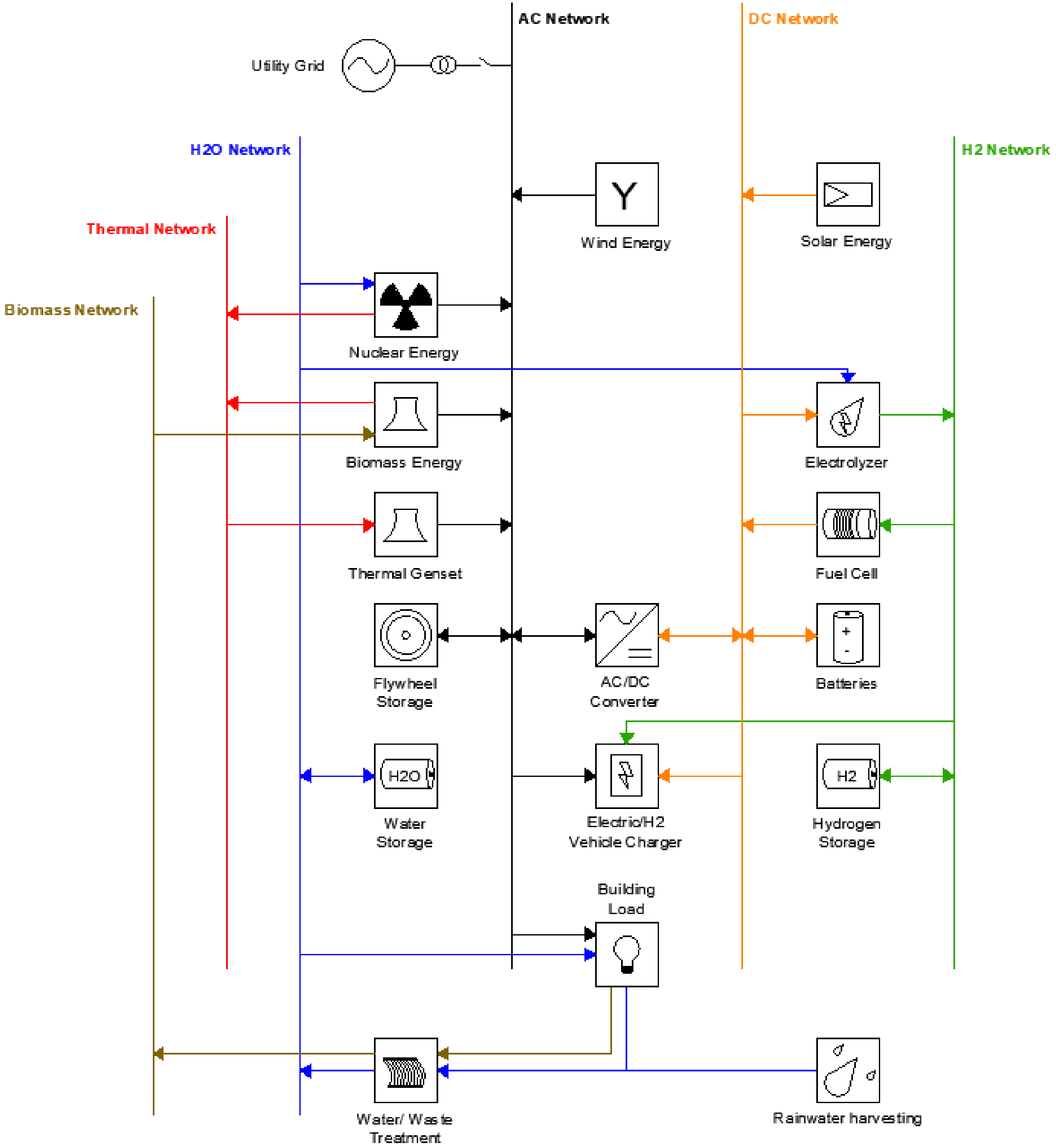


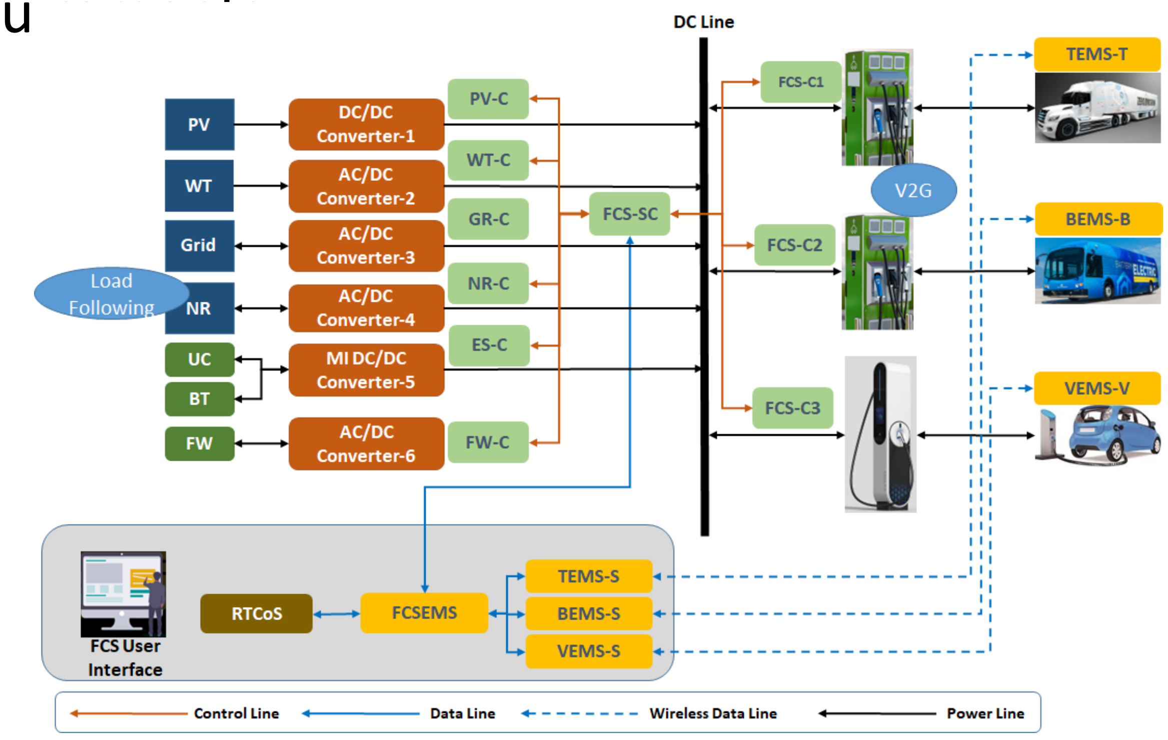
Fig: Energy Management Algorithm

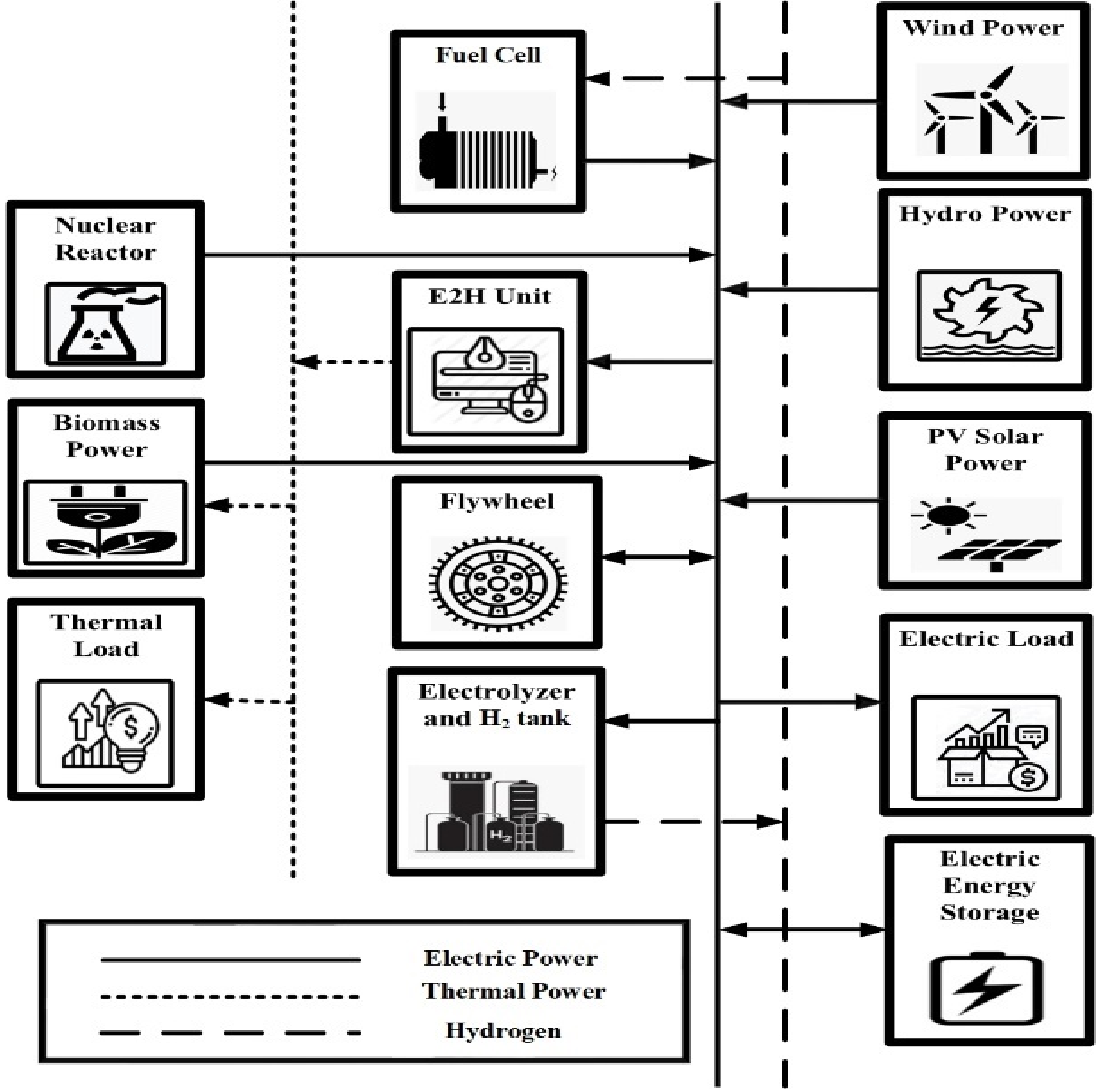
Hybrid Energy System



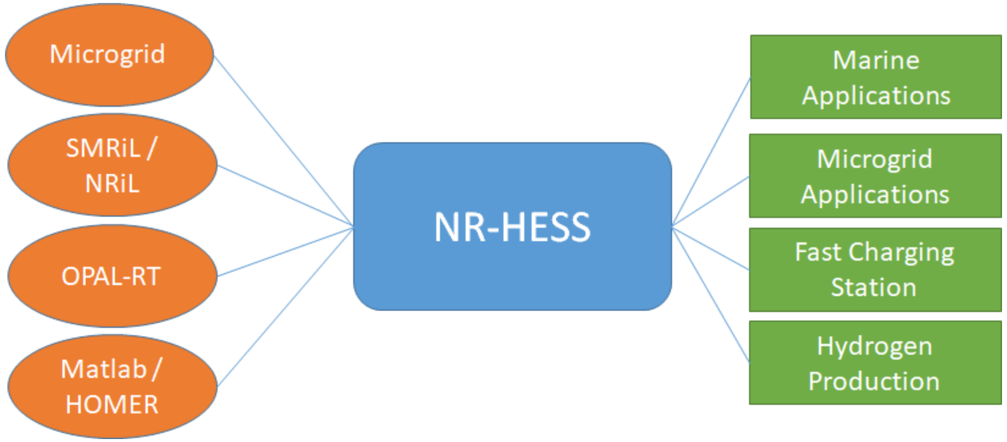
Nuclear-Renewable Hybrid Energy System Simulator

In direct coupling method, electricity is generated from different RESs and reactors, and the resources simultaneously serve the electric and thermal requ

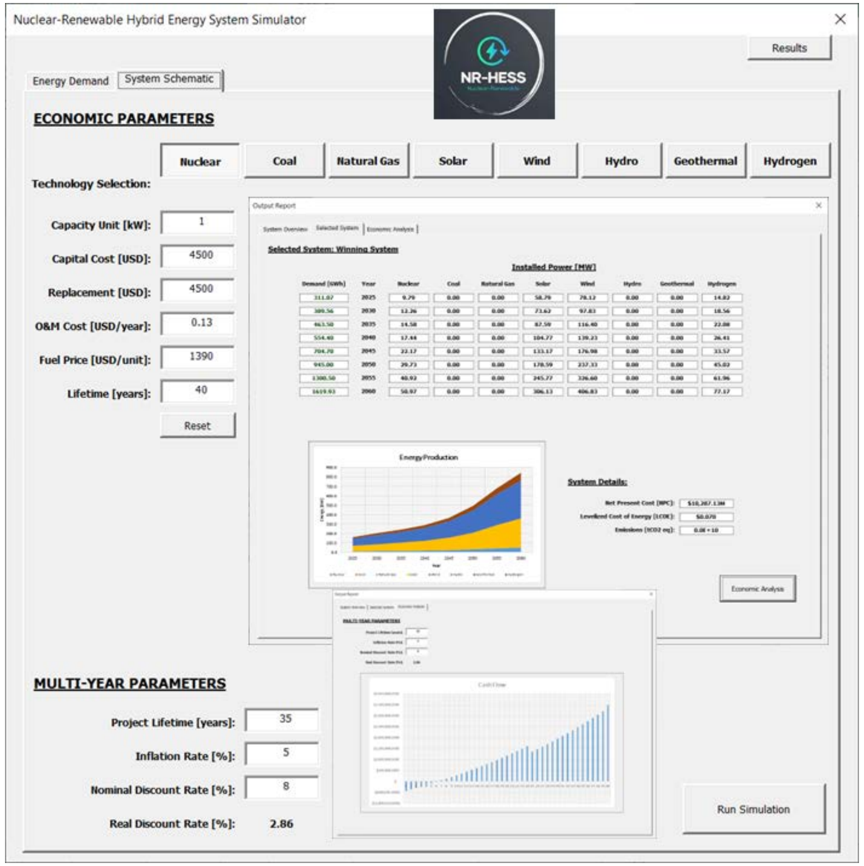


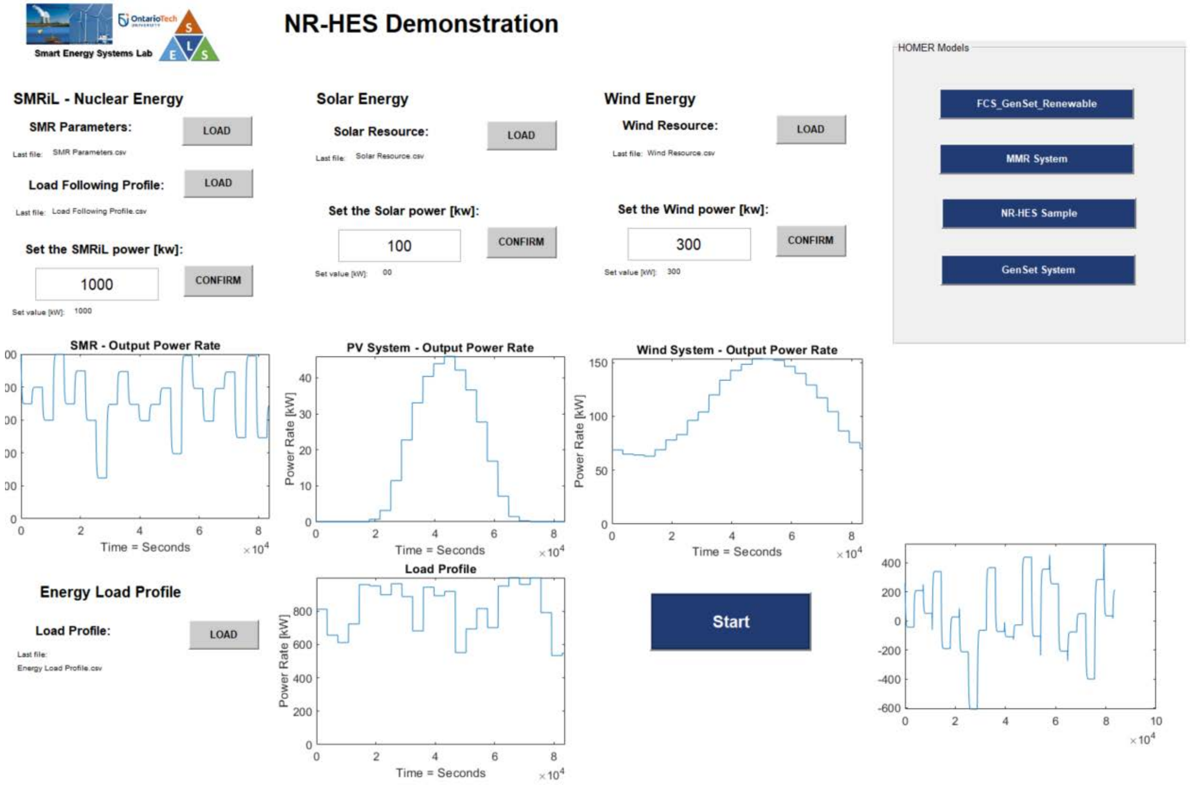


Deployments of Nuclear-Renewable Hybrid Energy Systems

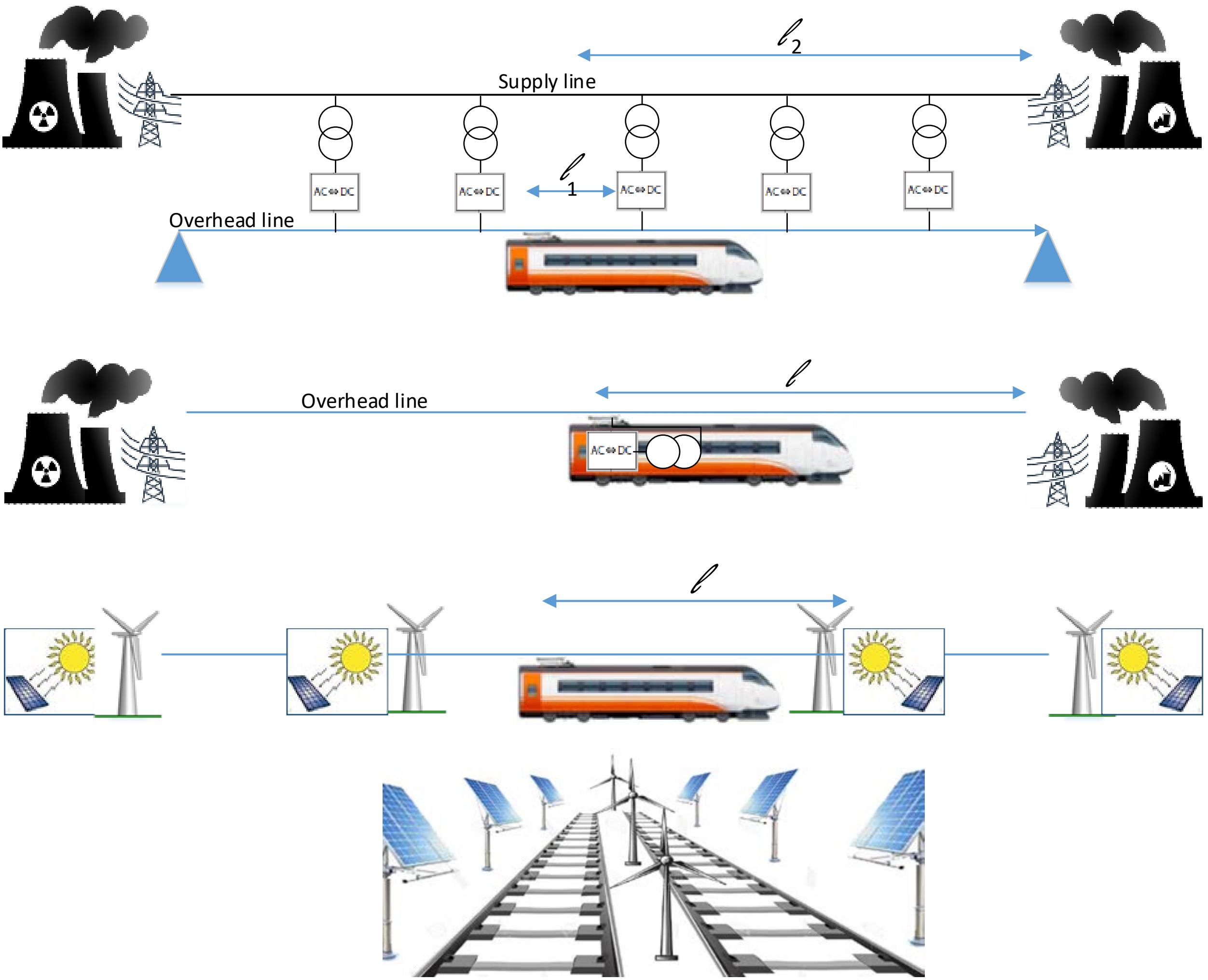


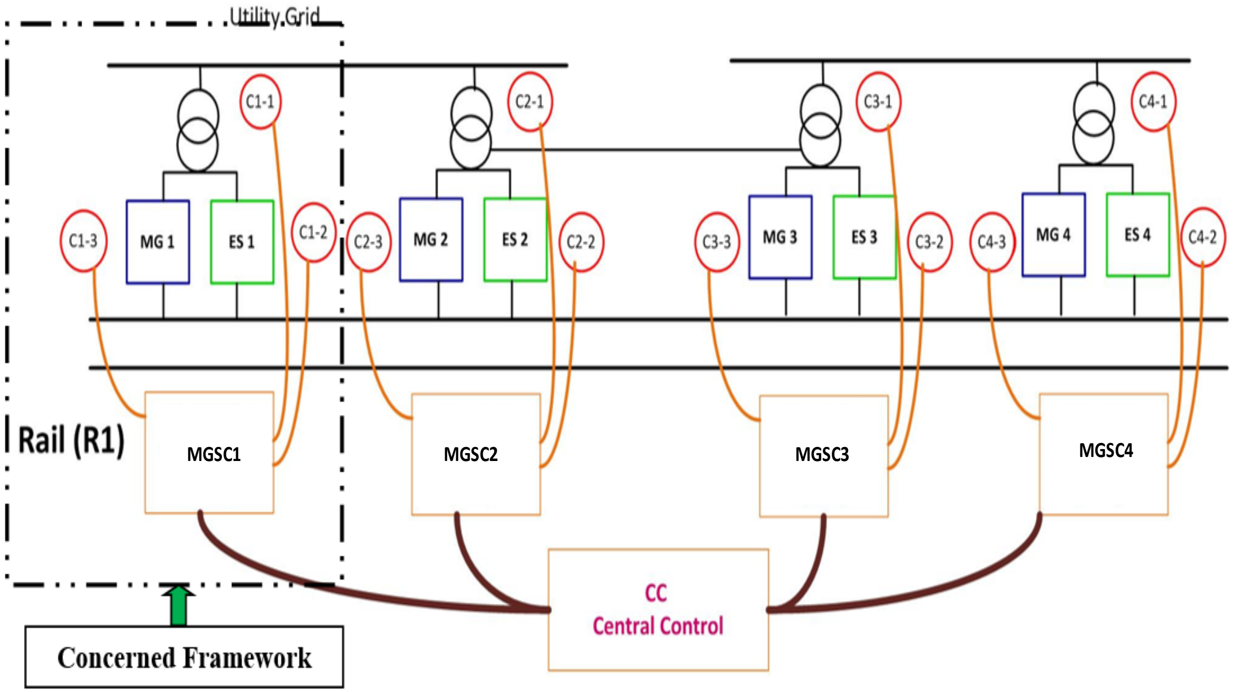
- Renewable Energy and Energy Storage Systems
- Nuclear Power Technologies
- Nuclear-Renewable Hybrid Energy Systems
- Demand Side Management
- Micro Hybrid Energy Systems
- Techno-Economic Analysis
- Group Discussions and Individual Work



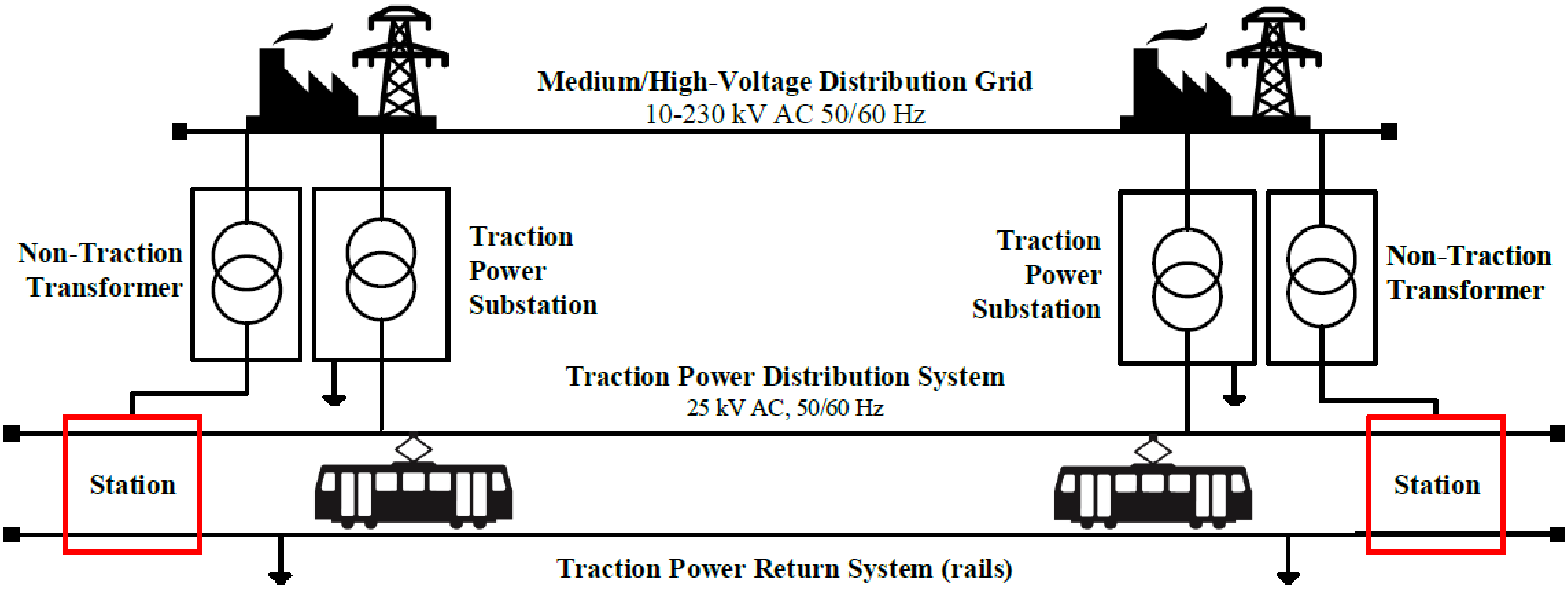


Resilient Interconnected Micro Energy Grids for Sustainable Railways

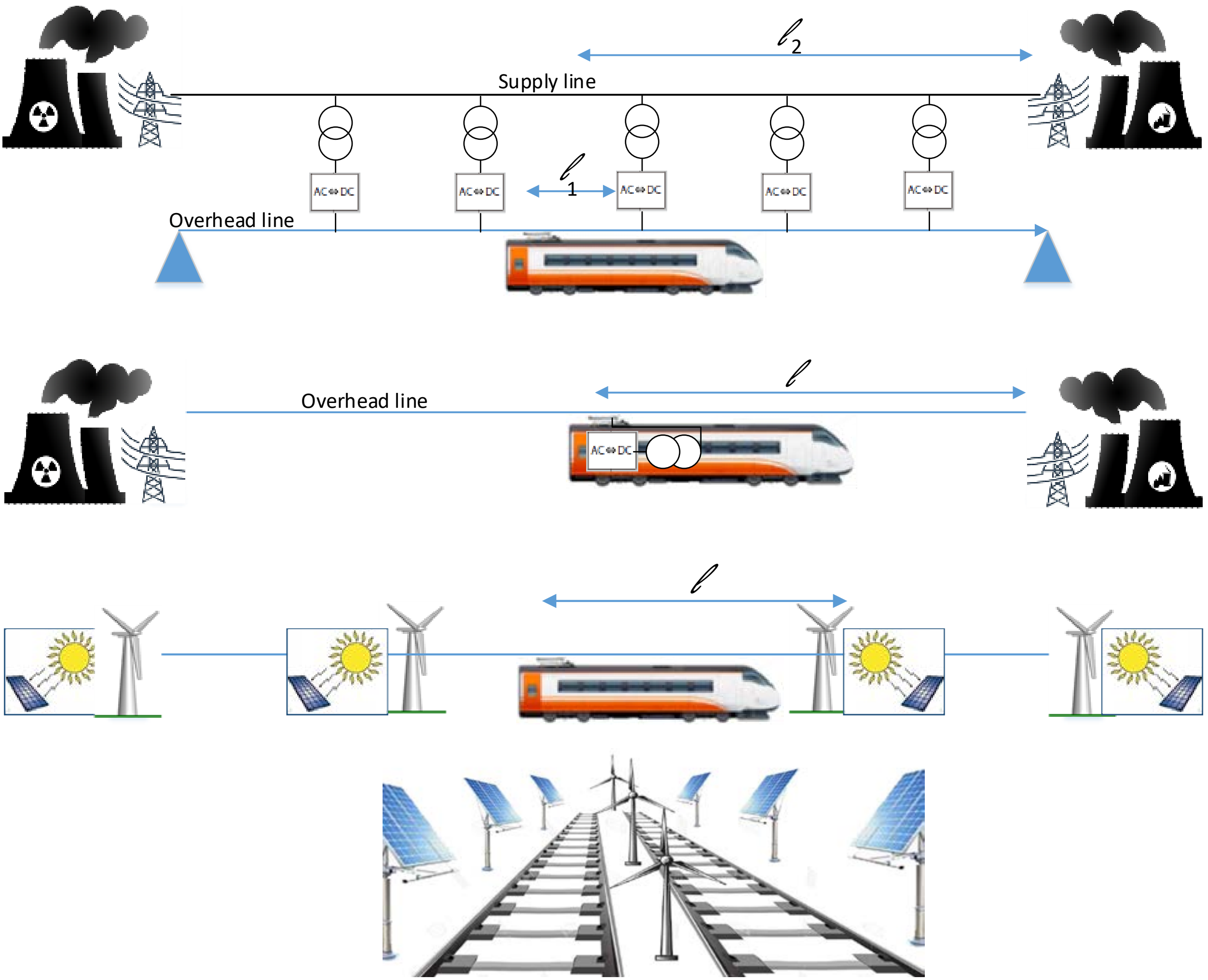


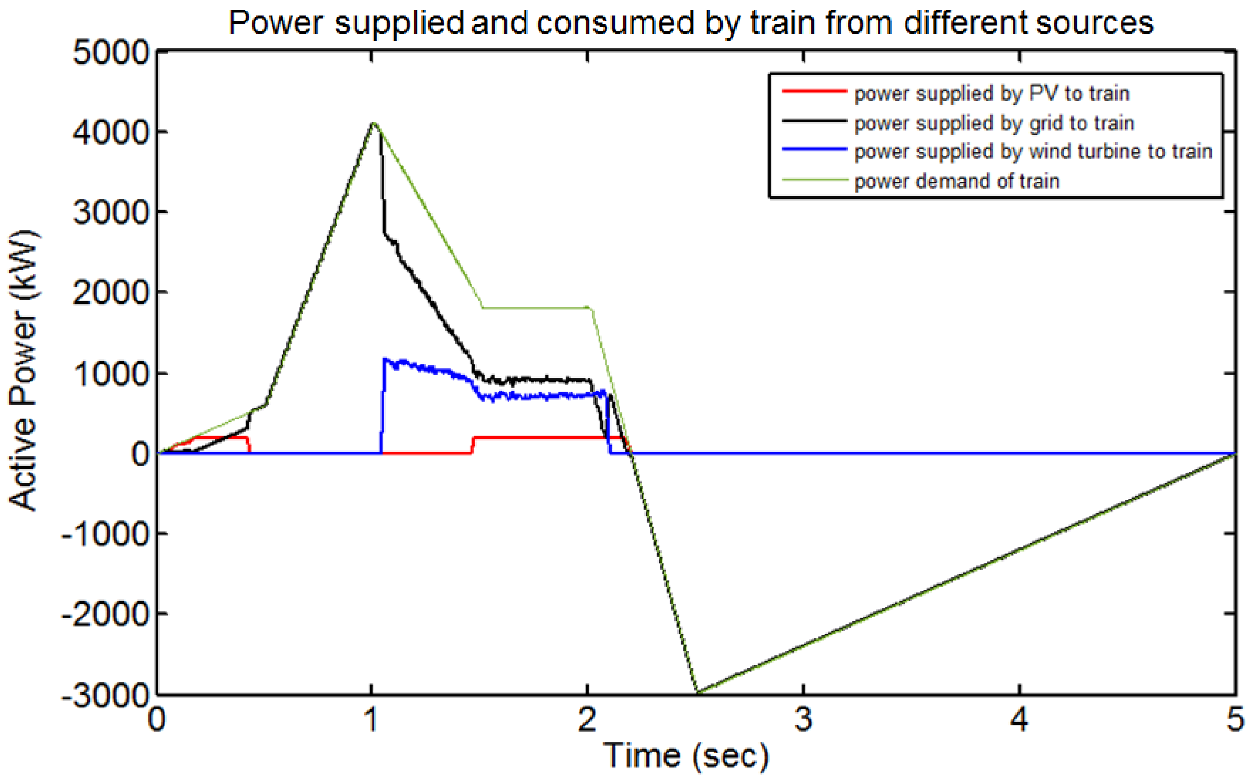


Typical Topology of an AC Railway Electrification

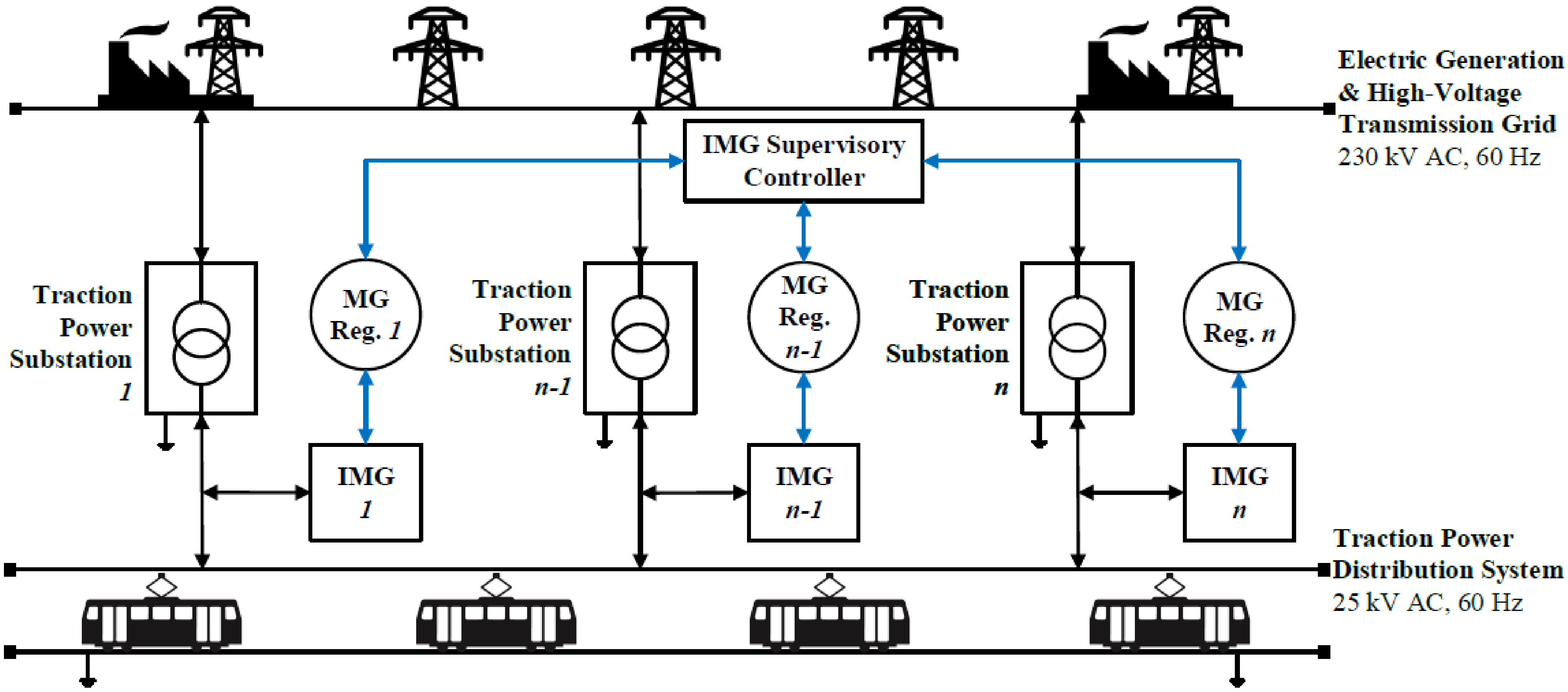


Resilient Interconnected Micro Energy Grids for Sustainable Railways

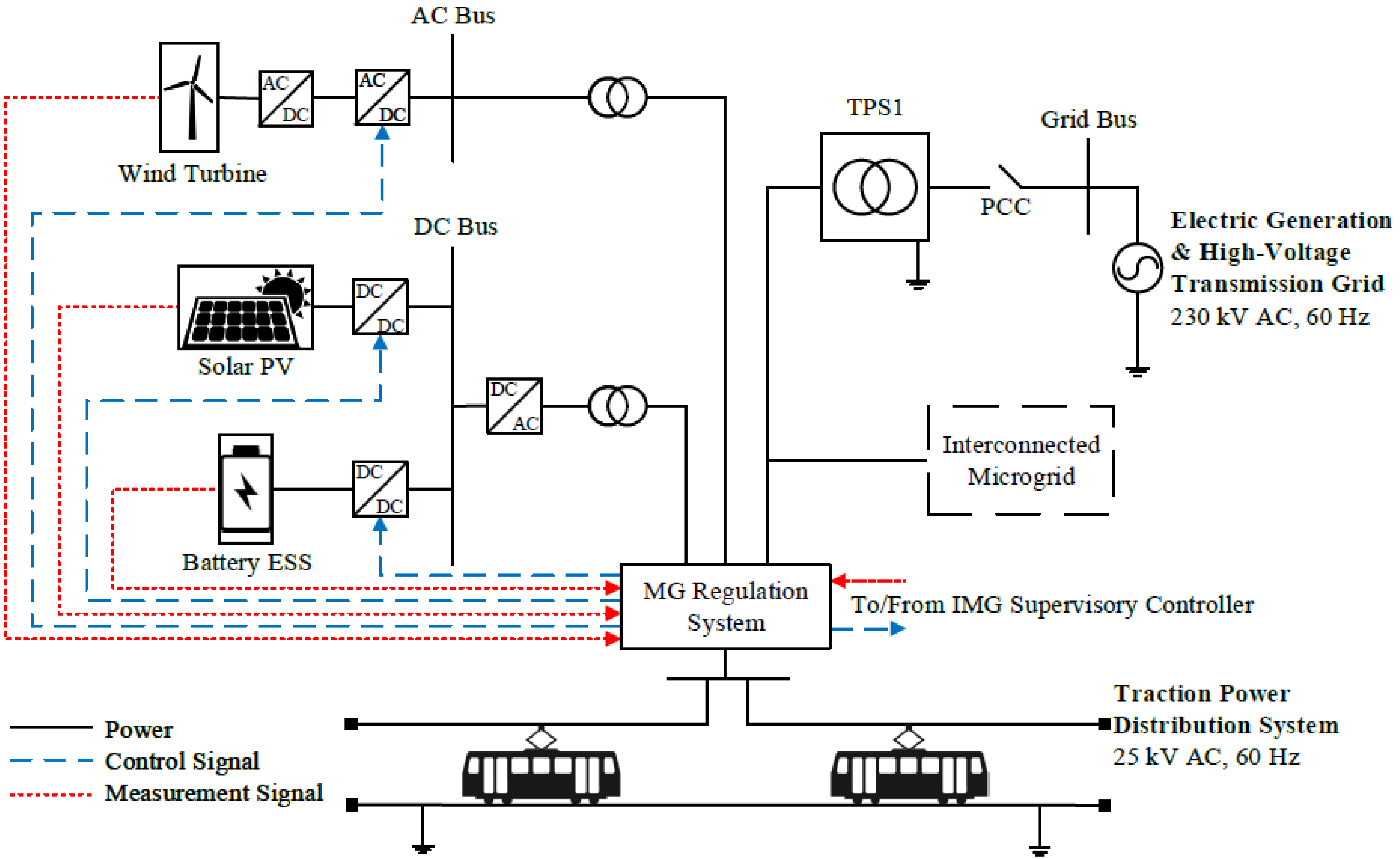


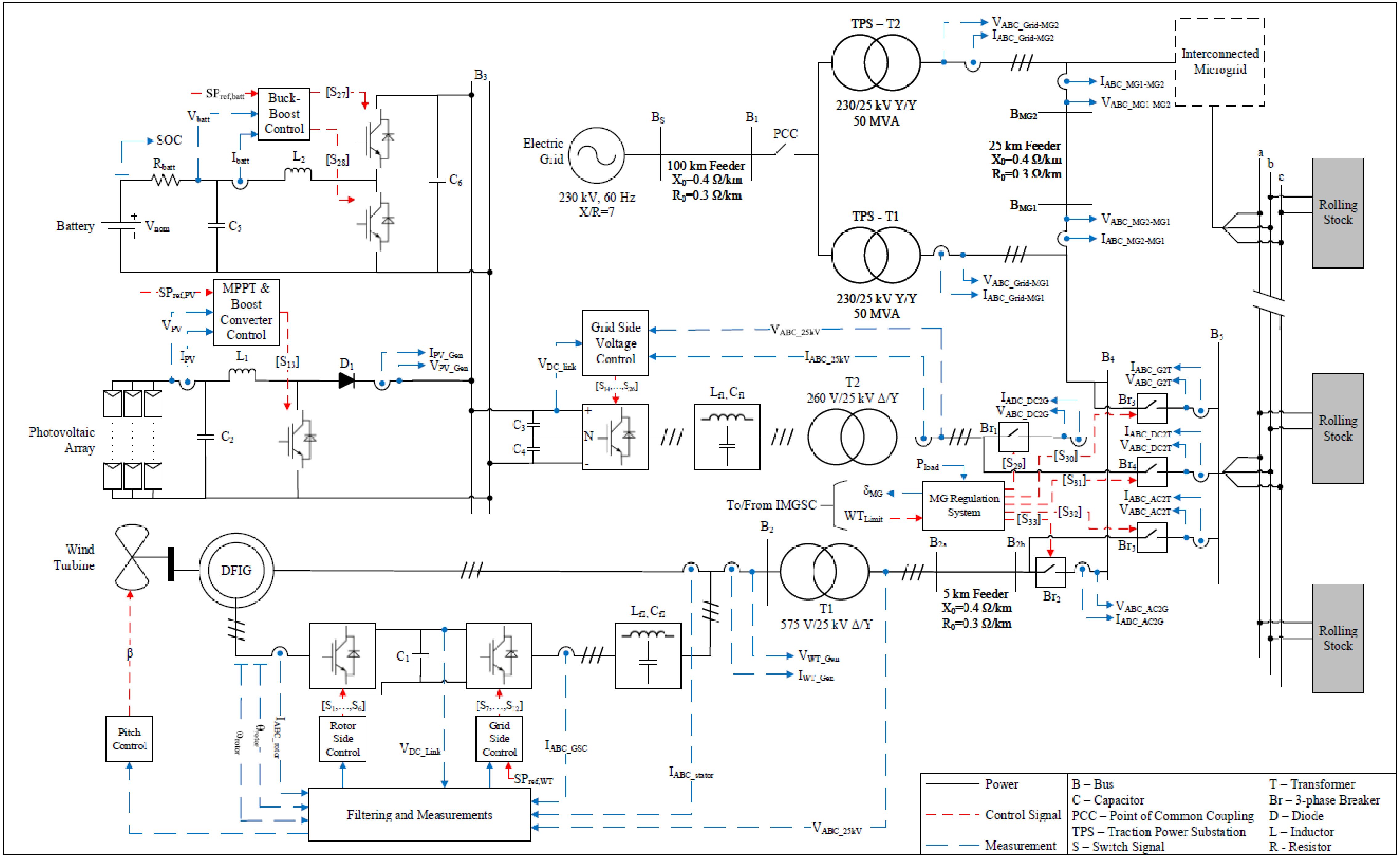


Interconnected Micro Grids for Transportation Charging



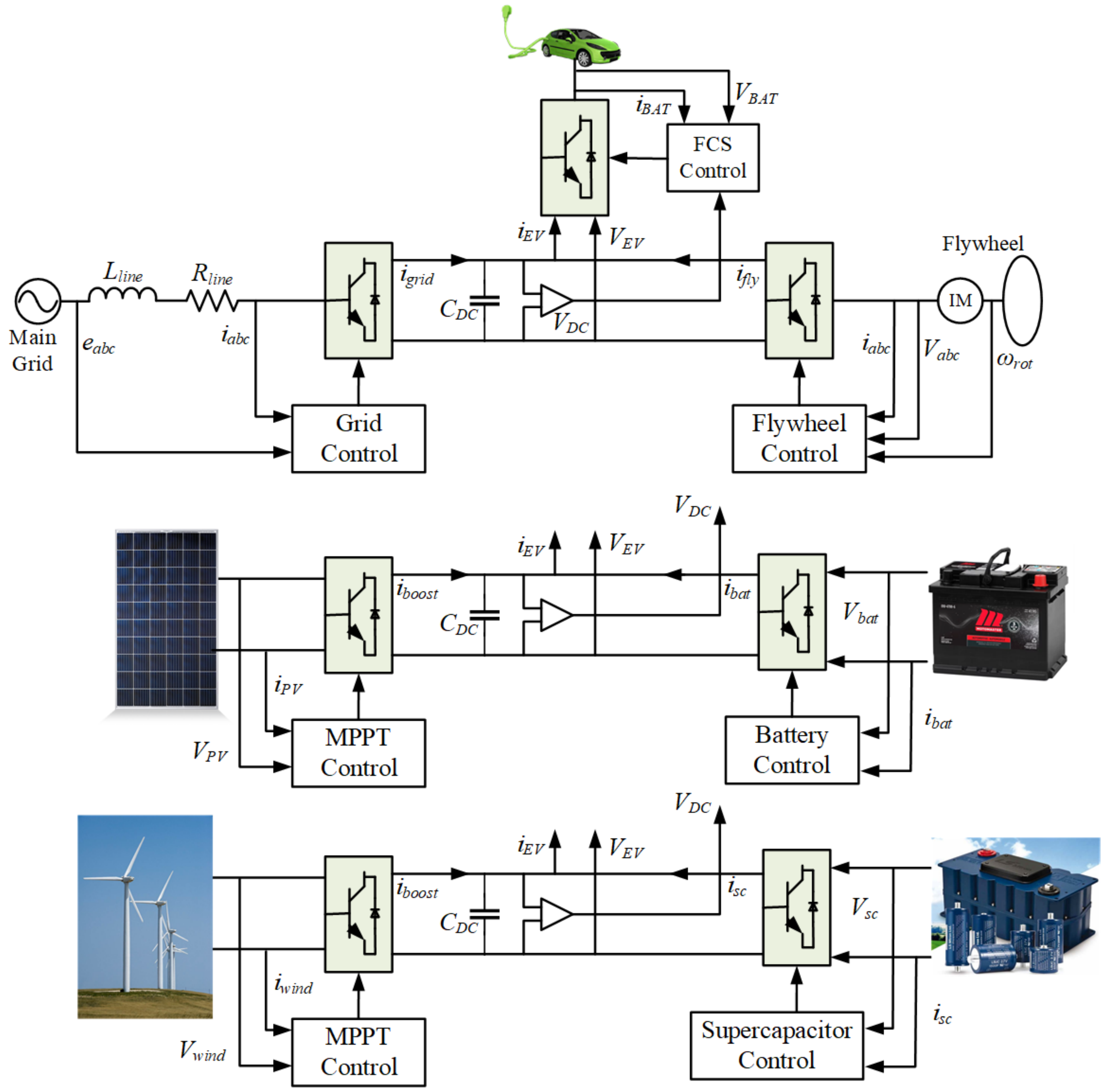
Schematic of Hybrid AC-DC RIMG Including Power and Energy Sources



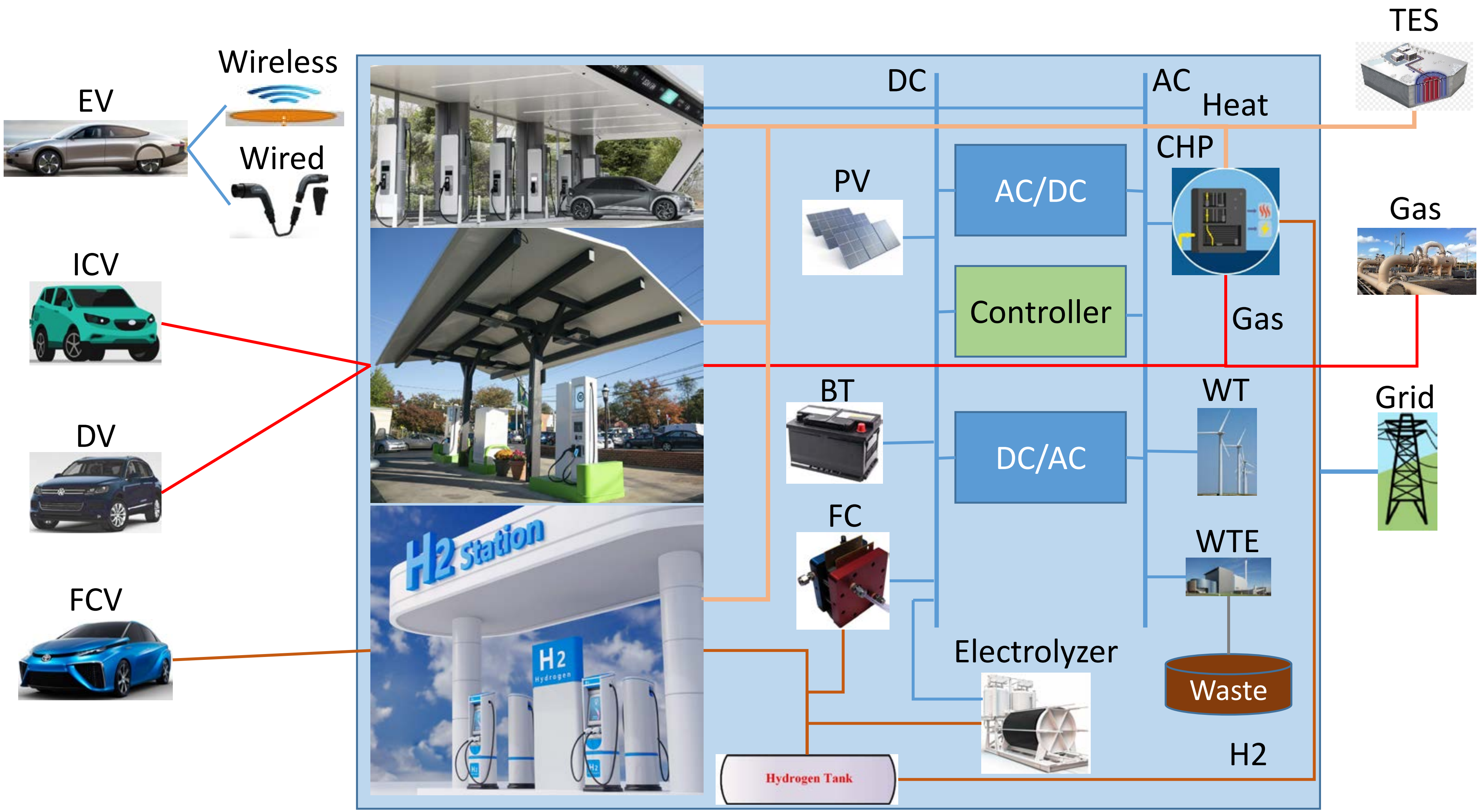


TPS – T2
230/25 kV Y/Y
50 MVA
V_ABC_Grid-MG2
I_ABC_Grid-MG2
Interconnected Microgrid
I_ABC_MG1-MG2
V_ABC_MG1-MG2
B_MG2
25 km Feeder
X0=0.4 Ω/km
R0=0.3 Ω/km
B_MG1
V_ABC_MG2-MG1
I_ABC_MG2-MG1
TPS - T1
230/25 kV Y/Y
50 MVA
V_ABC_Grid-MG1
I_ABC_Grid-MG1
Electric Grid
230 kV, 60 Hz
X/R=7
B_S
B_1
PCC
100 km Feeder
X0=0.4 Ω/km
R0=0.3 Ω/km
SP_ref,batt
Buck-Boost Control
[S27]
[S28]
V_batt
SOC
I_batt
R_batt
L2
C6
B3
Battery
V_nom
C5
SP_ref,PV
MPPT & Boost Converter Control
V_PV
I_PV
L1
[S13]
D1
I_PV_Gen
V_PV_Gen
Photovoltaic Array
C2
Grid Side Voltage Control
V_ABC_25kV
I_ABC_25kV
V_DC_link
[S14,...,S20]
C3
C4
N
Lf1, Cf1
T2
260 V/25 kV Δ/Y
Br1
I_ABC_DC2G
V_ABC_DC2G
B4
B5
I_ABC_G2T
V_ABC_G2T
Br3
I_ABC_DC2T
V_ABC_DC2T
Br4
I_ABC_AC2T
V_ABC_AC2T
Br5
[S29]
[S30]
[S31]
[S32]
[S33]
P_load
δ_MG
WT_Limit
To/From IMGSC
MG Regulation System
a
b
c
Rolling Stock
Rolling Stock
Rolling Stock
Wind Turbine
DFIG
B2
T1
575 V/25 kV Δ/Y
B2a
B2b
Br2
5 km Feeder
X0=0.4 Ω/km
R0=0.3 Ω/km
V_ABC_AC2G
I_ABC_AC2G
V_WT_Gen
I_WT_Gen
Lf2, Cf2
C1
β
[S1,...,S6]
[S7,...,S12]
Pitch Control
θ_rotor
θ_rotor
I_ABC_rotor
Rotor Side Control
V_DC_Link
Grid Side Control
SP_ref,WT
I_ABC_GSC
I_ABC_stator
Filtering and Measurements
V_ABC_25kV
Power
Control Signal
Measurement
B – Bus
C – Capacitor
PCC – Point of Common Coupling
TPS – Traction Power Substation
S – Switch Signal
T – Transformer
Br – 3-phase Breaker
D – Diode
L – Inductor
R - Resistor

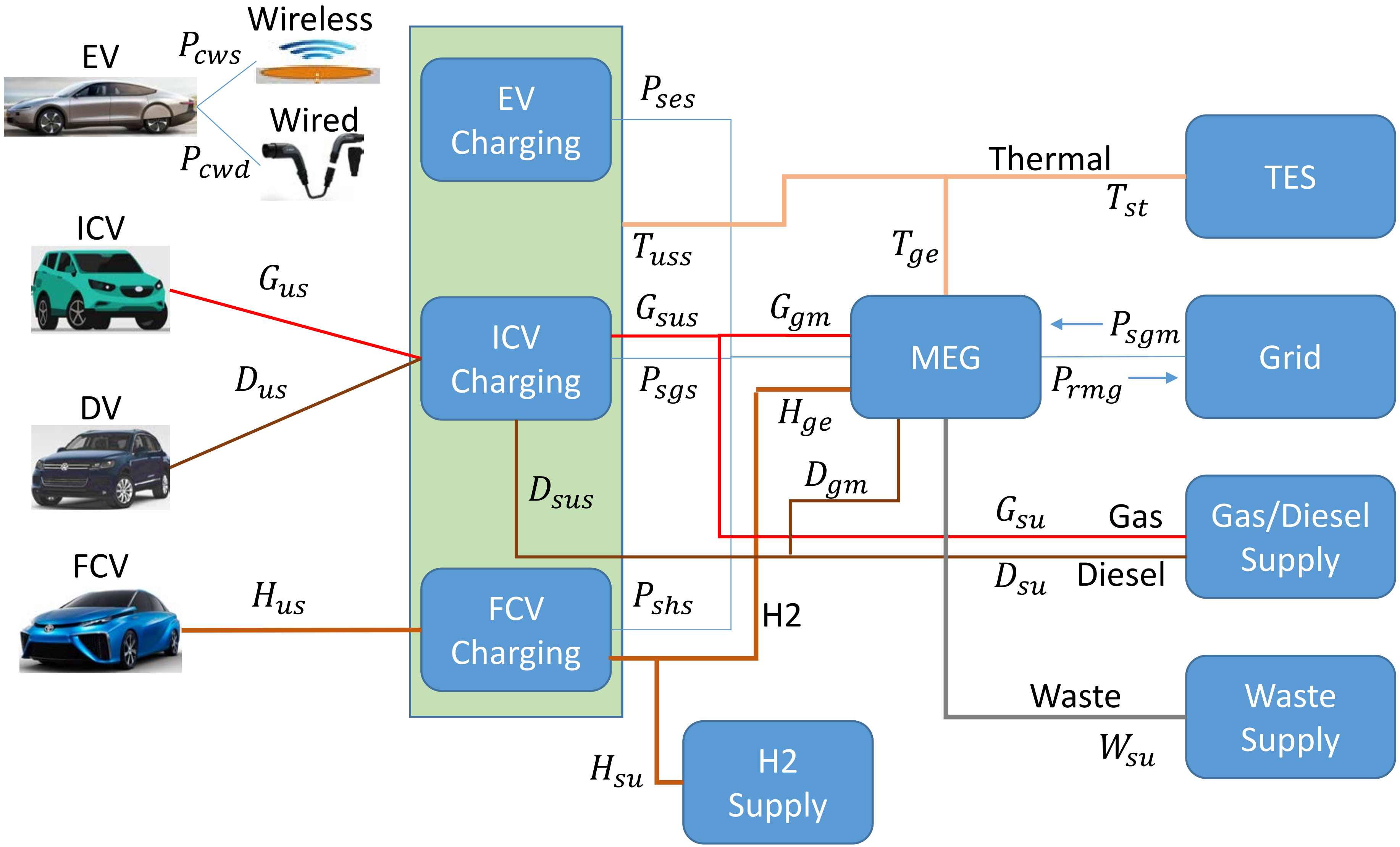
Integrated Control of Charging Station



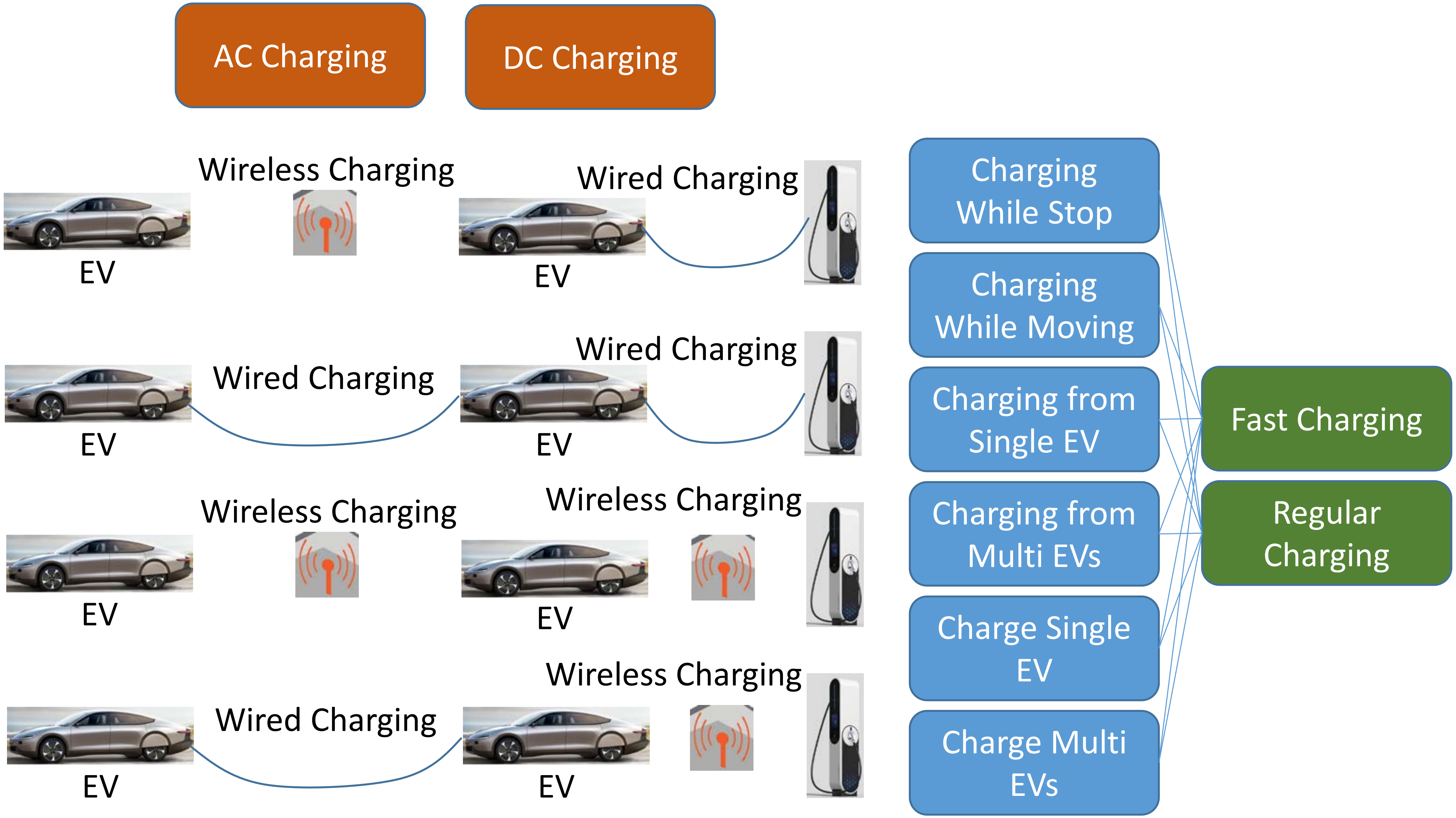
Hybrid Charging Station



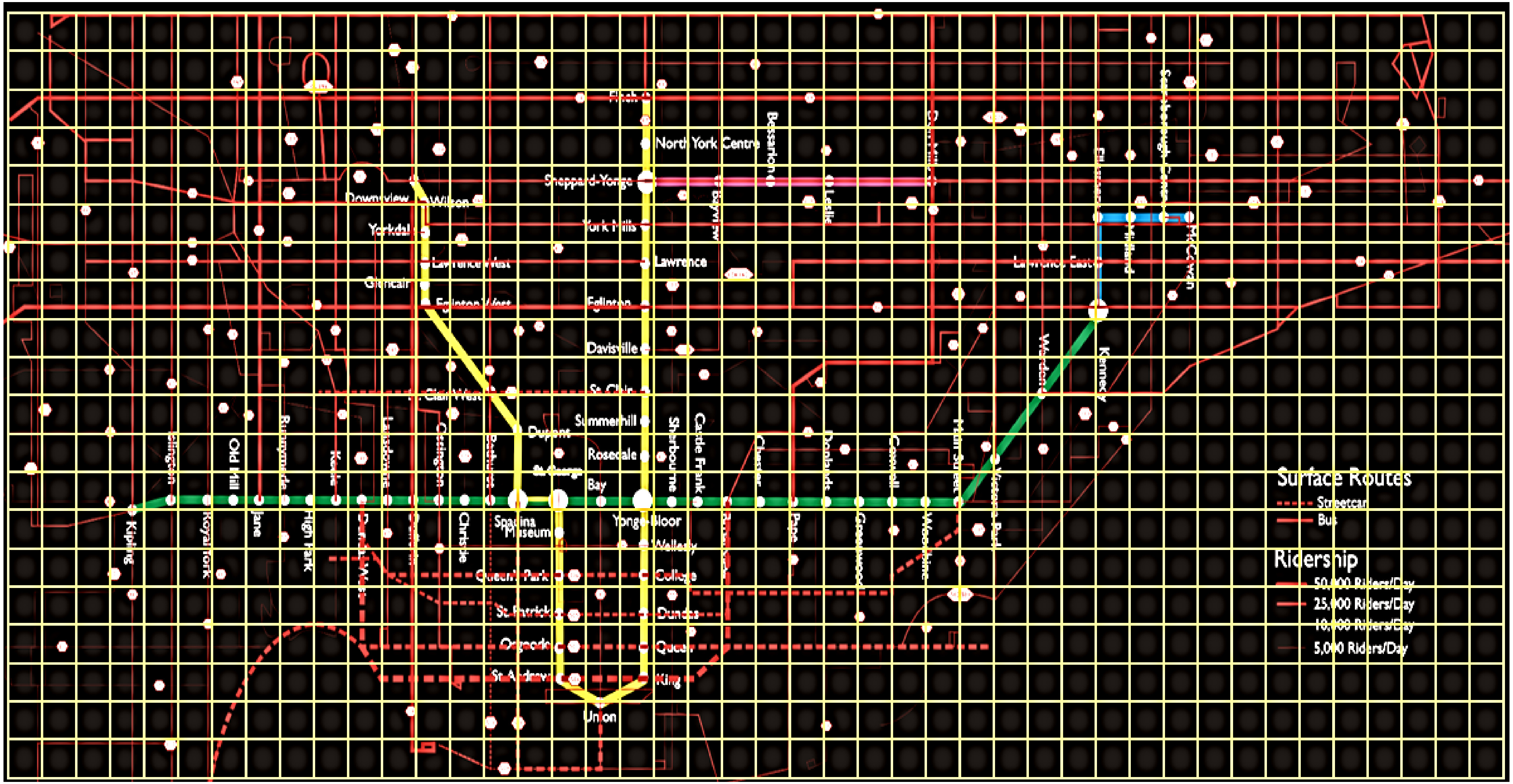
Hybrid Charging Station



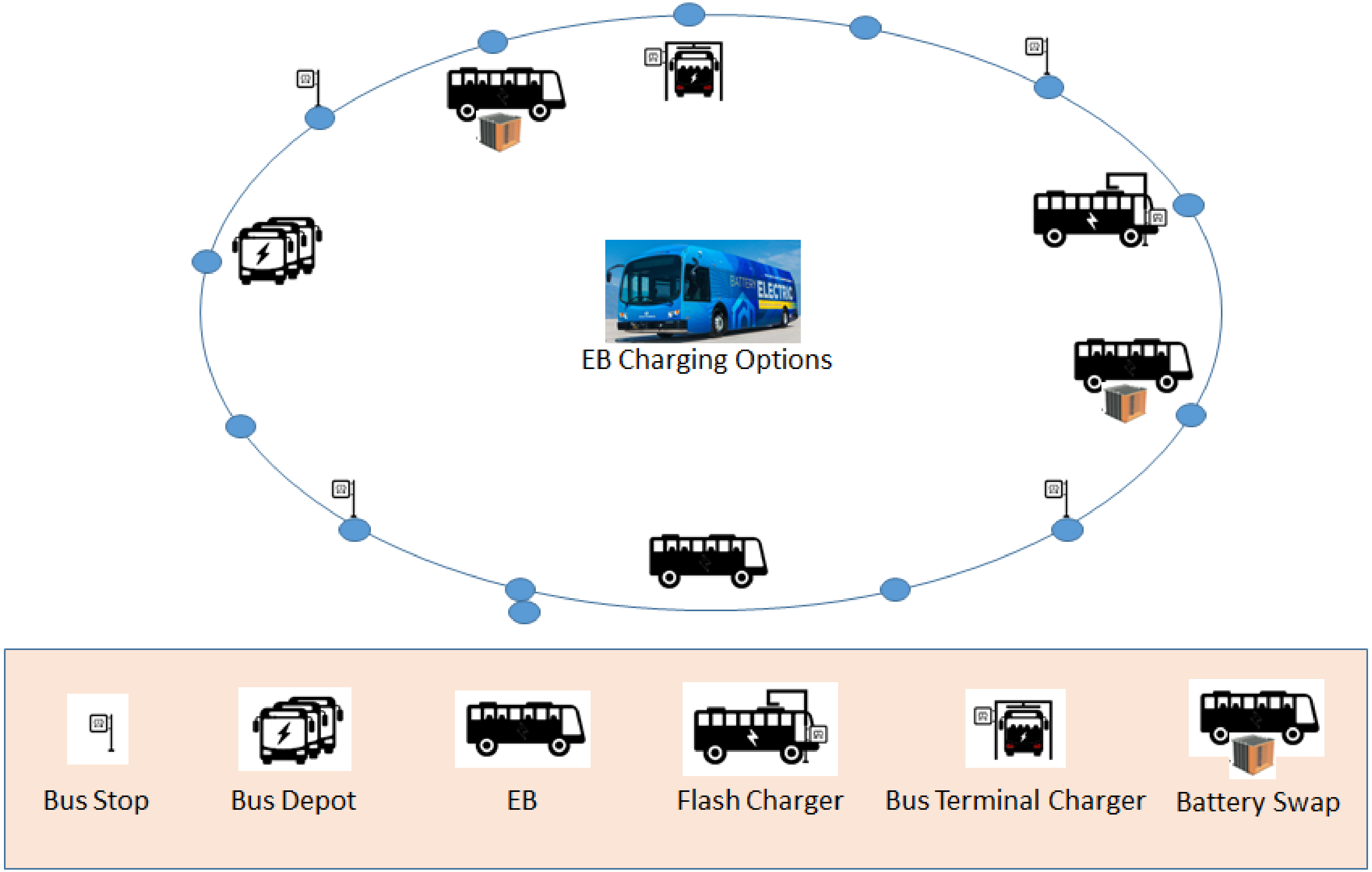
EV Charging Models



Charging of Toronto Bus Network



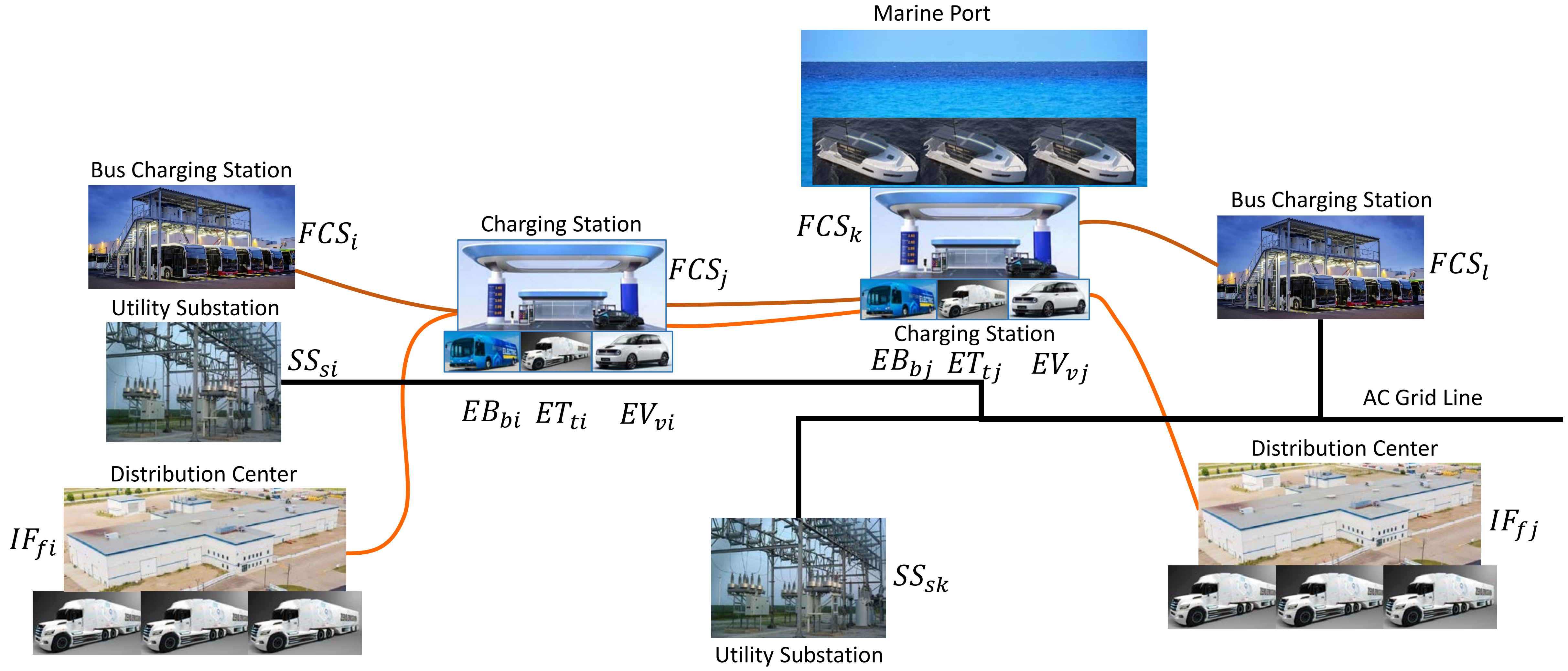
Electric Bus Charging On Route



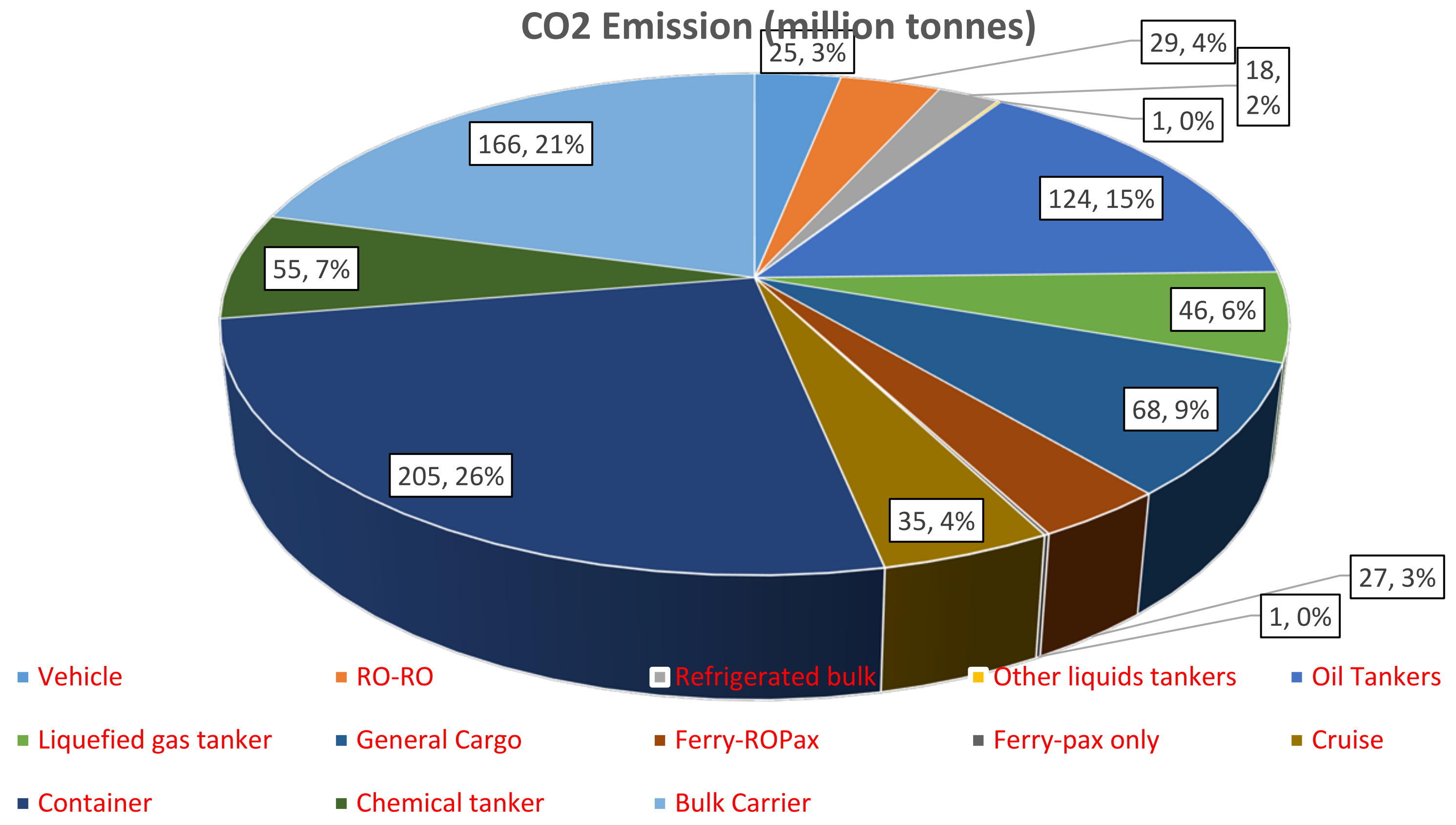
Optimization of Route Charging

	Route A	Route B	Route C
Number of Trips (per day)	7	14	16
Number of Stops (per trip)	70	80	75
Total Number of Stops (per day)	350	800	1200
Trip Length (km)	25	20	15
Bus Size (m)	18	24	24
Average Consumption (kWh/km)	1.8	2.2	2.2

Transportation Electrification Infrastructure



CO2 Gas Emission by Different Types of Marine Ships in 2012



CO_2 Emission by Different Marine Ships in 2012

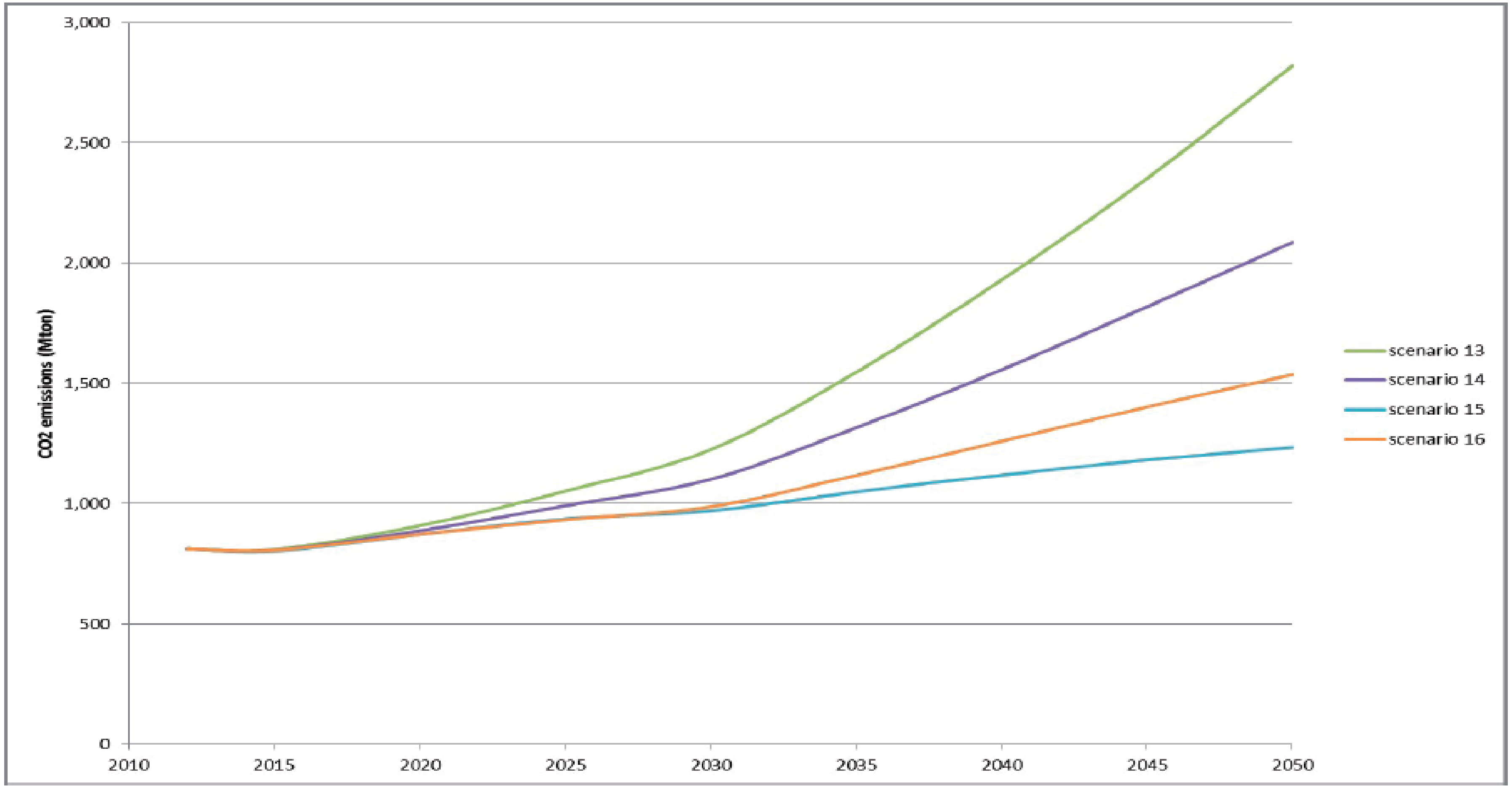
CO2 Emission by Marine Ships

- CO2 emission from shipping has been increased by 2.4% from 2013 to 2015
- CO2 emission was 910 million tons in 2013 but in 2015 it was 932 million tons

	Third IMO GHG Study (million tonnes)						ICCT (million tonnes)		
	2007	2008	2009	2010	2011	2012	2013	2014	2015
Global CO_2 Emissions	**31,959**	**32,133**	**31,822**	**33,661**	**34,726**	**34,968**	**35,672**	**36,084**	**36,062**
International Shipping	881	916	858	773	853	805	801	813	812
Domestic Shipping	133	139	75	83	110	87	73	78	78
Fishing	86	80	44	58	58	51	36	39	42
Total Shipping	**1,100**	**1,135**	**977**	**914**	**1,021**	**942**	**910**	**930**	**932**
% of global	3.5%	3.5%	3.1%	2.7%	2.9%	2.6%	2.5%	2.6%	2.6%

CO_2 Emission from Marine Ship

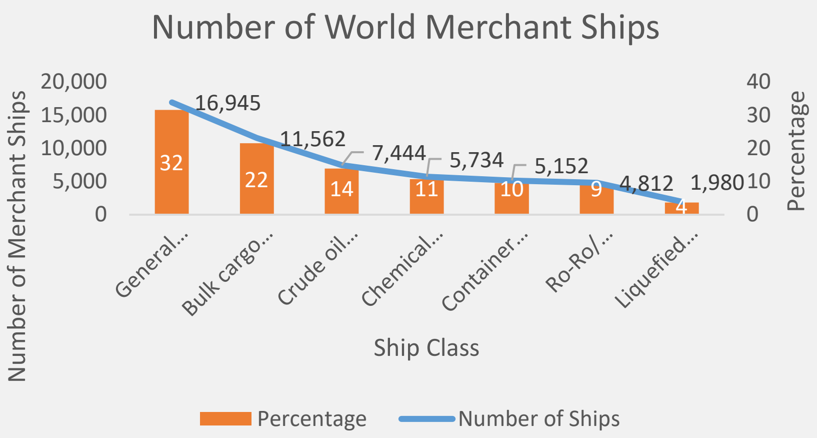
Projection of CO2 Emission by 2050



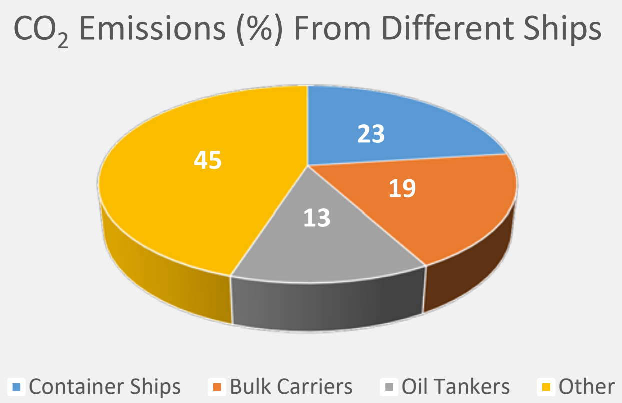
BAU projections of CO_2 emissions from international maritime transport 2012–2050 [4]

BAU: Business As Usual

International Shipping and Environmental Impact



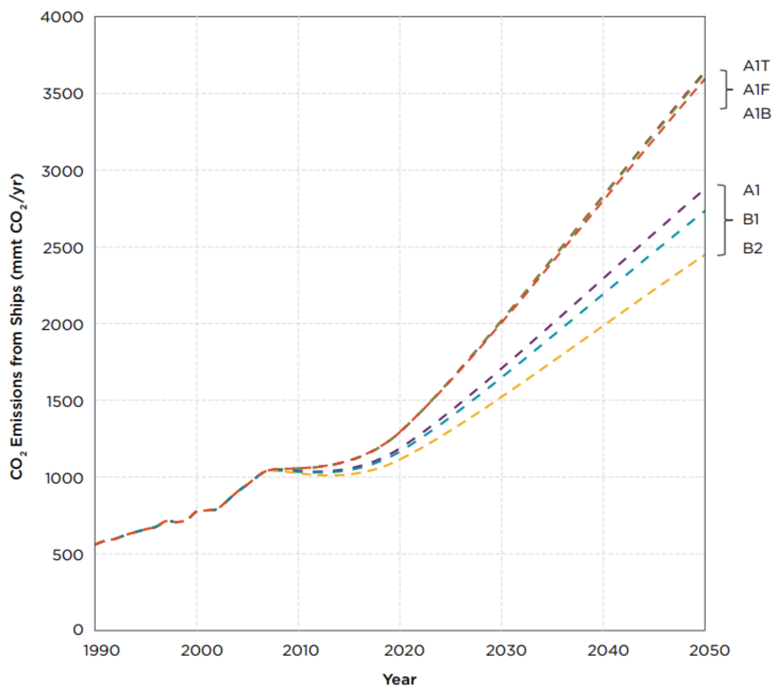
Distribution of World Merchant Ships



Percentage of CO_2 Emissions from Different Types of Ships

Projection of CO_2 Emissions from Marine Ships

- IMO predicts that tonne-miles of goods moved globally will increase 2% to 4% annually between now and 2050.
- In 2007, international shipping accounted for 870 million MT of CO_2 emissions and including domestic shipping it was around 1050 million MT
- At current rates of increase, shipping sector CO_2 is expected to climb to between 2,500 million MT and 3,650 million MT by 2050.



GHG emissions projection by marine ships

Marine Ships Vs GHG Emissions

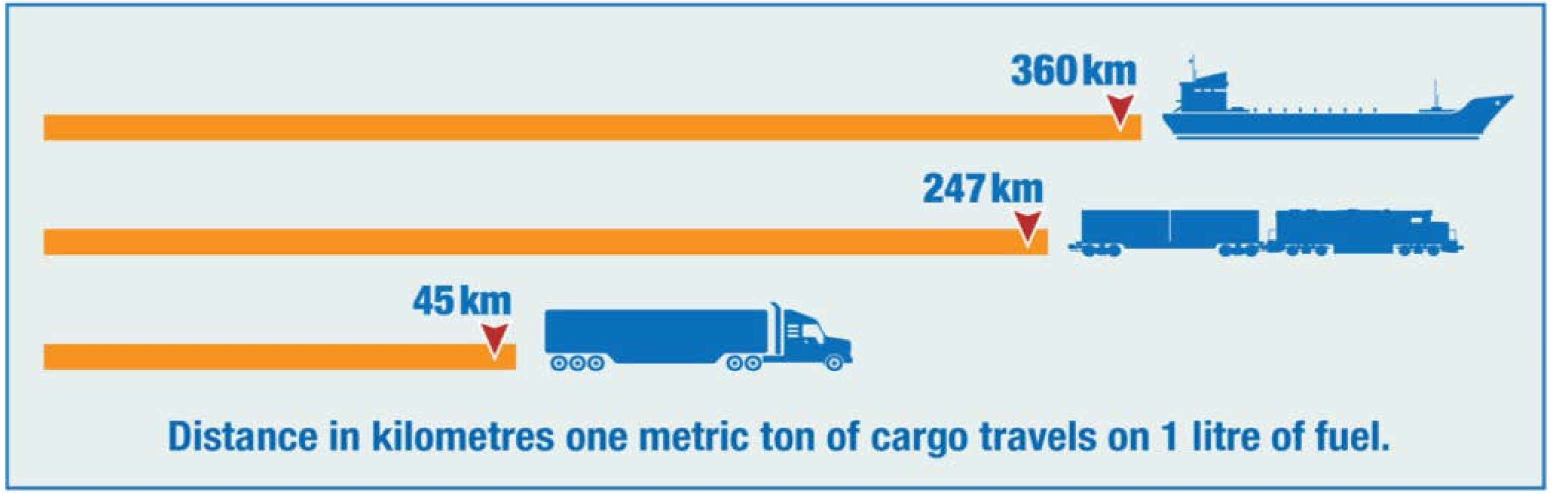
- If global shipping were a country, it would be considered as the sixth largest producer of GHG emission
- Ocean-going shipping is responsible for more than 3% of global GHG emission
- Emission from ocean-going ships is almost twice the emission from total registered cars in US
- 15 largest ships emit as much SOx as the worlds tot.al 760 million cars.

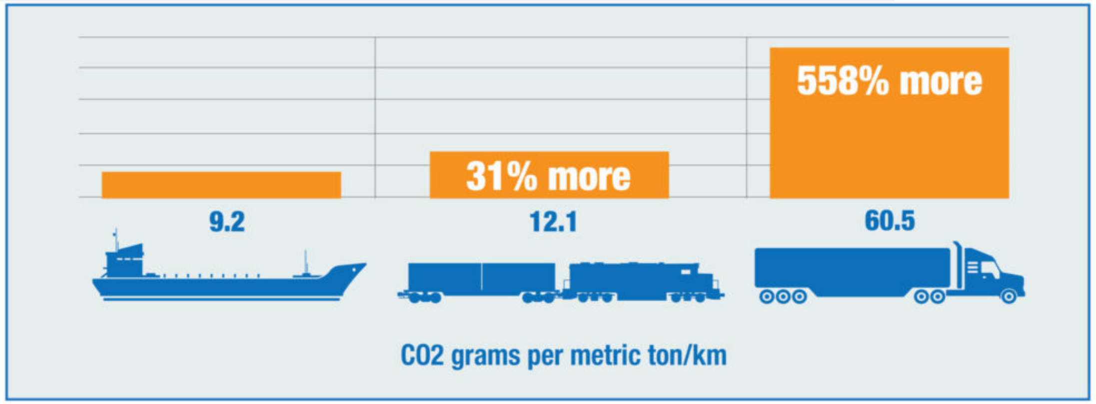
	Third IMO GHG Study (million tonnes)					ICCT (million tonnes)		
Year	2008	2009	2010	2011	2012	2013	2014	2015
Global CO2 Emissions	32,133	31,822	33,661	34,726	34,968	35,672	36,084	36,062
CO2 Emissions from International Shipping	916	858	773	853	805	801	813	812
CO2 Emissions from Domestic Shipping	139	75	83	110	87	73	78	78
CO2 Emissions from Fishing	80	44	58	58	51	36	39	42
Total CO2 Emissions from Shipping	1,135	977	914	1,021	943	910	930	932
Total CO2 Emissions from Shipping (%)	4	3	3	3	3	3	3	3
Percentage of International Shipping to Total Shipping Emissions	81	88	85	84	85	88	87	87

GHG emissions by marine ships

Fuel Efficiency and GHG Emissions with Marine

Marine ships are considered the 6th largest contributor to GHG emissions due to the use of conventional fossil fuel as energy supply.





Source: Research and Traffic Group analysis

Power and Weight Capacity of Marine Units

Marine unit	Size	Weight(kg)	Required power capacity (~hp)
Cargo ships	medium	25000	1378
Cruise	4000 passengers	20000	1102
Ferry	Medium	8000	441
Boat	6 persons	2100	115

Ship Parameters and Voyage Route

SL. NO	SHIP DESCRIPTION	
1	Ship's name (IMO number)	Baltic Sunrise (9307633)
2	Date delivered / Builder (where built)	Nov 08, 2005 / Hyundai Heavy Industries Co. Ltd., Ulsan Shipyard, Korea
3	Flag / Port of Registry	Marshall Islands / Majuro
4	Call sign	V7NP2 / 538006485
5	Type of ship	Oil Tanker
6	Length overall (LOA)	333.12 m
7	Length between perpendiculars (LBP)	324.00 m
8	Extreme breadth (Beam)	60.04 m
9	Deadweight	309373 MT
10	Displacement	352410 MT

Table: Parameters of ‘Baltic Sunrise’

Fig: Route of ‘Baltic Sunrise’

Estimation of Ship Energy Demand

SL. No	Parameter/ Assumption	Category	Notation	Value
1	Beam of the ship	Parameter	B	60 m
2	Volume displacement of the ship	Parameter	v	344649.08 m^3
3	Draught of the ship	Parameter	D	21.6 m
4	Extreme breadth (Beam)	Parameter	Bex	60.04 m
5	Average draught of the ship	Parameter	D_avg	16.15 m
6	Length between perpendiculars	Parameter	LBP	324 m
7	Gravitational acceleration	Parameter	g	9.81 m/s^2
8	Seawater density at 30^0C temperature	Parameter	ρ_w	1021.7 kg/m^3
9	Seawater viscosity at 30^0C temperature	Parameter	γ_w	0.84931× 10^{-6} m^3s^{-1}
10	Average speed of the ship	Parameter	Vs_avg	11.94 kn or 6.1424 ms^{-1}
11	Incremental resistance coefficient due to surface roughness of ship	Assumption	C_A	0.0004
12	Maximum speed of the ship	Parameter	Vs_max	17.9 kn or 9.2185 ms^{-1}

Table: Parameters of 'Baltic Sunrise'

$$P_{ship\ (x,y)} = R_{TBHS} \cdot V_{s(x,y)}$$

$$R_{TBHS} = C_{TBHS} \cdot \frac{1}{2}\rho_w \cdot S_s \cdot V_{s\_avg}{}^2$$

$$C_{TBHS} = C_{Fs} + C_{Rs} + C_A$$

$$L_{wl} = \frac{LBP}{0 \cdot 97}$$

$$S_s = 1 \cdot 7L_{wl} \cdot B + \frac{v}{D}$$

$$R_{ns} = \frac{Vs\_avg \times L_{wl}}{\gamma_w}$$

$$C_{Fs} = \frac{0.075}{(\log R_{ns} - 2)^2}$$

$$F_{ns} = \frac{Vs\_max}{\sqrt{g \times L_{wl}}}$$

$$\frac{v}{L_{wl}^3} \ ; \ \frac{B}{D}$$

$$A_m = B_{ex} \times D\_avg$$

$$C_p = \frac{v}{A_m L_{wl}}$$

Ship Speed Vs Propulsive Energy Demand

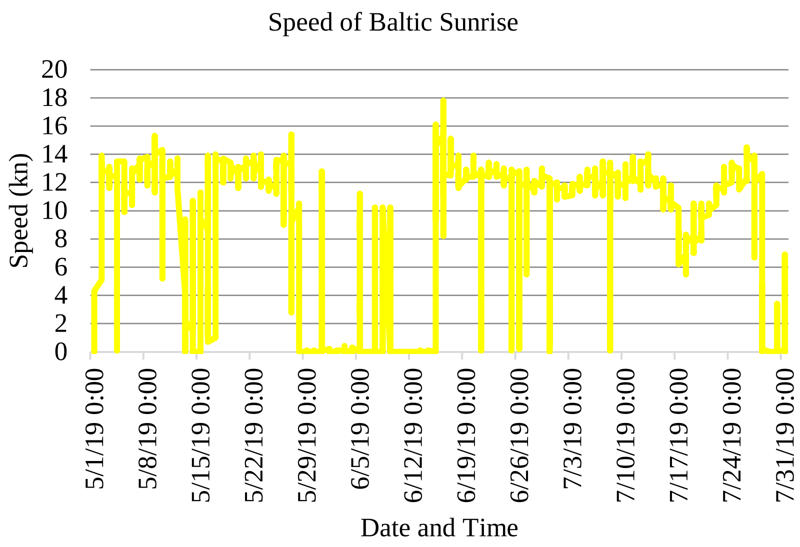


Fig: Speed of 'Baltic Sunrise'

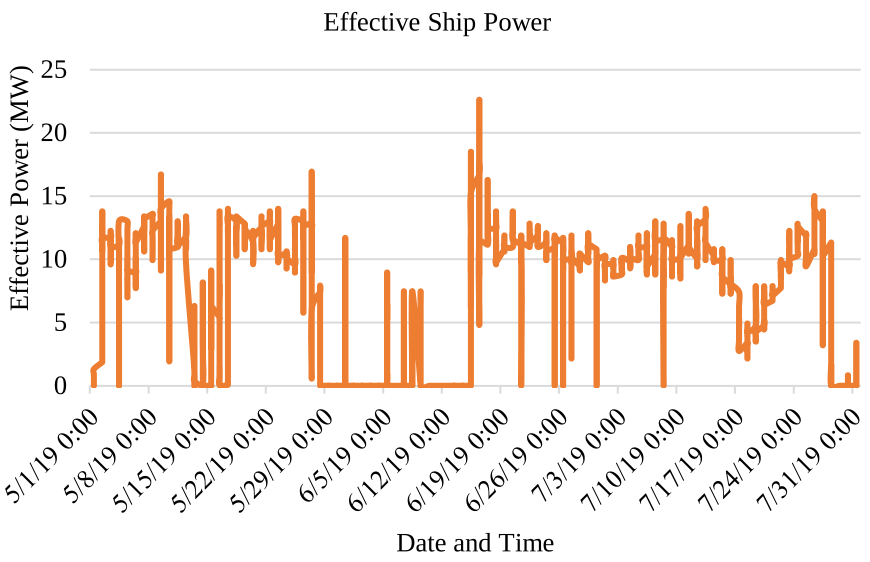


Fig: Effective power of 'Baltic Sunrise'

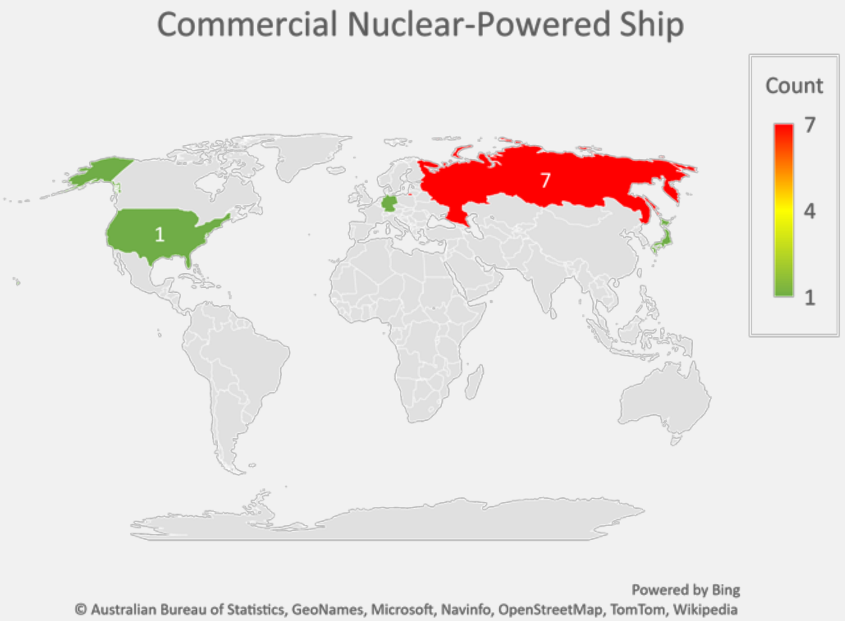
SMR, vSMR, MR/MMR

- SMR is a fourth-generation nuclear reactor having power equivalent to 300 MWe or less.
- vSMR has power rating less than 15 Mwe.
- Microreactor (MR/MMR) is typically ranges from 1 MWe to 50 MWe.

Nuclear Powered Ship

Nuclear Powered Ship (Non-Military)

Ship Name	Country	Ship Type	Reactor Type	Power Output (MW)	Built	Status	Decommissioning Year
Savannah	USA	Container	PWR	80	1962	Not In Service	1977
Otto Hahn	Germany	Ore Carrier	FDR	38	1968	Not In Service	1982
Mutsu	Japan	Cargo	PWR	36	1972	Not In Service	1996
Vaygach	Russia	Icebreaker	KLT-40M	171	1989	In Service	
Artika	Russia	Icebreaker	PWR	342	1975	Not In Service	2008
Sevmorput	Russia	Icebreaker	KLT-40M	135	1988	In Service	
Taimyr	Russia	Icebreaker	KLT-40M	171	1989	In Service	
Sovetski Souz	Russia	Icebreaker	OK-900A	342	1989	In Service	
Let Pobedy	Russia	Icebreaker	OK-900A	342	2007	In Service	
Lenin	Russia	Icebreaker	PWR	318	1989	Not In Service	2008



Distribution of Nuclear Powered Ships

700 naval nuclear reactors and 200 of them are still in operation for military use

Estimation of Ship Energy Demand

SL. No	Parameter/ Assumption	Category	Notation	Value
1	Beam of the ship	Parameter	B	60 m
2	Volume displacement of the ship	Parameter	v	344649.08 m^3
3	Draught of the ship	Parameter	D	21.6 m
4	Extreme breadth (Beam)	Parameter	Bex	60.04 m
5	Average draught of the ship	Parameter	D_avg	16.15 m
6	Length between perpendiculars	Parameter	LBP	324 m
7	Gravitational acceleration	Parameter	g	9.81 m/s^2
8	Seawater density at 30^0C temperature	Parameter	ρ_w	1021.7 kg/m^3
9	Seawater viscosity at 30^0C temperature	Parameter	γ_w	0.84931× 10^{-6} m^3s^{-1}
10	Average speed of the ship	Parameter	Vs_avg	11.94 kn or 6.1424 ms^{-1}
11	Incremental resistance coefficient due to surface roughness of ship	Assumption	C_A	0.0004
12	Maximum speed of the ship	Parameter	Vs_max	17.9 kn or 9.2185 ms^{-1}

Parameters of 'Baltic Sunrise'

$$P_{ship\ (x,y)} = R_{TBHS} \cdot V_{s(x,y)}$$

$$R_{TBHS} = C_{TBHS} \cdot \frac{1}{2}\rho_w \cdot S_s \cdot {V_{s\_avg}}^2$$

$$C_{TBHS} = C_{Fs} + C_{Rs} + C_A$$

$$L_{wl} = \frac{LBP}{0 \cdot 97}$$

$$S_s = 1 \cdot 7L_{wl} \cdot B + \frac{v}{D}$$

$$R_{ns} = \frac{Vs\_avg \times L_{wl}}{\gamma_w}$$

$$C_{Fs} = \frac{0.075}{(\log R_{ns} - 2)^2}$$

$$F_{ns} = \frac{Vs\_max}{\sqrt{g \times L_{wl}}}$$

$$\frac{v}{L_{wl}^3} \ ; \ \frac{B}{D}$$

$$A_m = B_{ex} \times D\_avg$$

$$C_p = \frac{v}{A_m L_{wl}}$$

Estimation of Energy Demand of Marine Ship for a Given Route

- Estimation of Ship Power

$$R_{TBHS} = C_{TBHS} \cdot \frac{1}{2} \rho_w \cdot s_s \cdot v^2$$

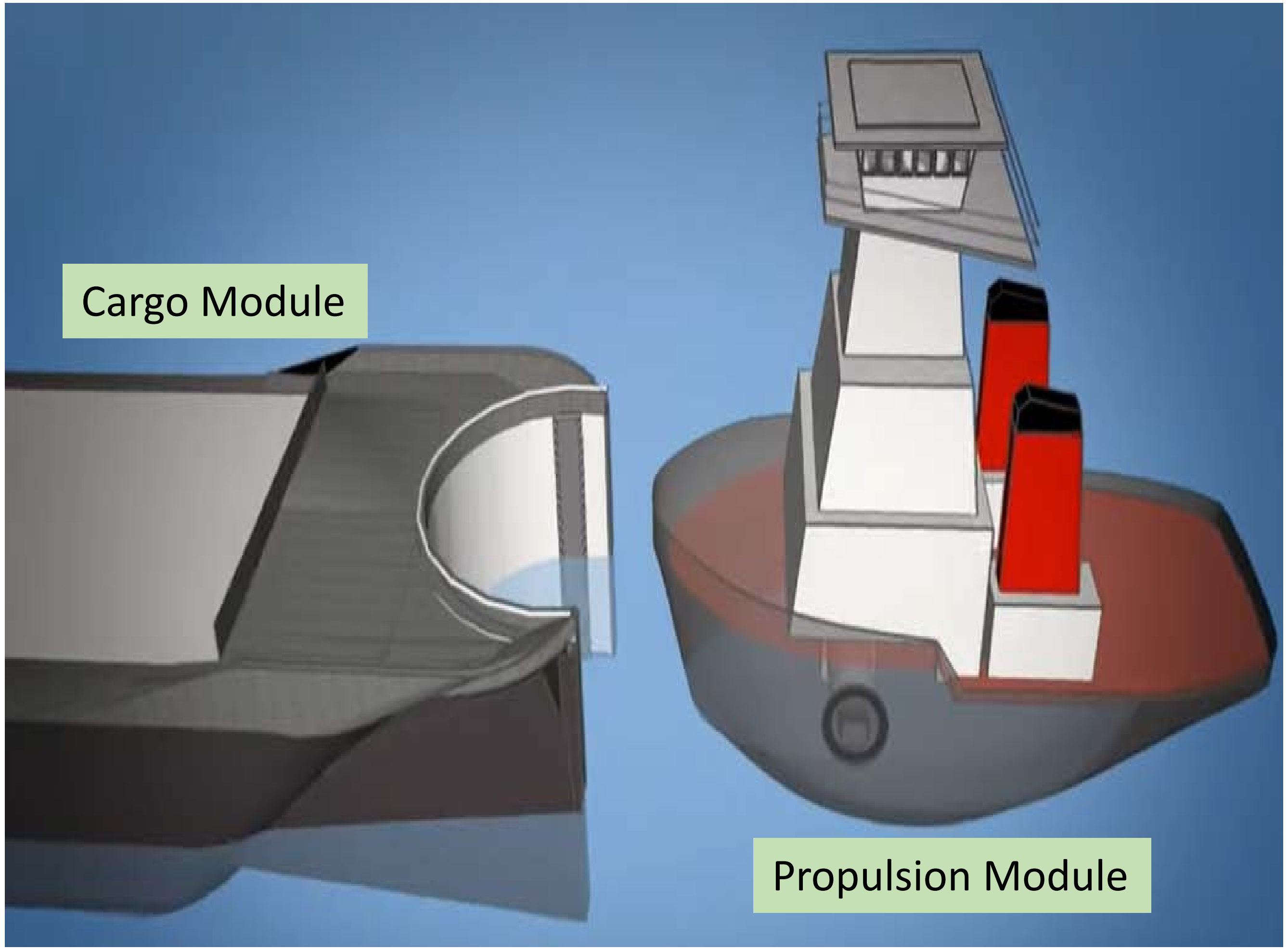
R_{TBHS} = Total bare hull resistance of ship

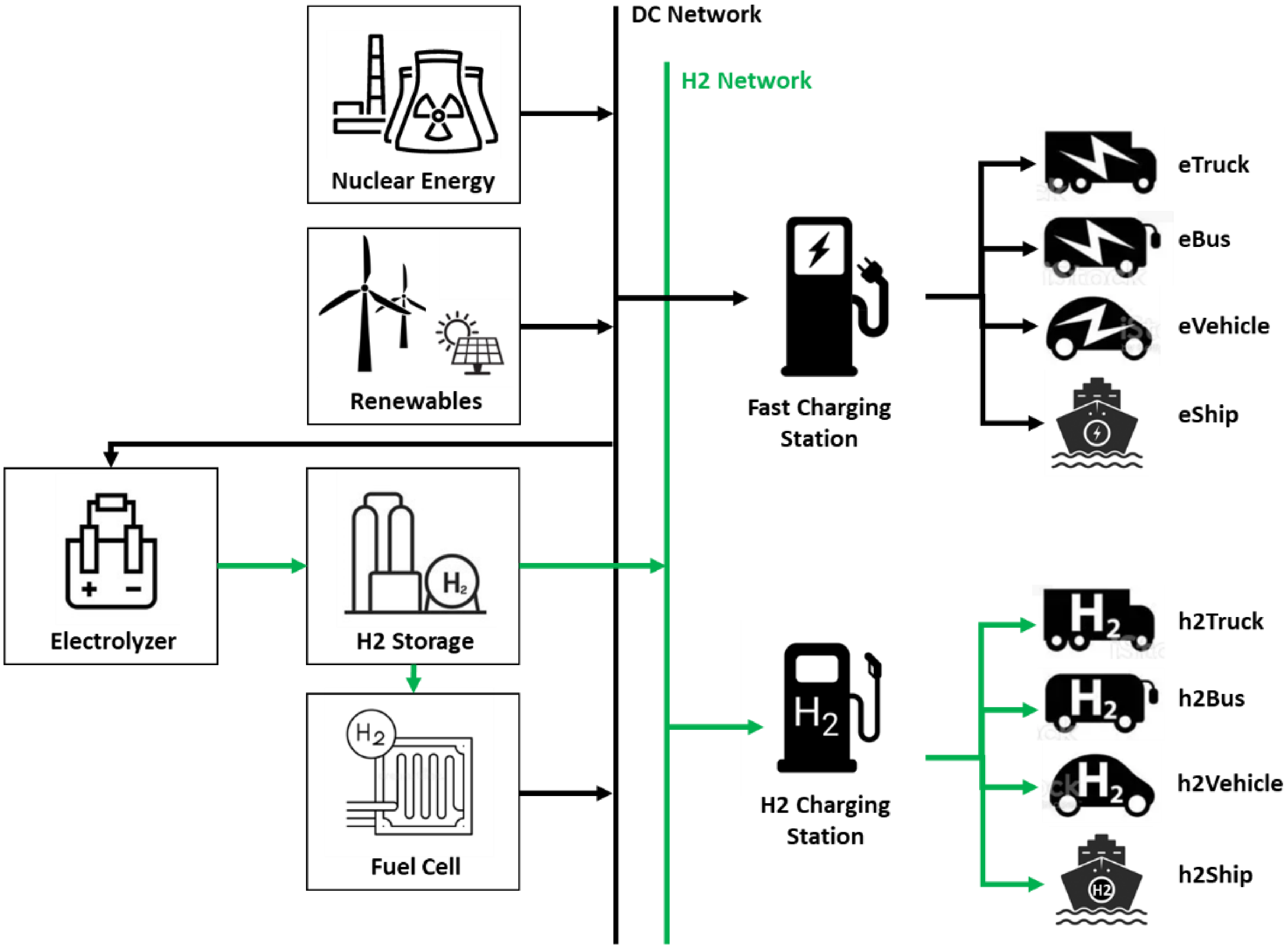
C_{TBHS} = Total hull resistance of ship coefficient

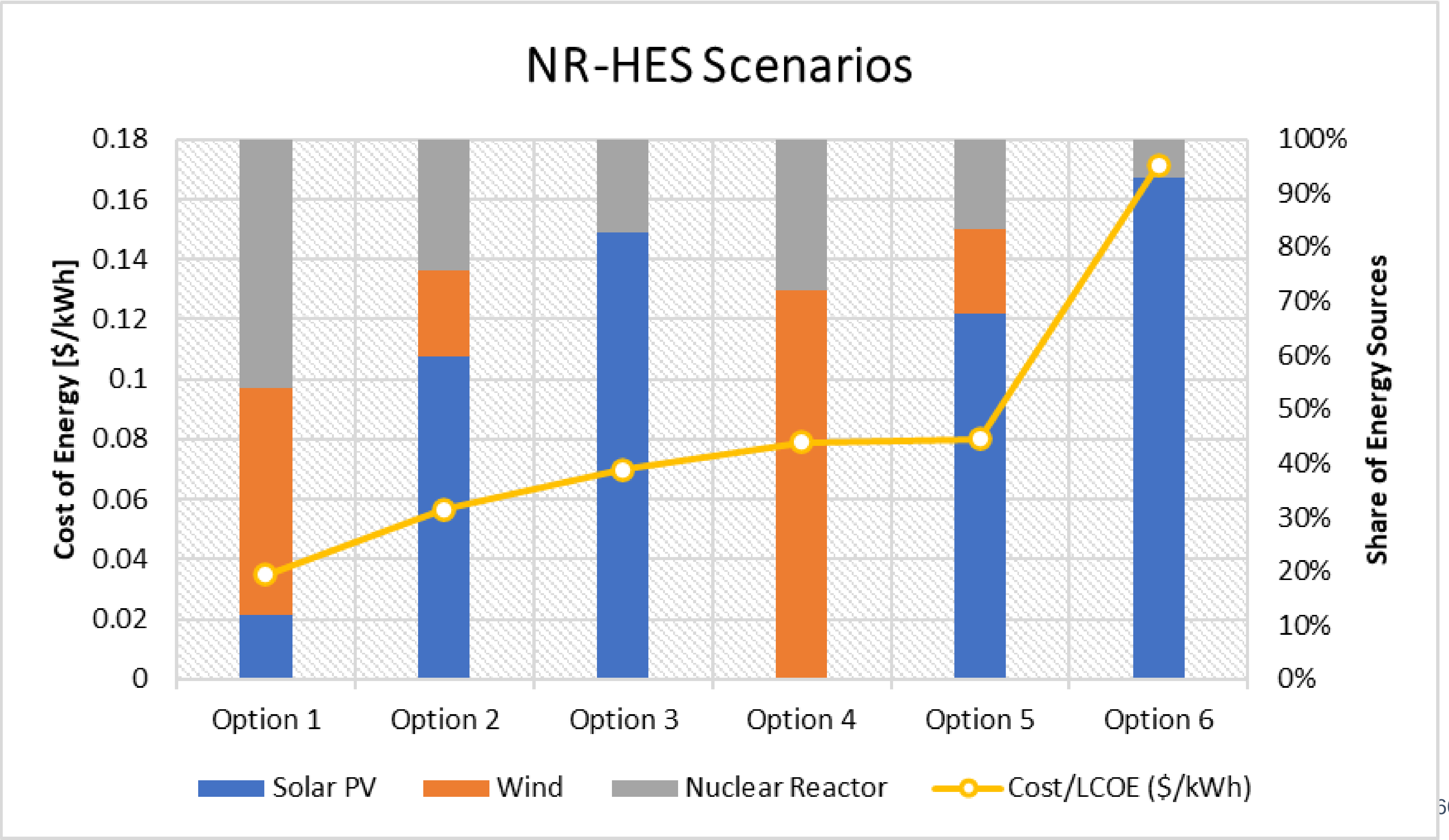
s_s = Ship surface wetted

v = Speed of the ship

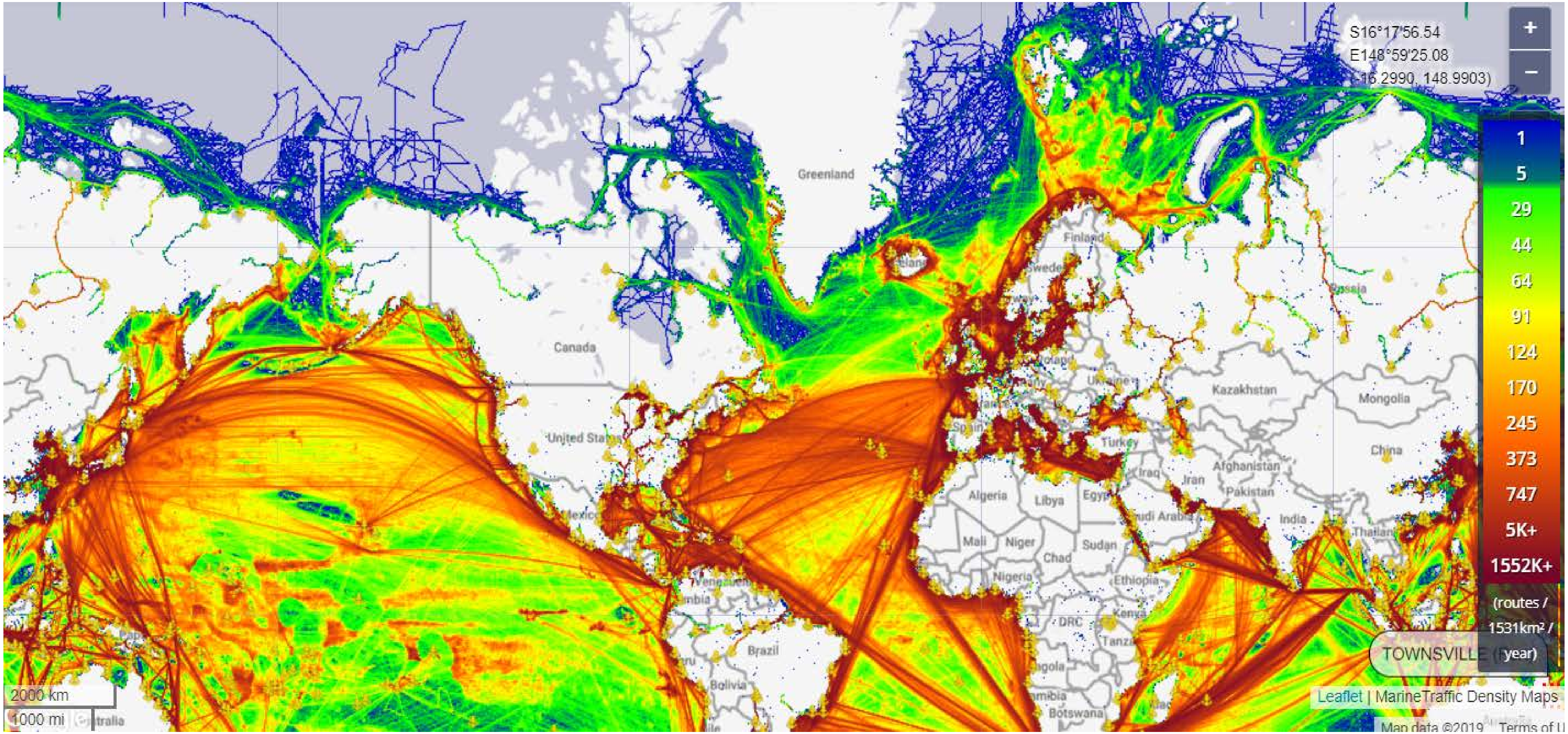
Applications on Marine Ships with SMR



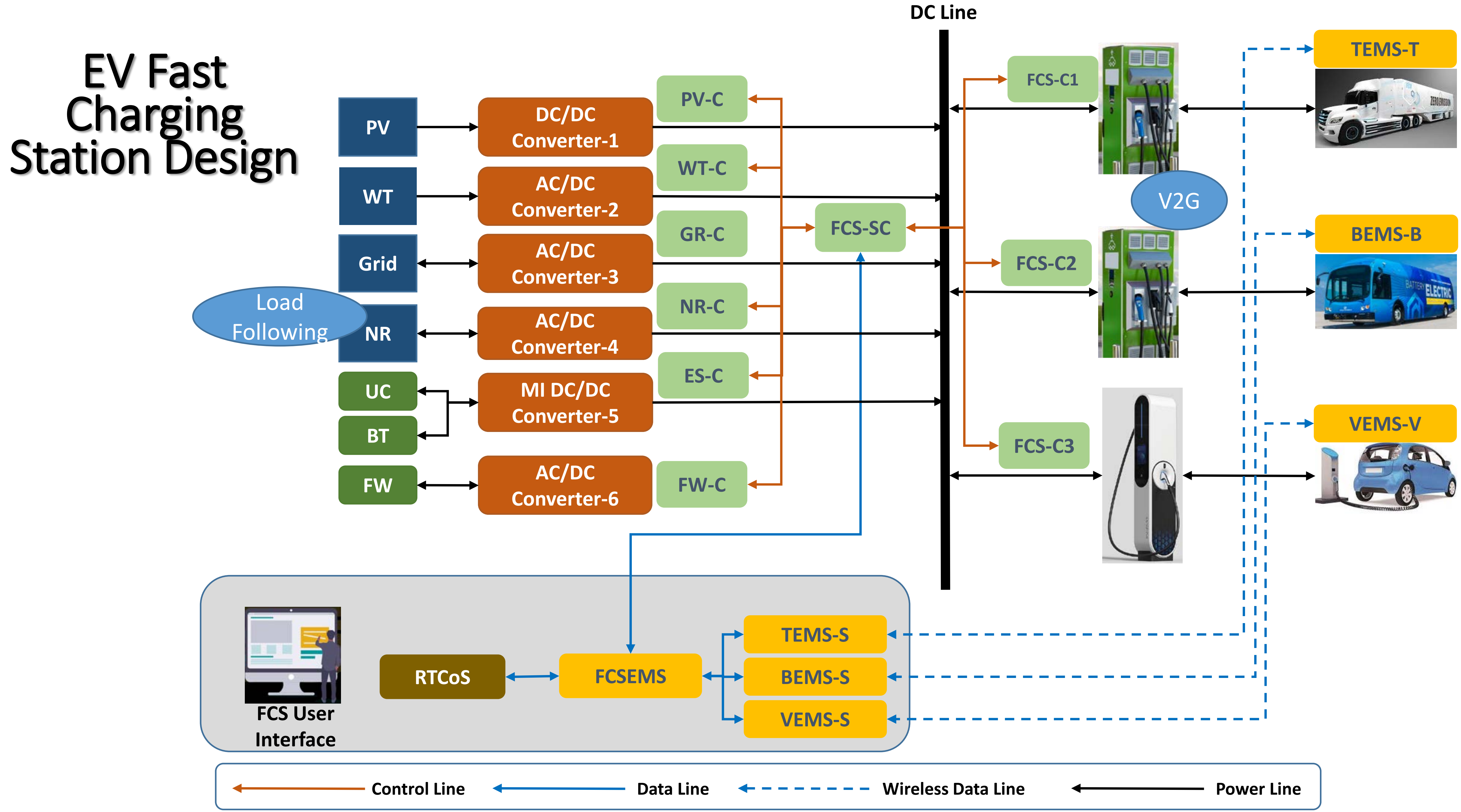

DC Network
H2 Network
Nuclear Energy
Renewables
Electrolyzer
H2 Storage
Fuel Cell
Fast Charging
Station
H2 Charging
Station
eTruck
eBus
eVehicle
eShip
h2Truck
h2Bus
h2Vehicle
h2Ship


NR-HES Scenarios
Cost of Energy [$/kWh]
Share of Energy Sources
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Option 1
Option 2
Option 3
Option 4
Option 5
Option 6
Solar PV
Wind
Nuclear Reactor
Cost/LCOE ($/kWh)

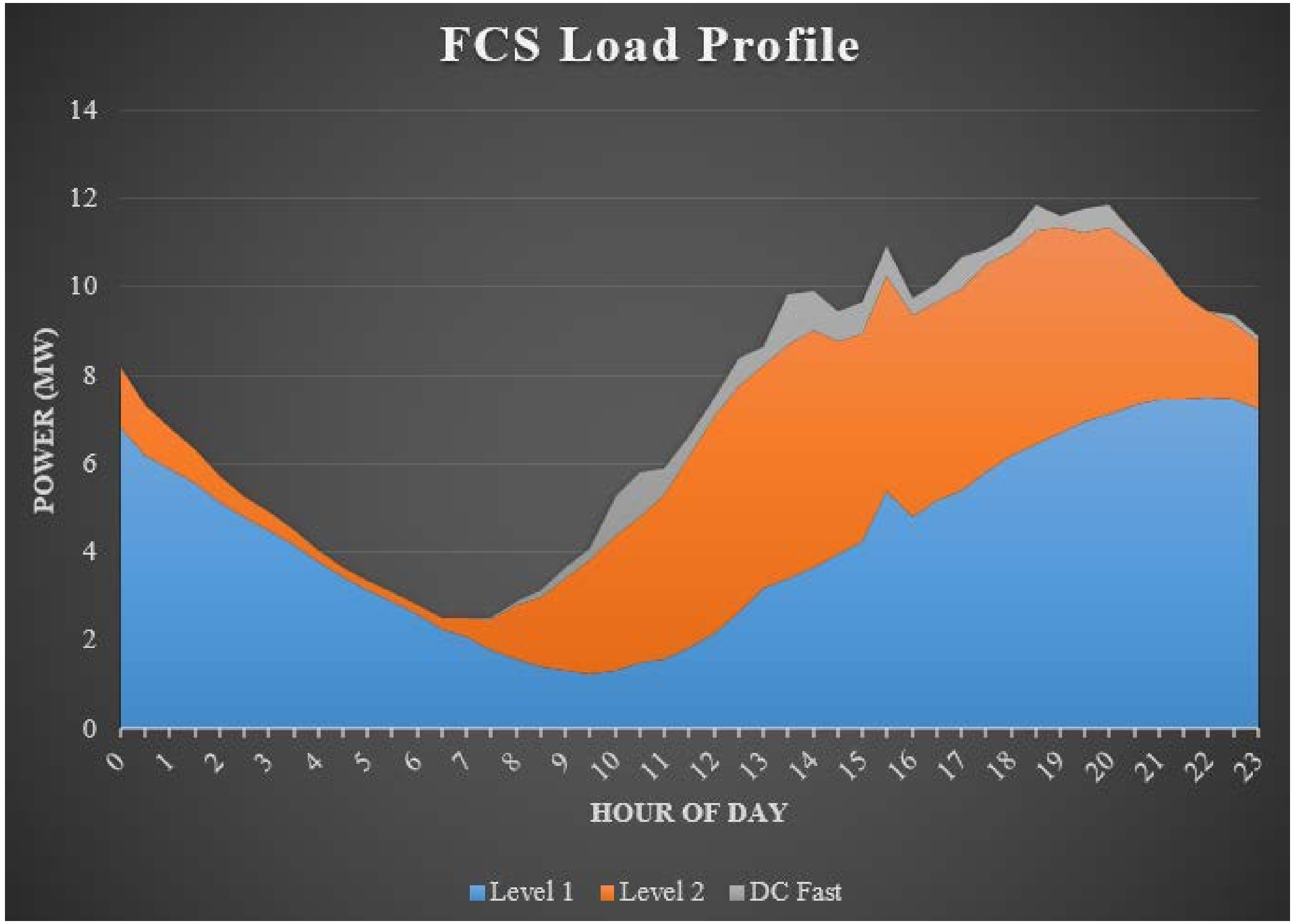
Implementation in Marine Ships



https://www.marinetraffic.com/en/ais/home/centerx:-12.0/centery:24.8/zoom:2


EV Fast Charging Station Design
DC Line
PV
WT
Grid
NR
Load Following
UC
BT
FW
DC/DC Converter-1
AC/DC Converter-2
AC/DC Converter-3
AC/DC Converter-4
MI DC/DC Converter-5
AC/DC Converter-6
PV-C
WT-C
GR-C
NR-C
ES-C
FW-C
FCS-SC
FCS-C1
FCS-C2
FCS-C3
V2G
TEMS-T
BEMS-B
VEMS-V
FCS User Interface
RTCoS
FCSEMS
TEMS-S
BEMS-S
VEMS-S
Control Line
Data Line
Wireless Data Line
Power Line

FCS Load Profile



Hourly load profile of a typical fast charging station

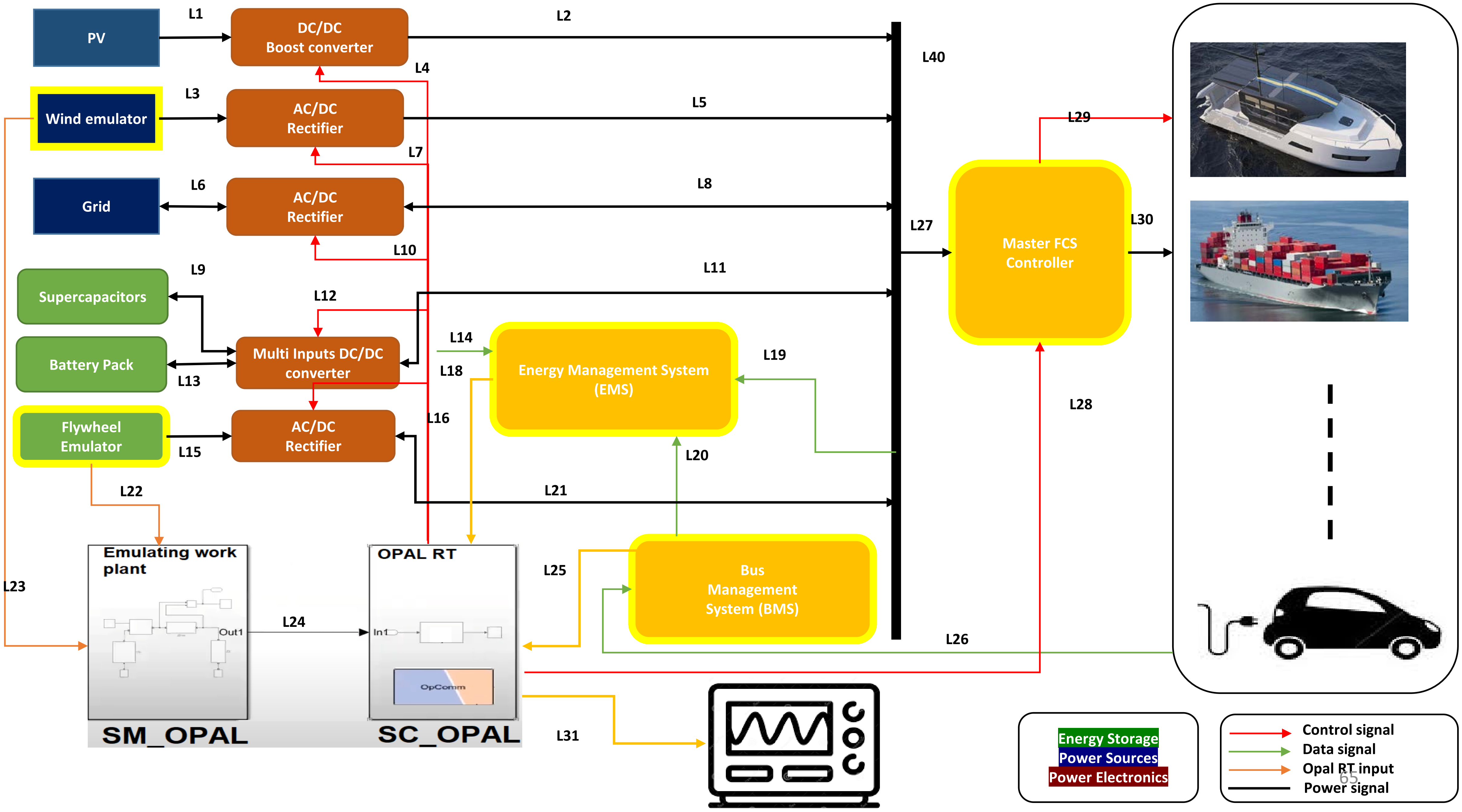
The proposed FCS load profile includes 35% Level 1, 35% Level 2, and 30% DC fast charging vehicles and the station can handle 1000 vehicles per day.
Source: https://afdc.energy.gov/stations/#/find/nearest

Framework to Calculate Total Daily Load at Hybrid Charging Station (HCS)

Calculate Daily Load at HCS_i	Daily Load at HCS_i = Total Daily Load for EVs + Total Daily Load for EBs + Total Daily Load for ETs + Total Daily Load for IF_j + Total Daily Load for SS_k + Total Daily Load to Charge Swapped Batteries
Calculate Daily Load at HCS_i for Charging EVs	Daily EVs Charging Load at HCS_i = Daily Number of EVs Charged * Energy Charged per EV Trip
Calculate Daily Load at HCS_i for Charging EBs	Daily EBs Charging Load at HCS_i = Daily Number of EBs Charged * Energy Charged per EB Trip
Calculate Daily Load at HCS_i for Charging ETs	Daily ETs Charging Load at HCS_i = Daily Number of ETs Charged * Energy Charged per ET Trip
Calculate Daily Load at HCS_i for Charging IF_j	Daily IF_j Load at HCS_i = Number of Charging IF loads * Energy Charged per Time
Calculate Daily Load at HCS_i for Charging SS_k	Daily SS_j Load at HCS_i = Number of Charging SS loads * Energy Charged per Time
Total Daily Load to Charge Swapped Batteries at HCS_i	Daily Load of Charging Swapped Batteries at HCS_i = Total Daily Load of Swapped Batteries for EVs + Total Daily Load of Swapped Batteries for EBs + Total Daily Load of Swapped Batteries for ETs + Total Daily Load of Swapped Batteries from other HCSs

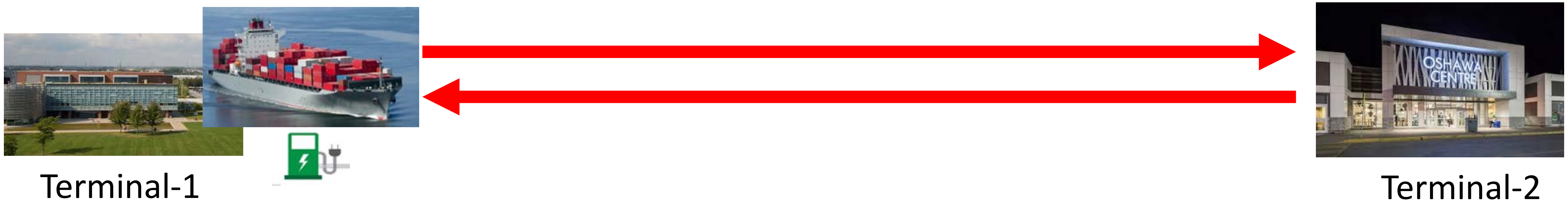
SS: Station location index
IF: Industrial facility location index
EB: Electric bus
EM: Electric marine
ET: Electric truck

FCS Hybrid System

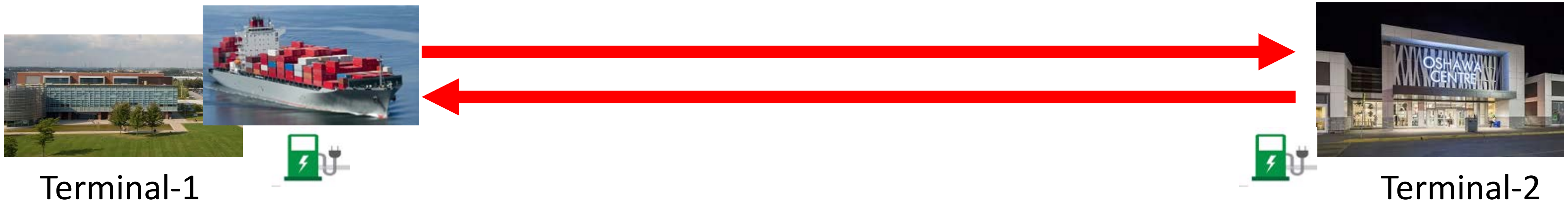


Scenarios

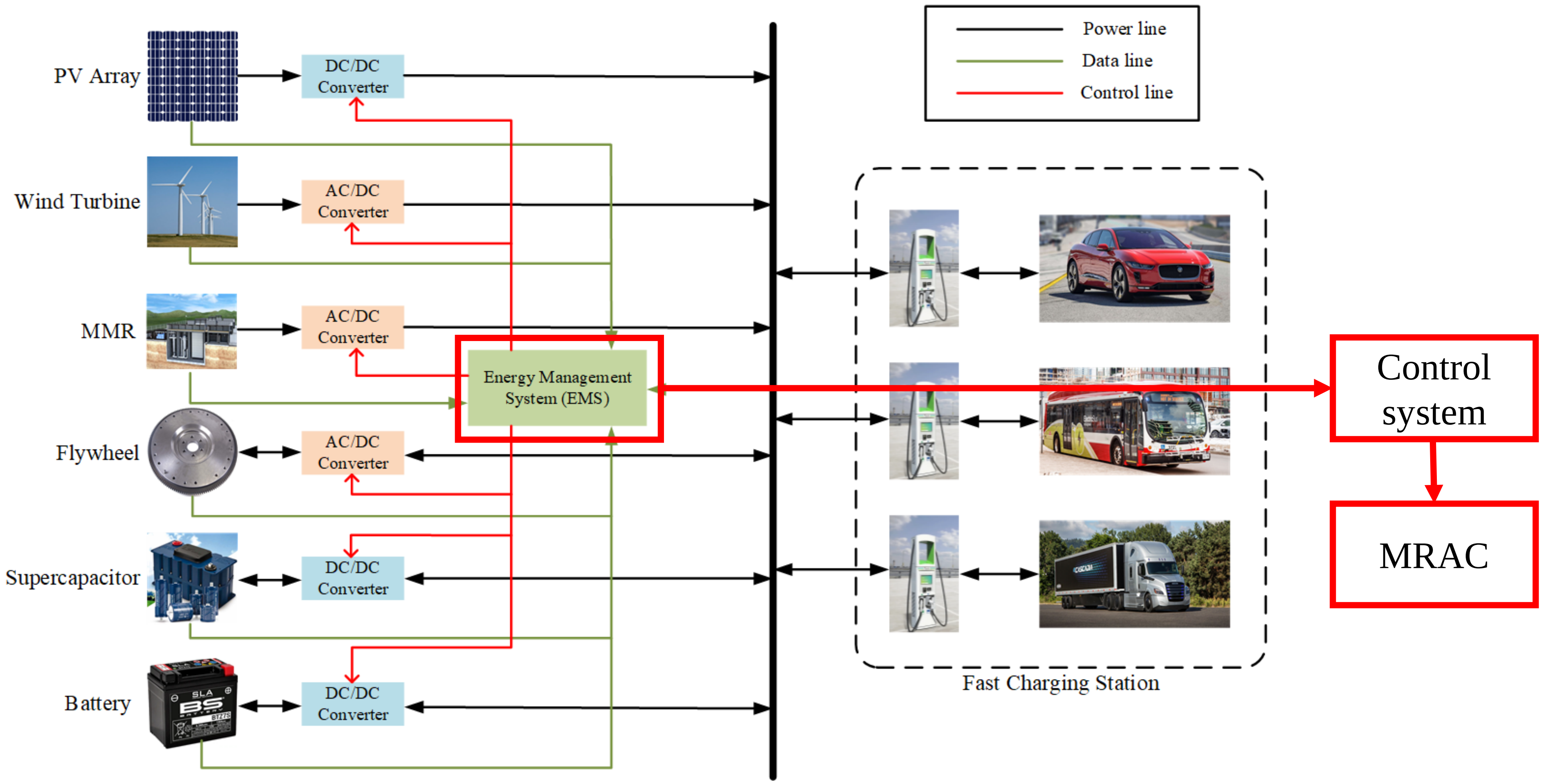
- Scenario-1: Single on-route terminal charging station



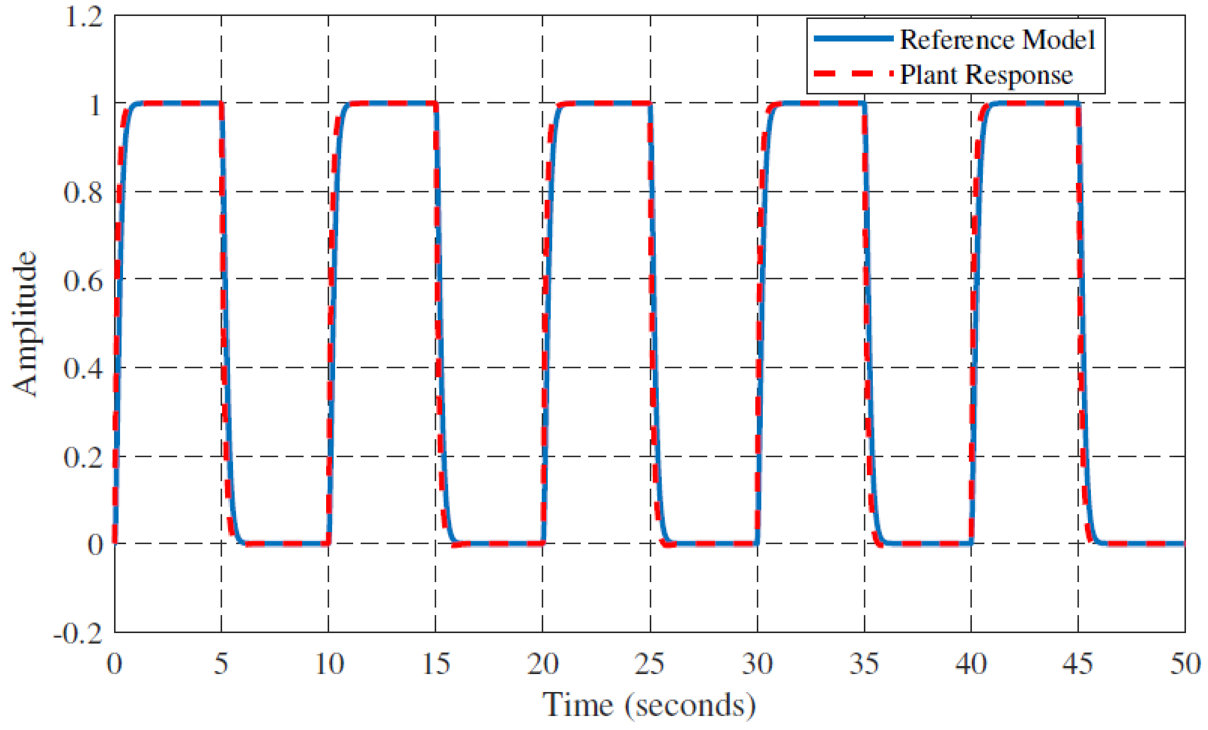
- Scenario-2: Two on-route terminal charging stations



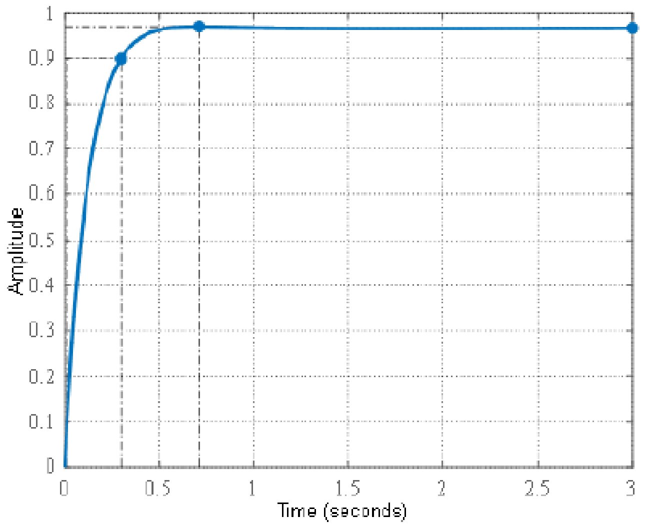
Energy Management System



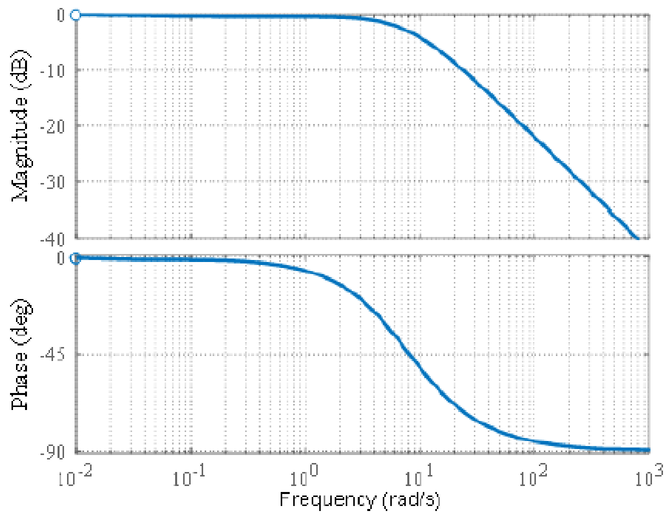
Tracking Performance and Stability



(a)



(b)



(c)

(a) Tracking performance, (b) step response, and (c) bode plot of MRAC system

MRAC with Mixed-Integer Linear Programming

Step 1: Optimization Problem Formulation

The entire optimization issue may be stated as follows, taking into account the constraints and objective function established in the preceding sections:

minimize	R
subject to	binary variables
	storage model
	storage constraints
	power balance

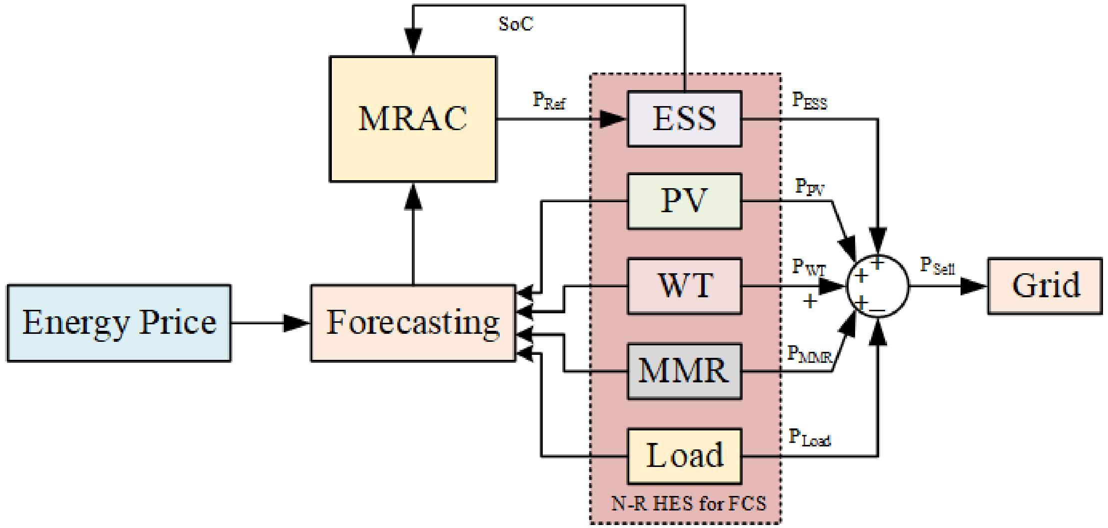


Illustration of MRAC system with optimization strategy

MRAC with Mixed-Integer Linear Programming

Step 2: Optimization Problem Solution

The optimum input sequence for the prediction horizon N_p is found by solving the MILP problem:

$$u_{opt}(k) = \left[(u_{opt}(0))^T \quad (u_{opt}(1))^T \quad \dots \quad (u_{opt}(N_p - 1))^T \right]$$

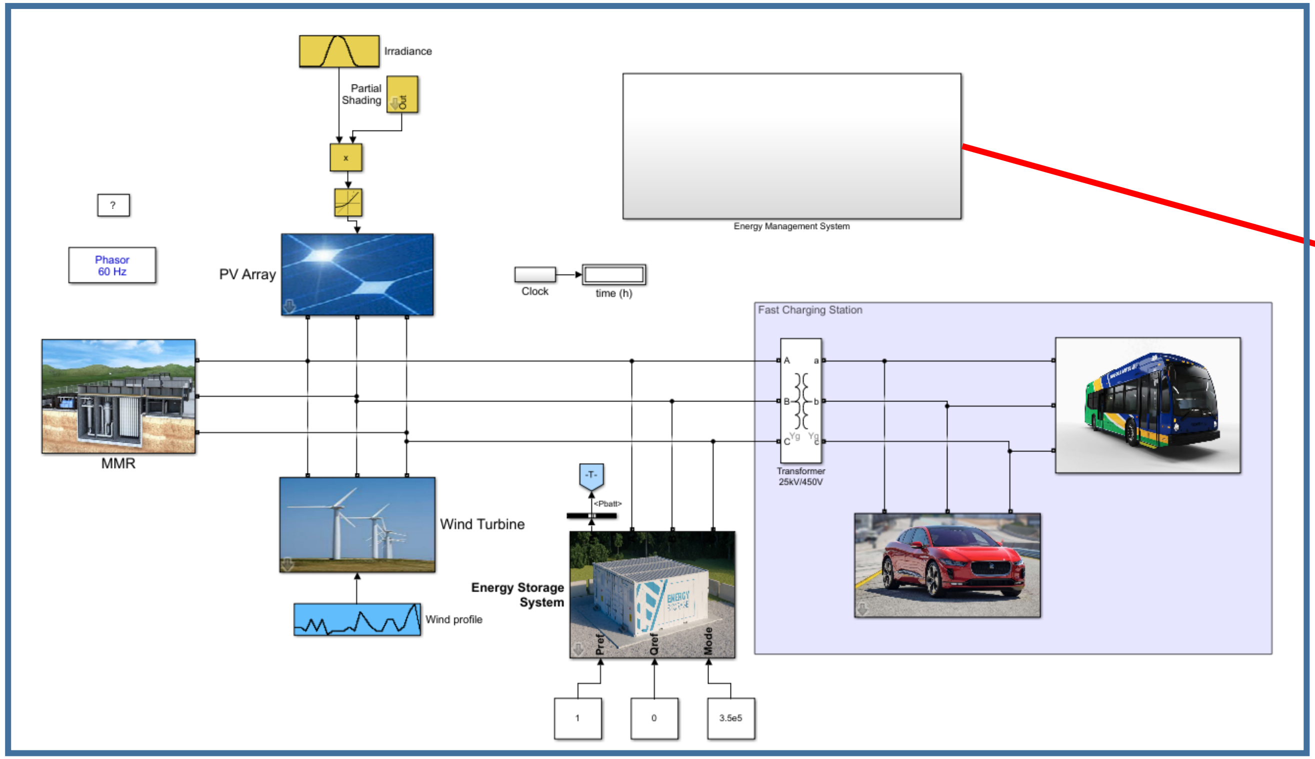
Step 3: Control Set-Points Execution

Although a whole series of N_p future control signals is calculated, only $u_{opt}(0)$ is applied to the system, and the other optimum values in $u_{opt}(k)$ are omitted

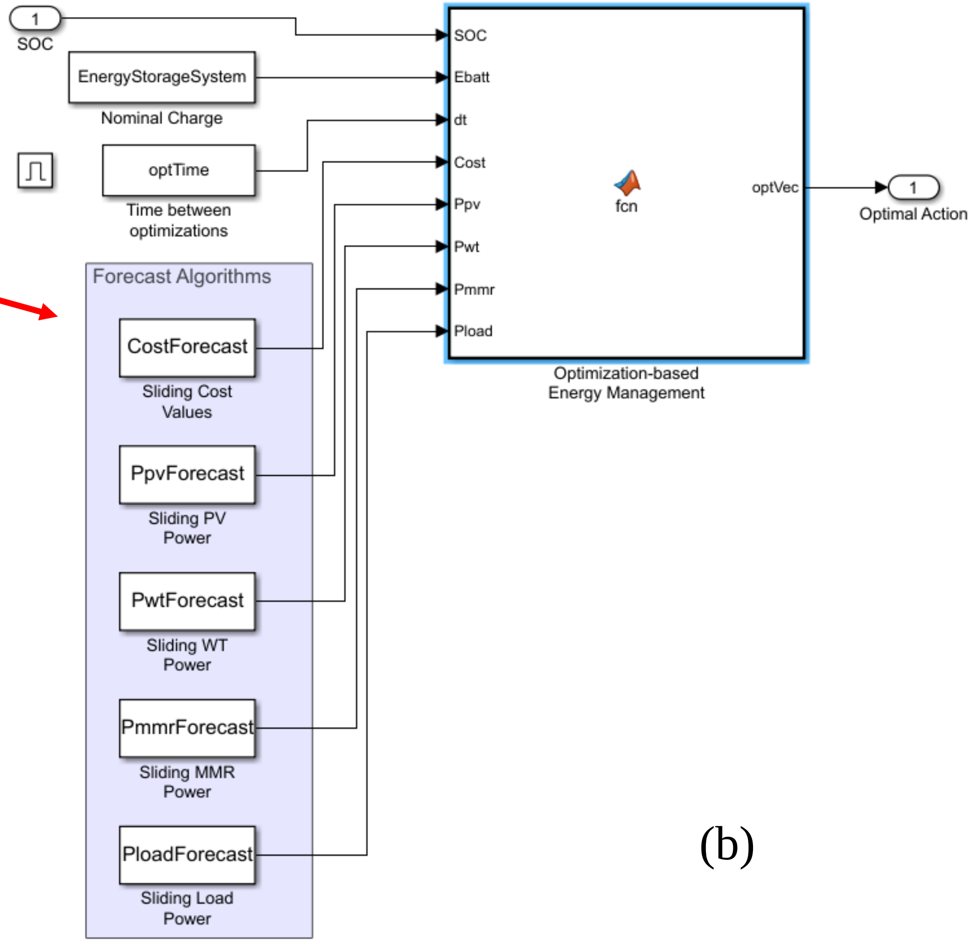
Step 4: Shift the Prediction Horizon

The prediction horizon is shifted, and steps 1 – 3 are repeated to generate a new optimum sequence, $u_{opt}(k)$. All this is done by re-evaluating the system's current state, re-calculating power electronic efficiencies, and then resolving a new optimization issue.

Simulation of EMS with Optimization



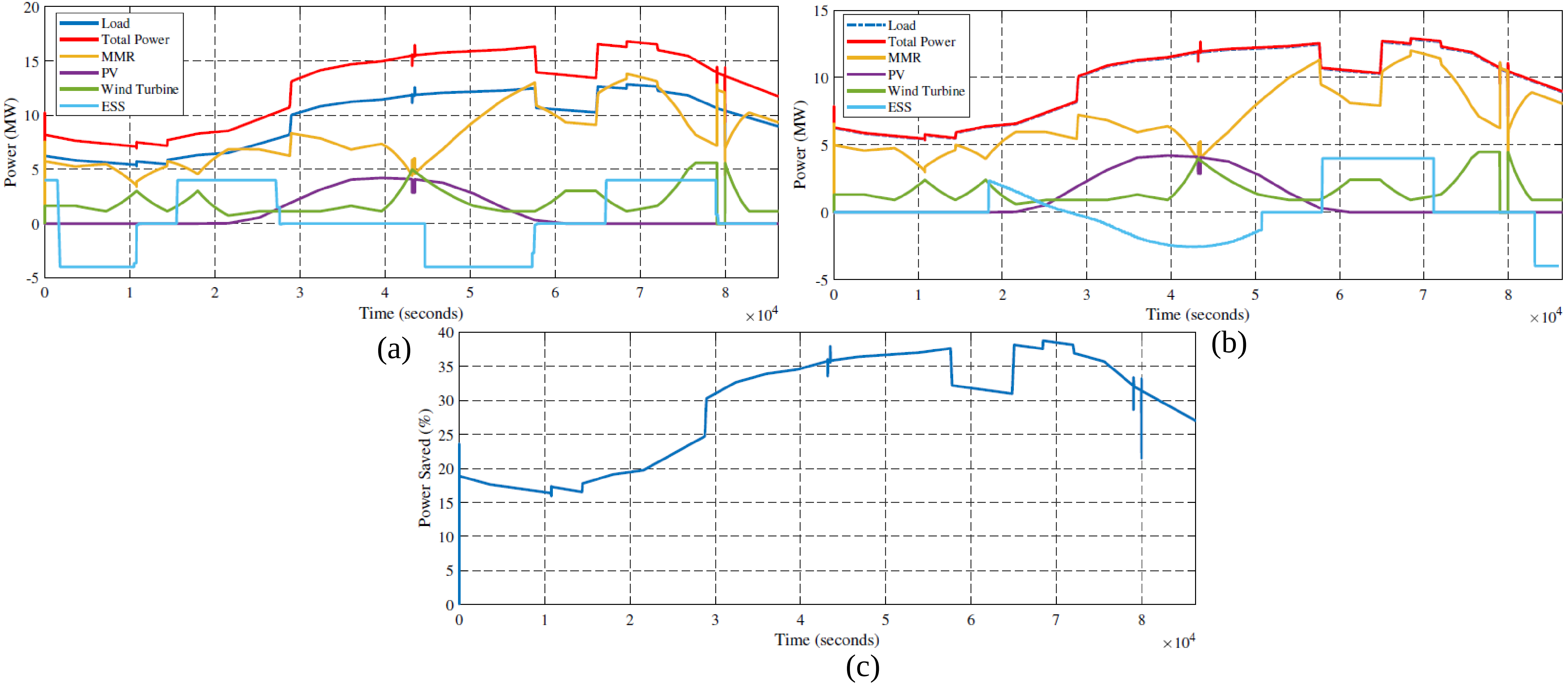
(a)



(b)

(a) Simulink model of the proposed EMS (b) MATLAB function block for EMS

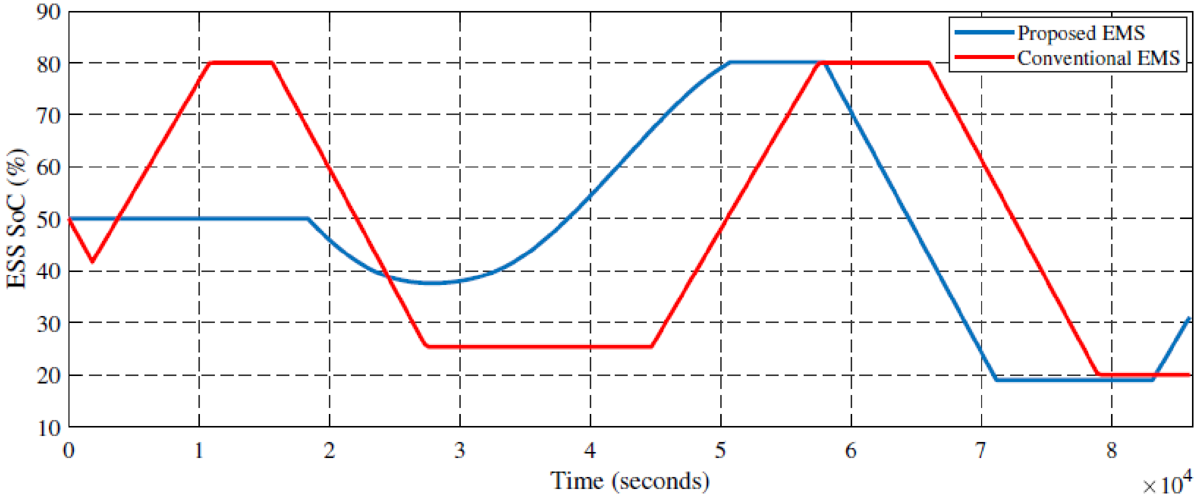
Performance Analysis



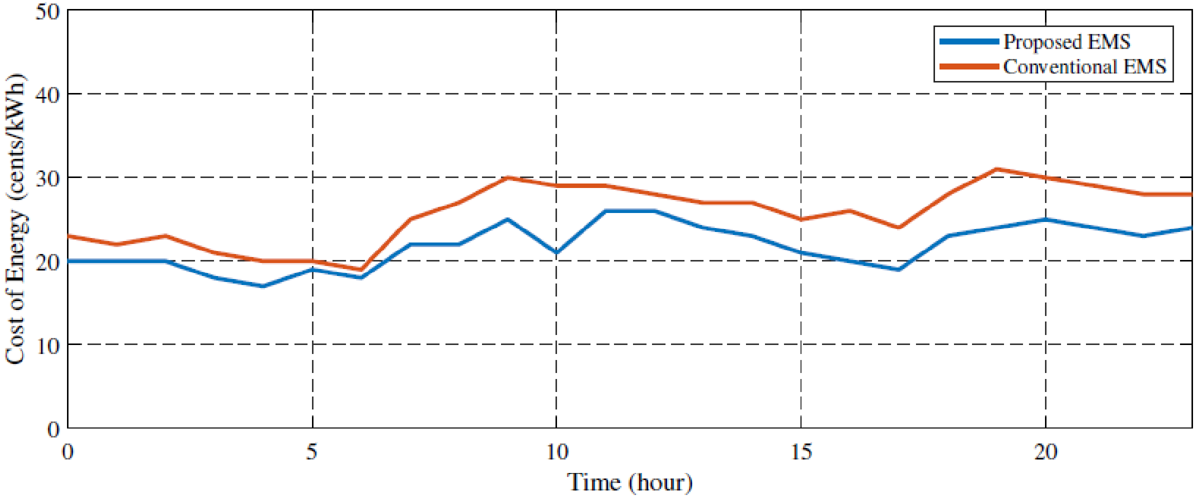
Performance of the system with (a) conventional EMS (b) Proposed EMS (c) Power saving by the proposed EMS

Performance Analysis

The proposed system improves the utilization of the ESS and reduces the COE.



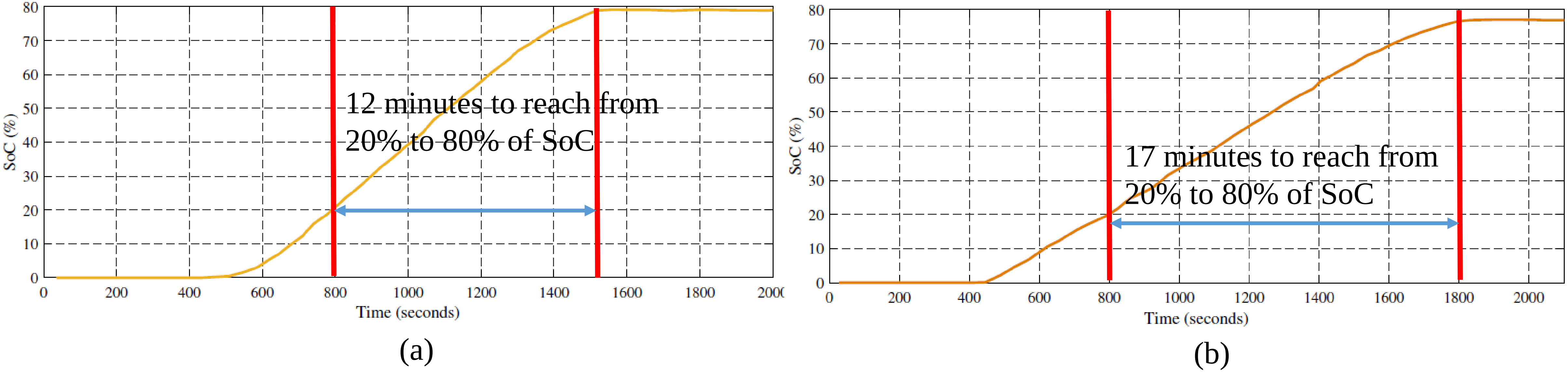
(a)



(b)

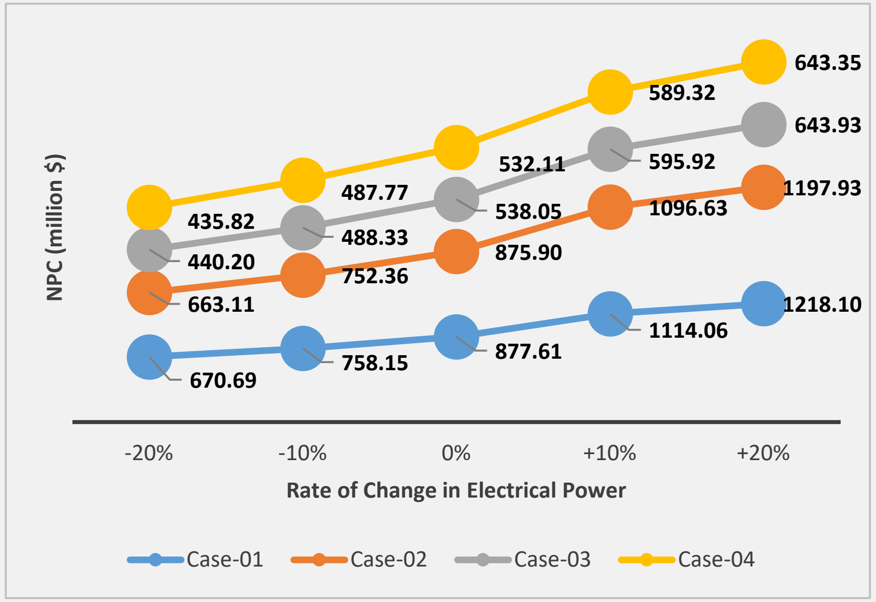
(a) Energy storage system SoC profile (b) cost of energy of the system

Performance Analysis

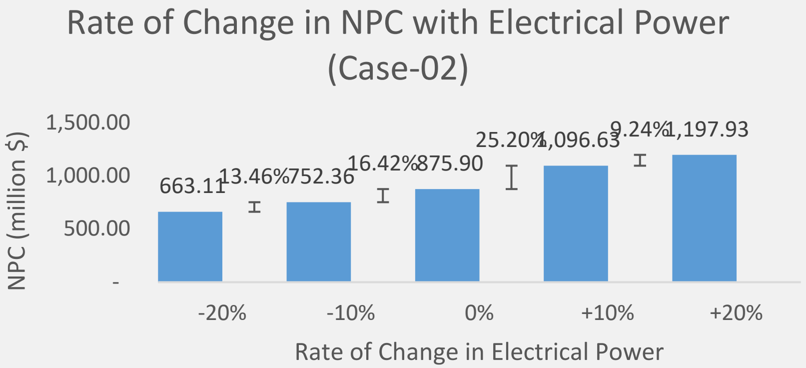


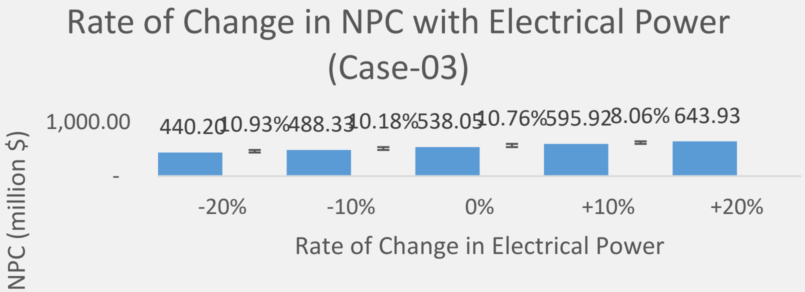
: Charging profile of (a) electric vehicle (b) electric bus from the proposed fast charging station

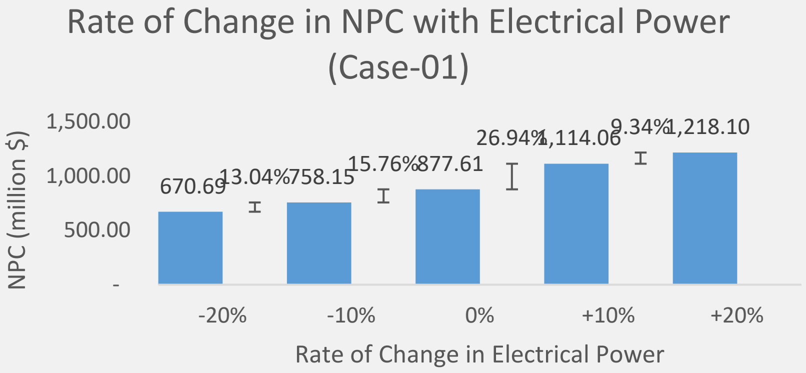
Sensitivity Analysis - Electrical Power Requirement

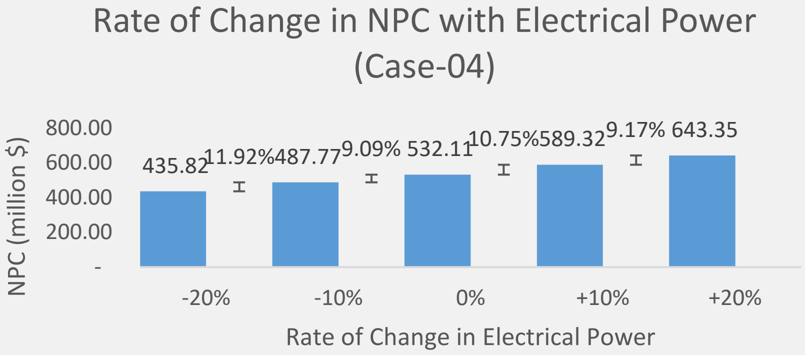


Sensitivity Assessment of Electrical Power on NPC

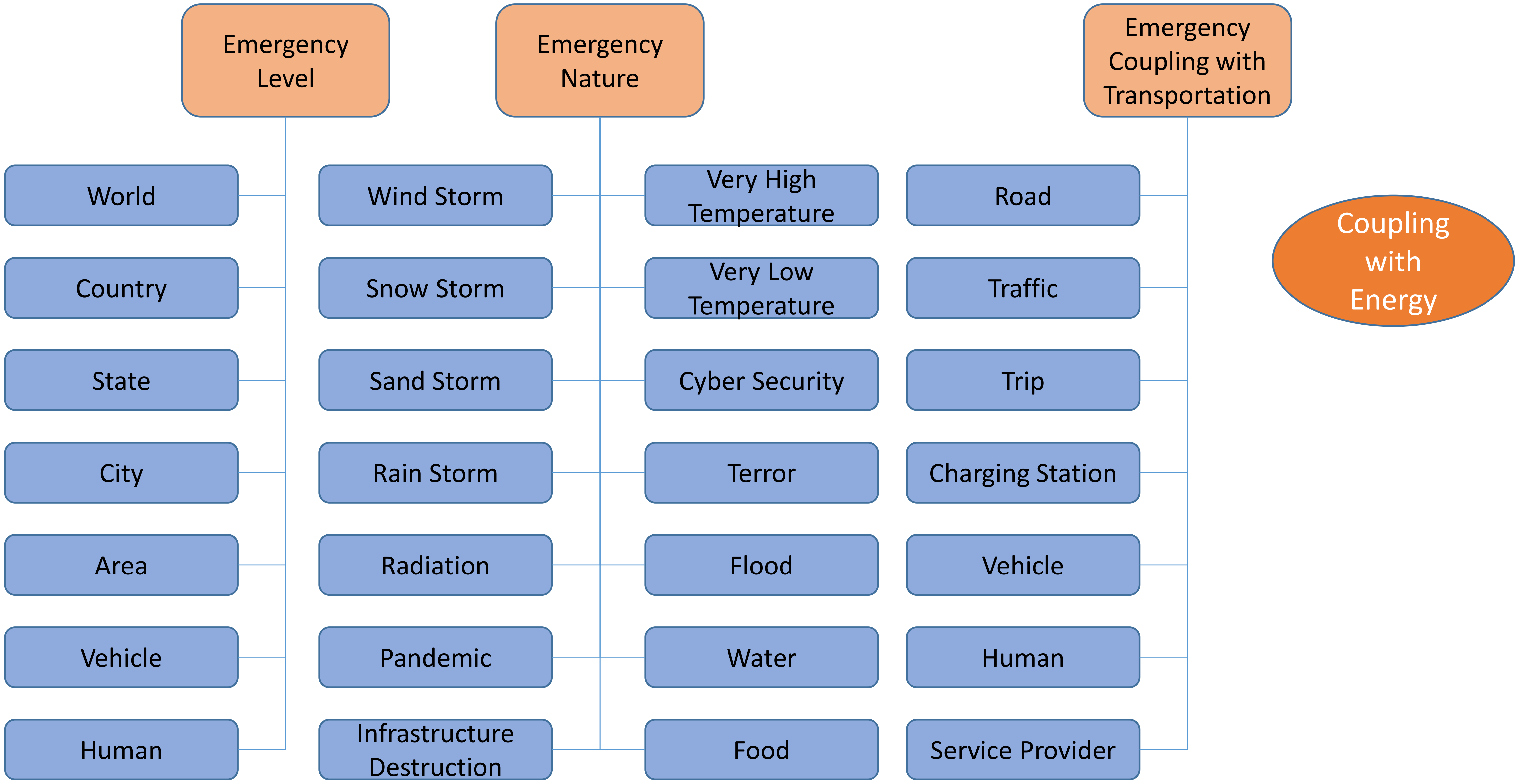




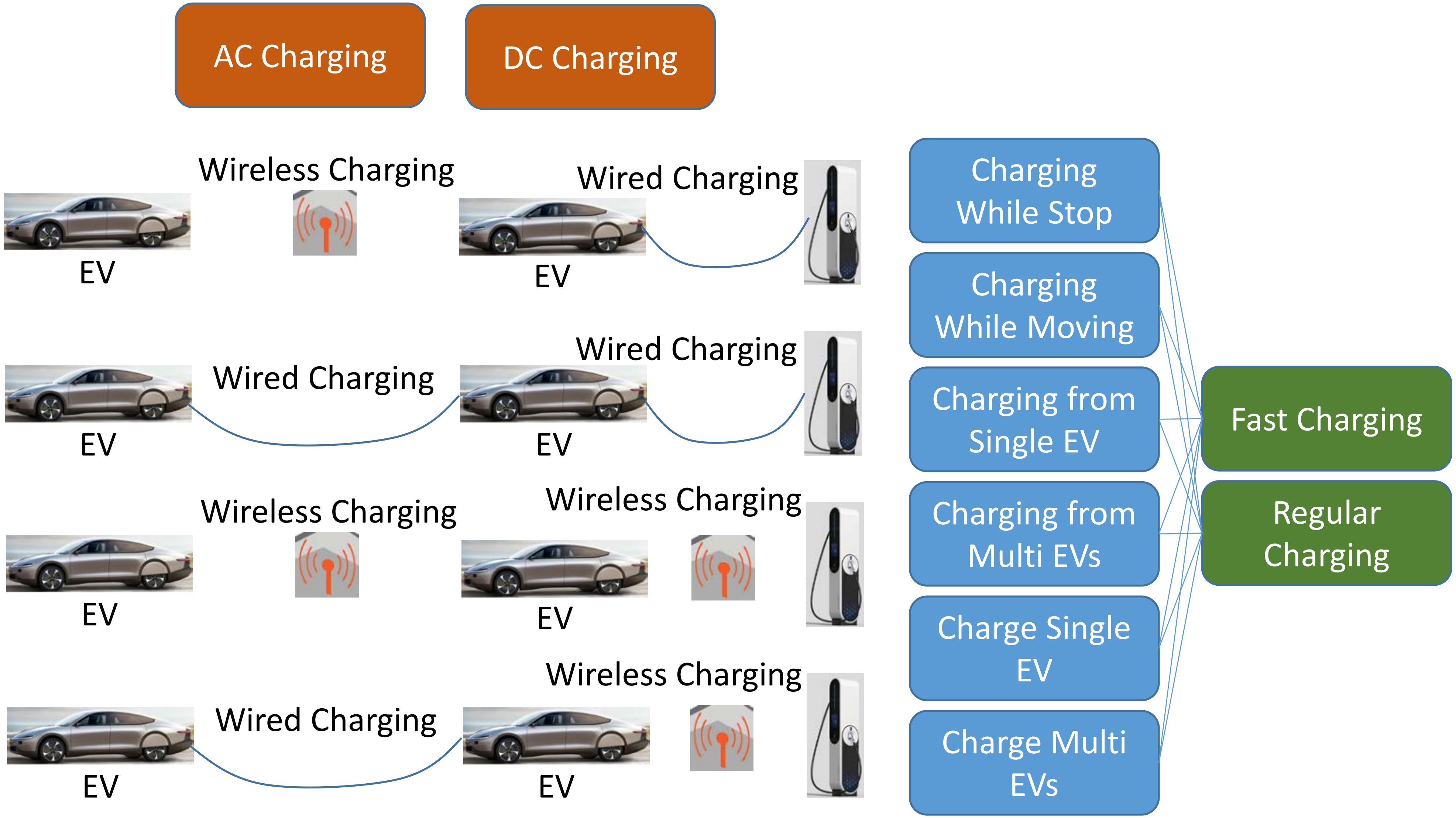




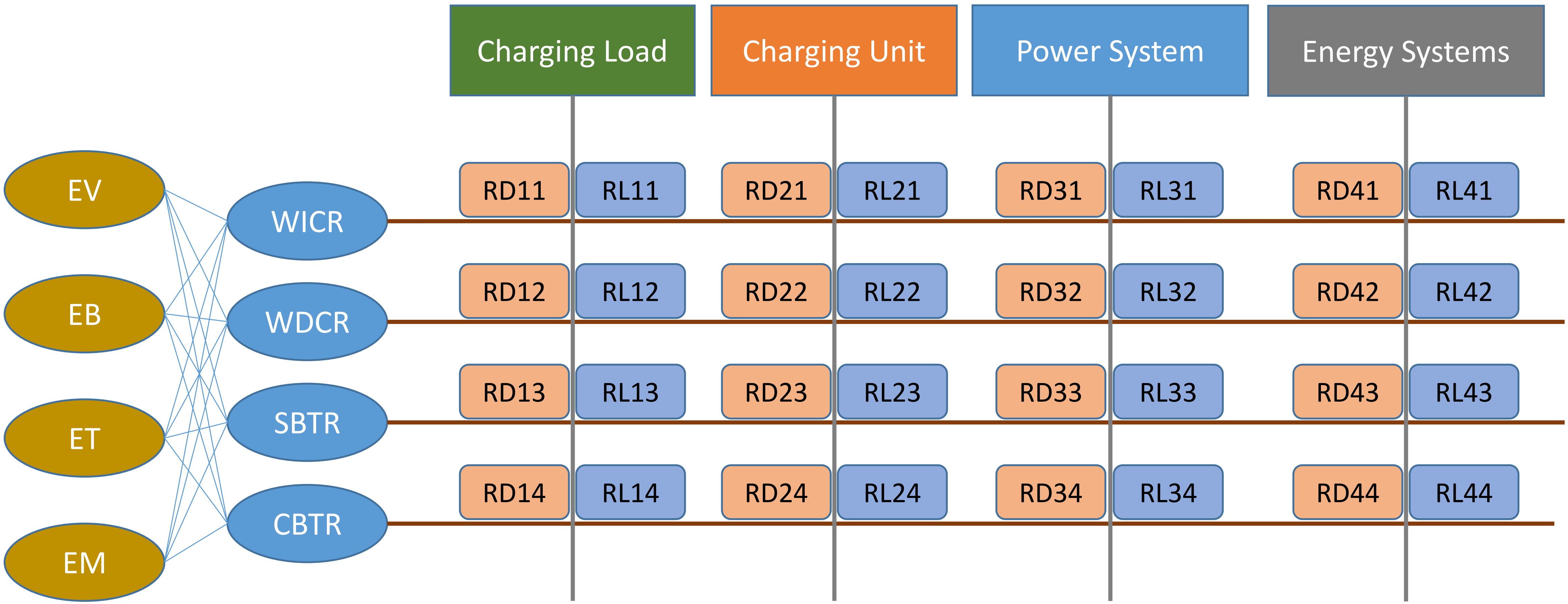
Emergency Analysis for Fast Charging Infrastructure



EV Charging Models



Layers of Resiliency Analysis (LORA) of FCS

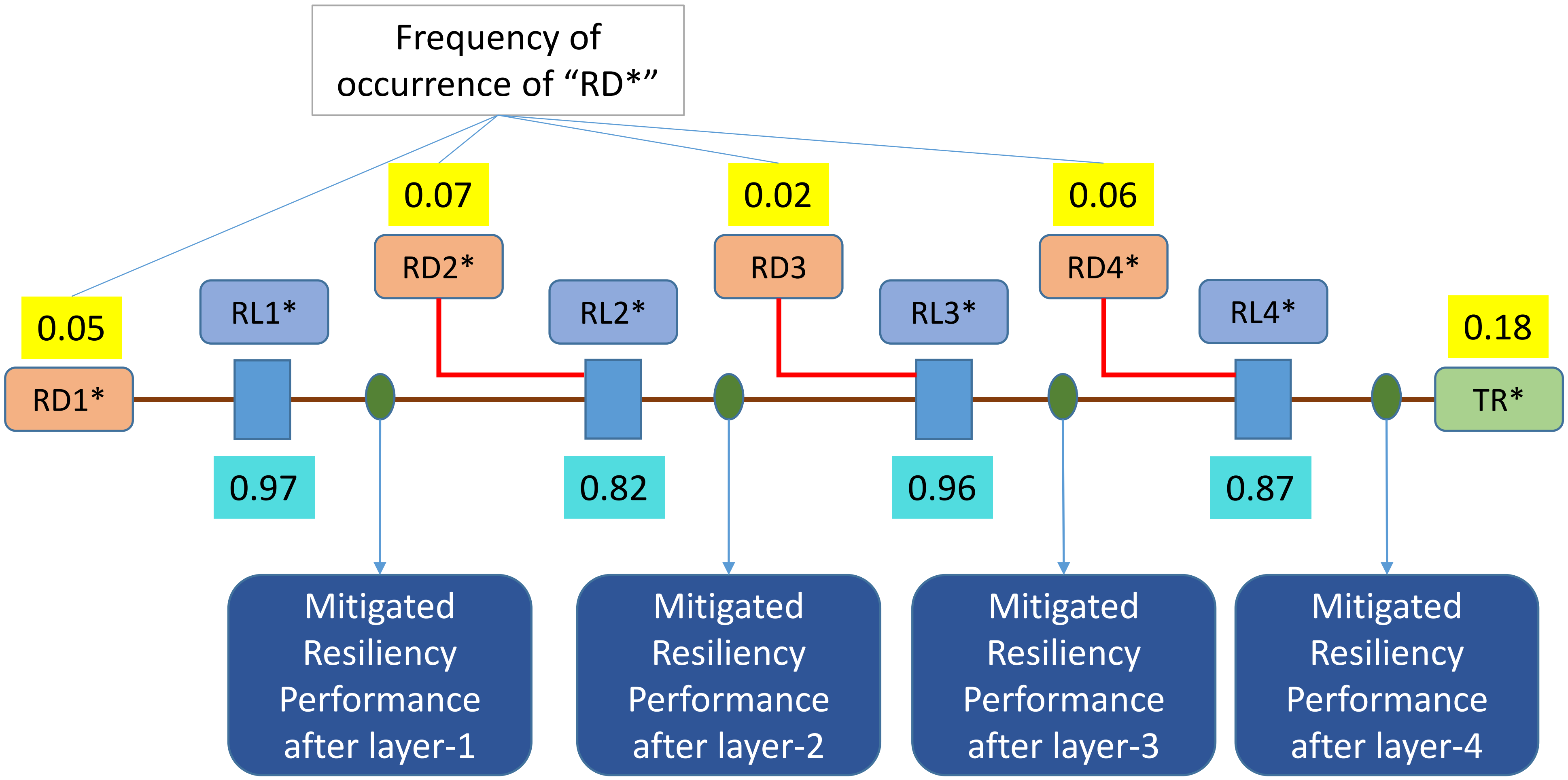


WICR: Wireless Charging
WDCR: Wired Charging

SBTR: Swap BT
CBTR: Charge BT

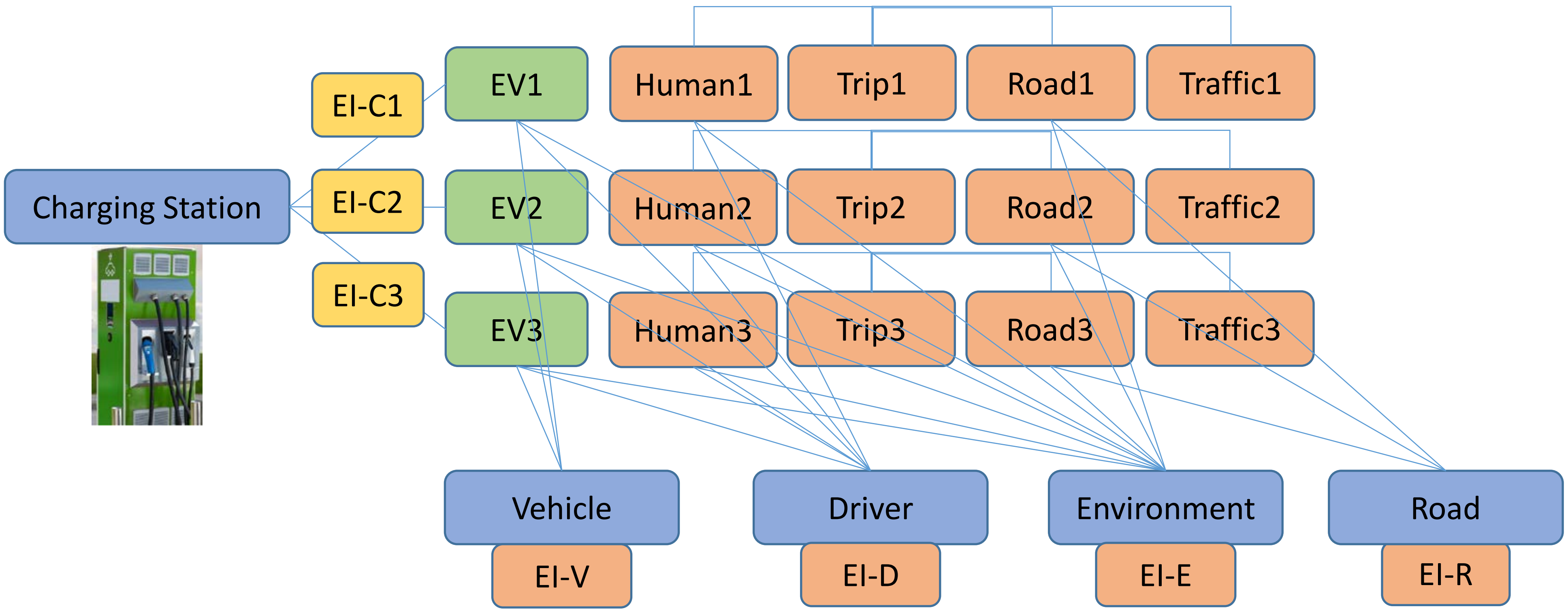
Resiliency Demand: RD
Resiliency Likelihood: RL

Layers of Resiliency Analysis (LORA) of FCS



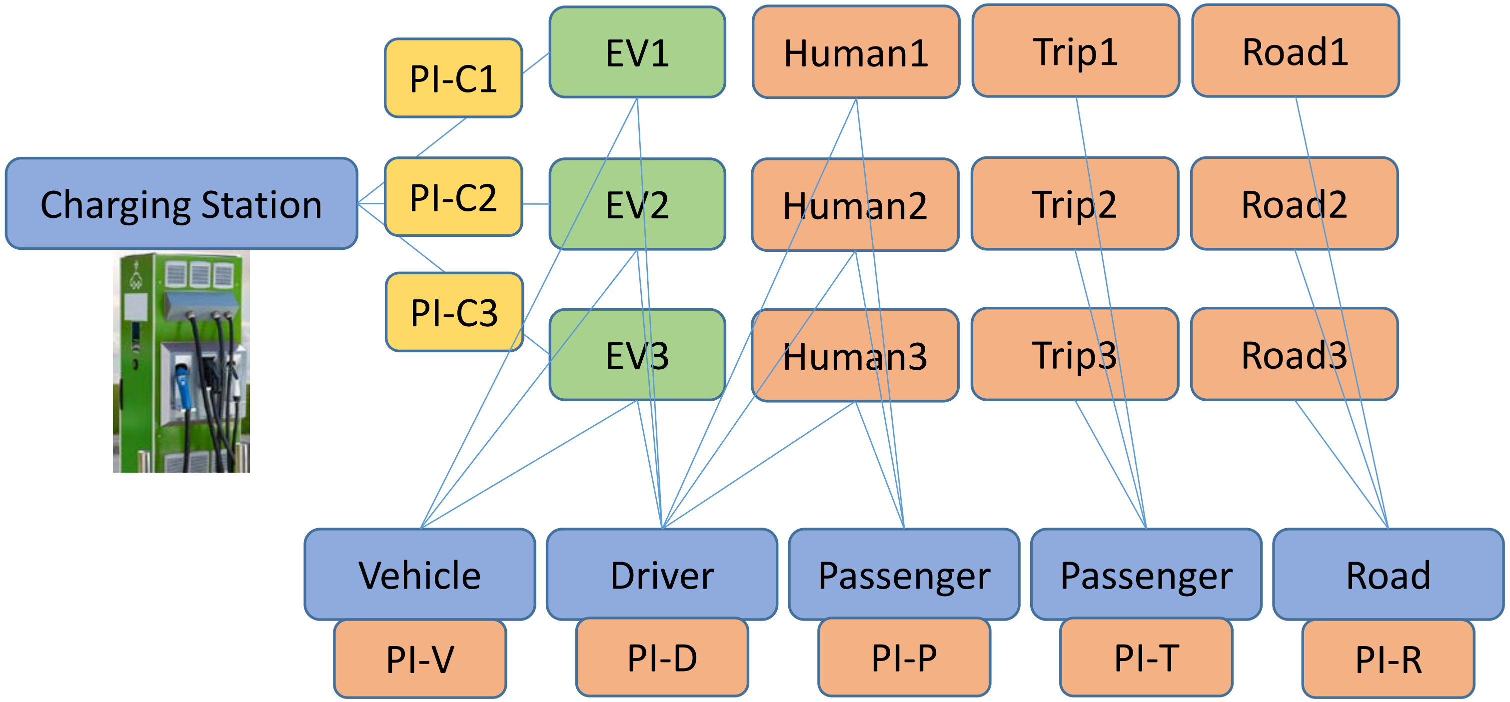
RD: Resiliency Demand, RL: Resiliency Likelihood

Emergency Index Analysis for Charging Station



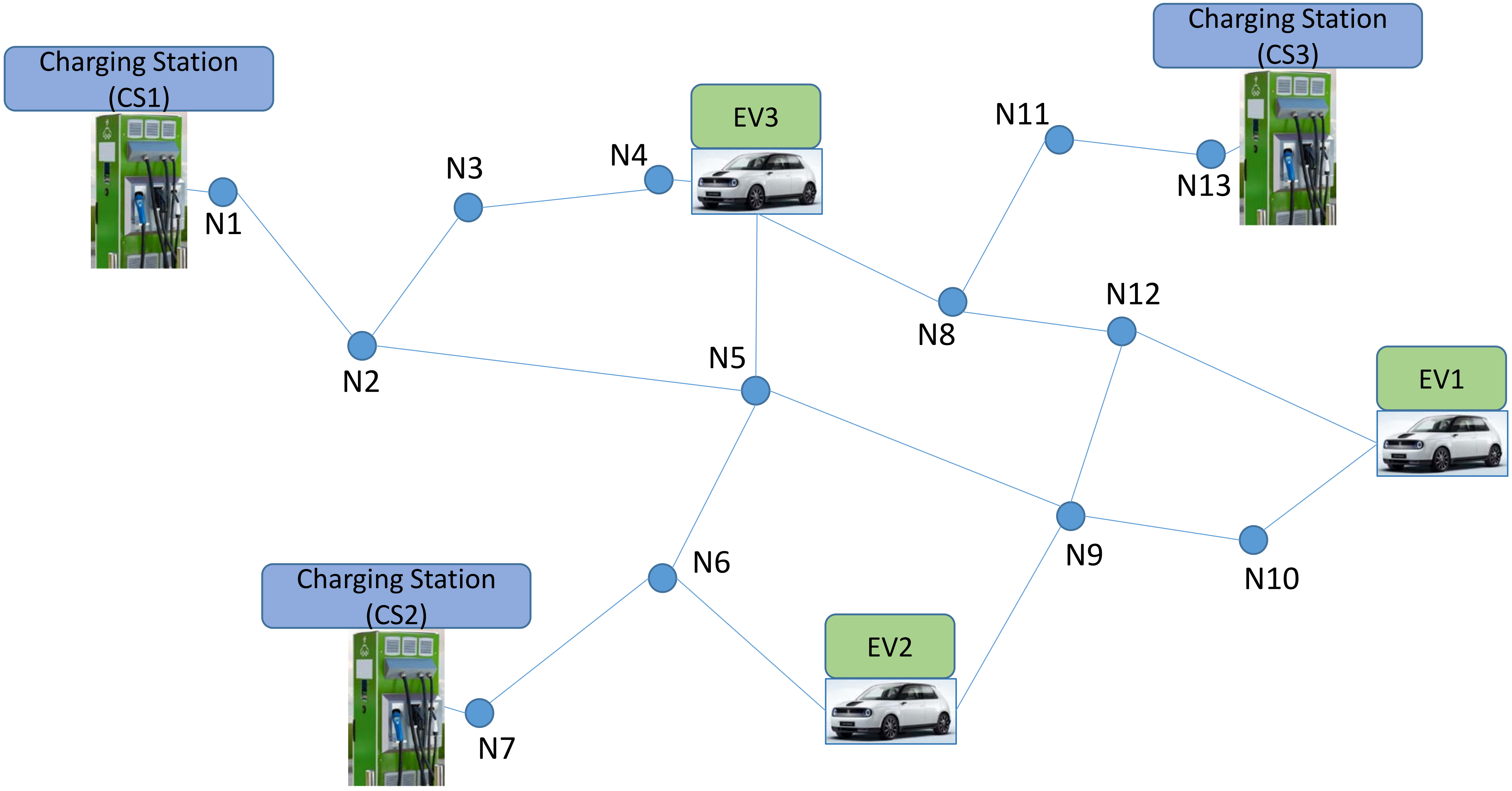
EI: Emergency Index

Performance Index Analysis for Charging Station

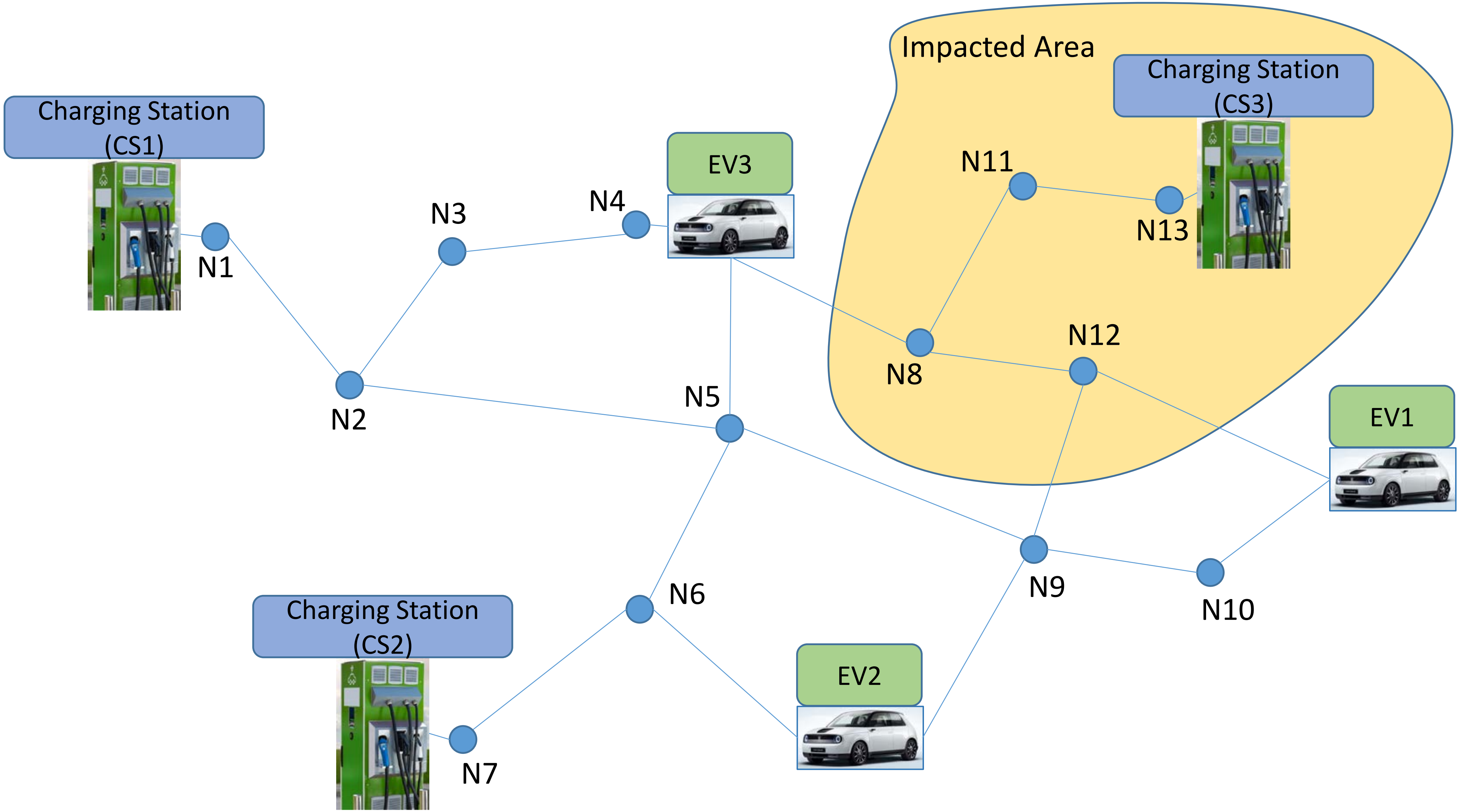


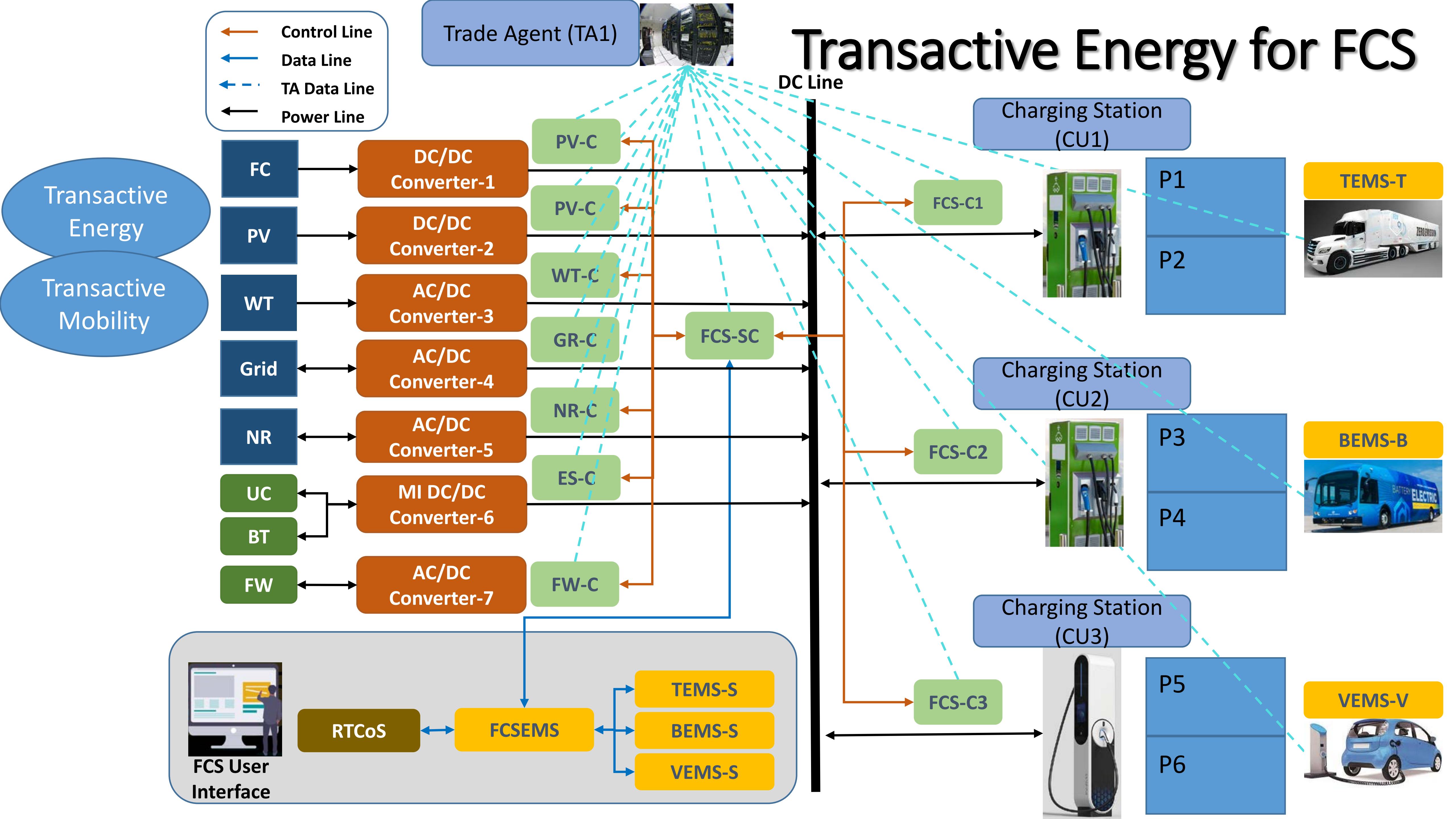
PI: Performance Index

Vehicle Energy Management for Charging in Emergencies



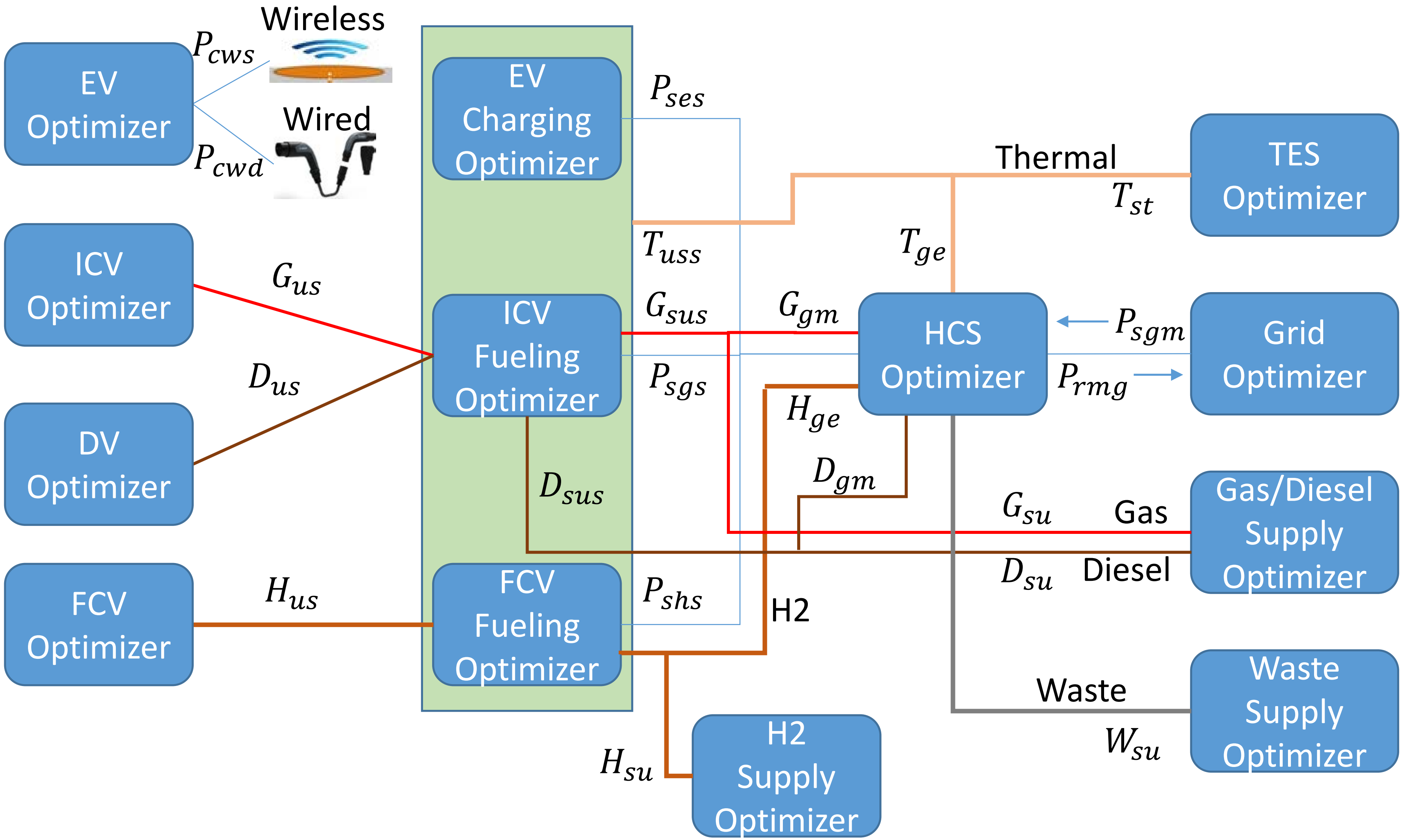
Vehicle Energy Management for Charging in Emergencies





Transactive Energy for FCS
Control Line
Data Line
TA Data Line
Power Line
Trade Agent (TA1)
DC Line
Transactive Energy
Transactive Mobility
FC
PV
WT
Grid
NR
UC
BT
FW
DC/DC Converter-1
DC/DC Converter-2
AC/DC Converter-3
AC/DC Converter-4
AC/DC Converter-5
MI DC/DC Converter-6
AC/DC Converter-7
PV-C
PV-C
WT-C
GR-C
NR-C
ES-C
FW-C
FCS-SC
FCS-C1
FCS-C2
FCS-C3
Charging Station (CU1)
Charging Station (CU2)
Charging Station (CU3)
P1
P2
P3
P4
P5
P6
TEMS-T
BEMS-B
VEMS-V
FCS User Interface
RTCoS
FCSEMS
TEMS-S
BEMS-S
VEMS-S

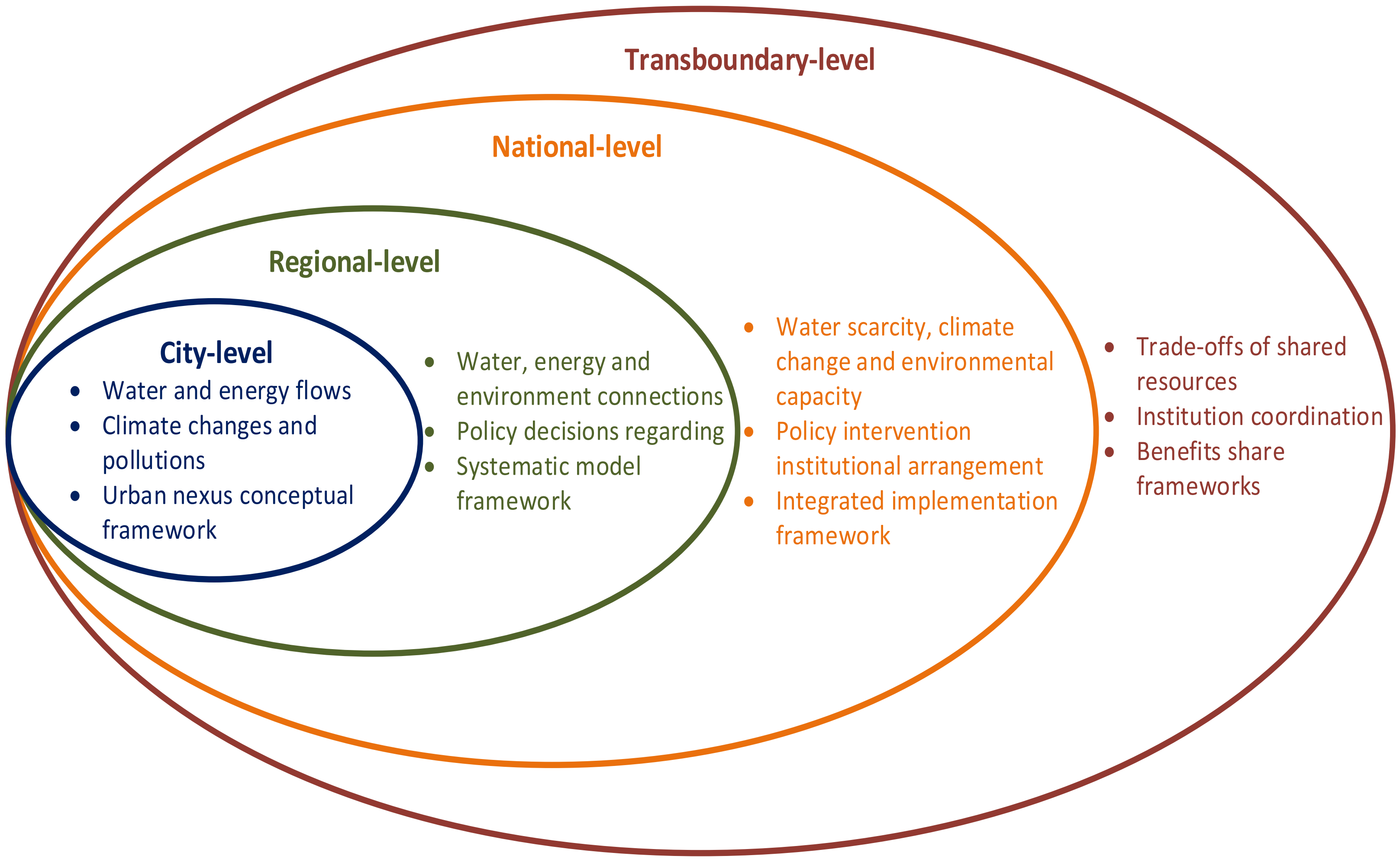
Distributed Optimization Model



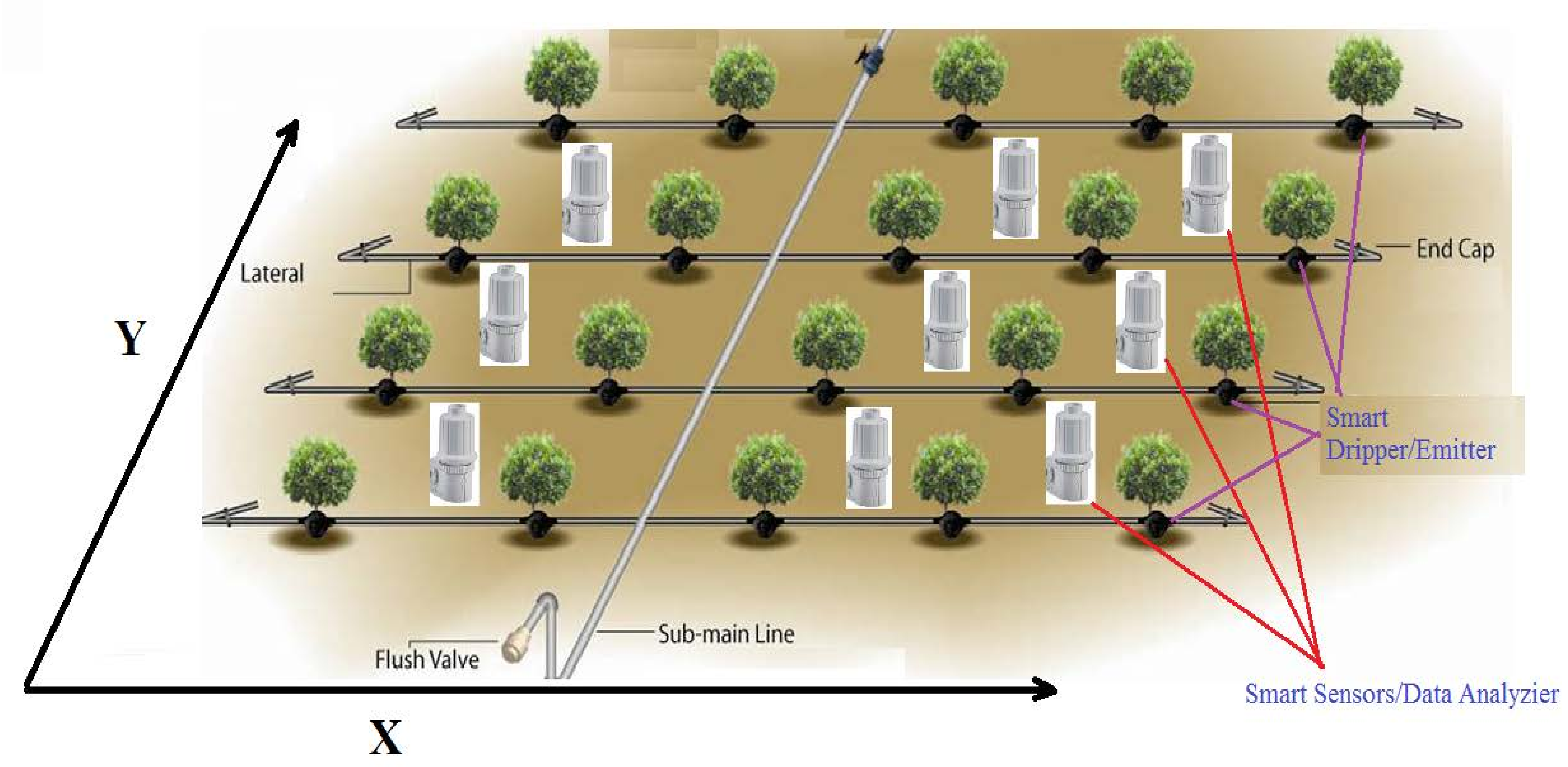
Energy-Water Coupling

Energy-Water Coupling	Supply Strategy
Energy inputs into Water Grids	Energy supply to water sources
	Energy supply to water treatment
	Energy supply to water storage
	Energy supply to water transfer
	Energy supply to water loads
Water inputs into Energy Grids	Water supply to energy sources
	Water supply to energy conversion
	Water supply to energy storage
	Water supply to energy transfer
	Water supply to energy loads

Water-Energy Analysis Levels (Food-Health)



Energy-Water in Farms

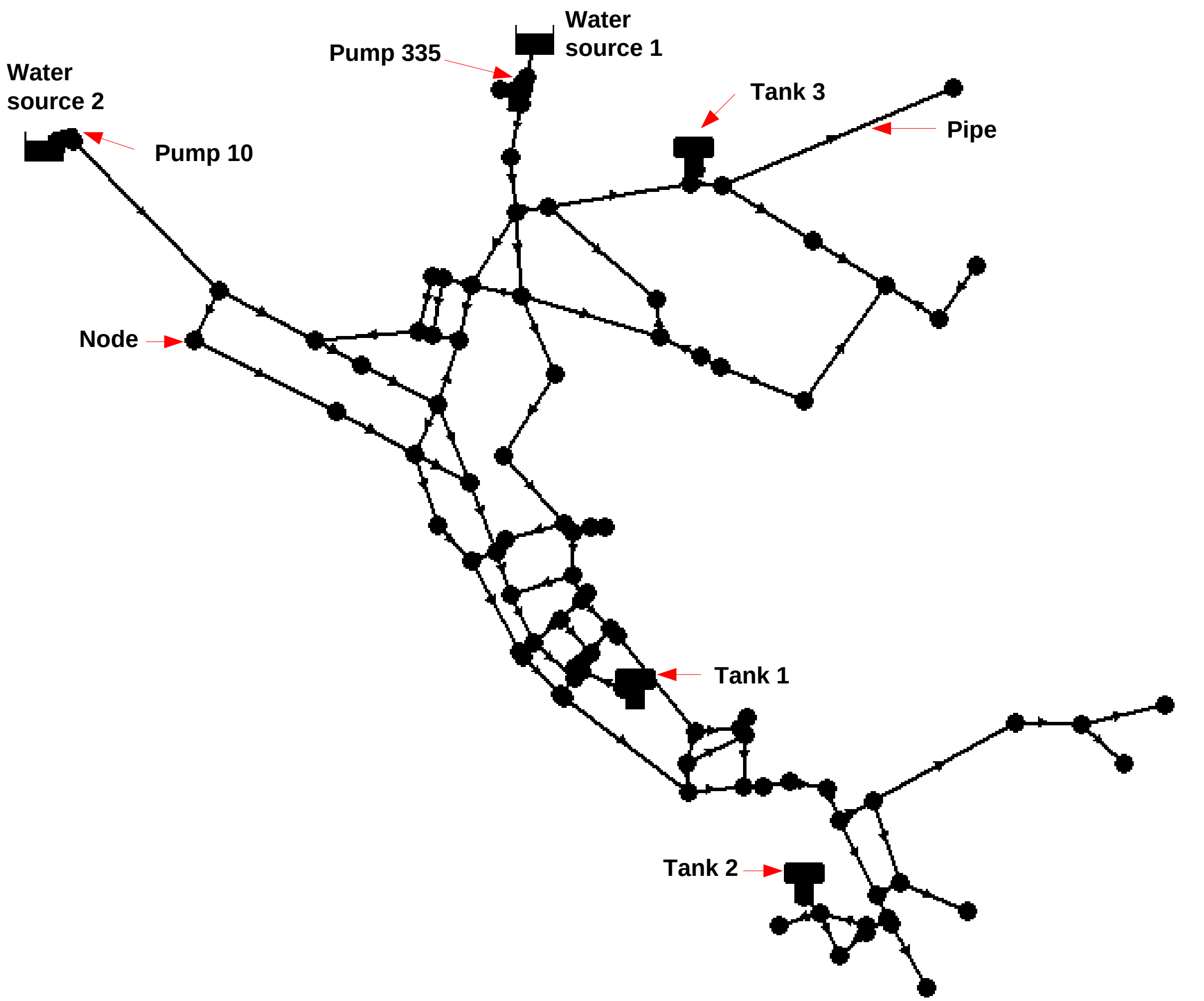


Energy-Water Optimization

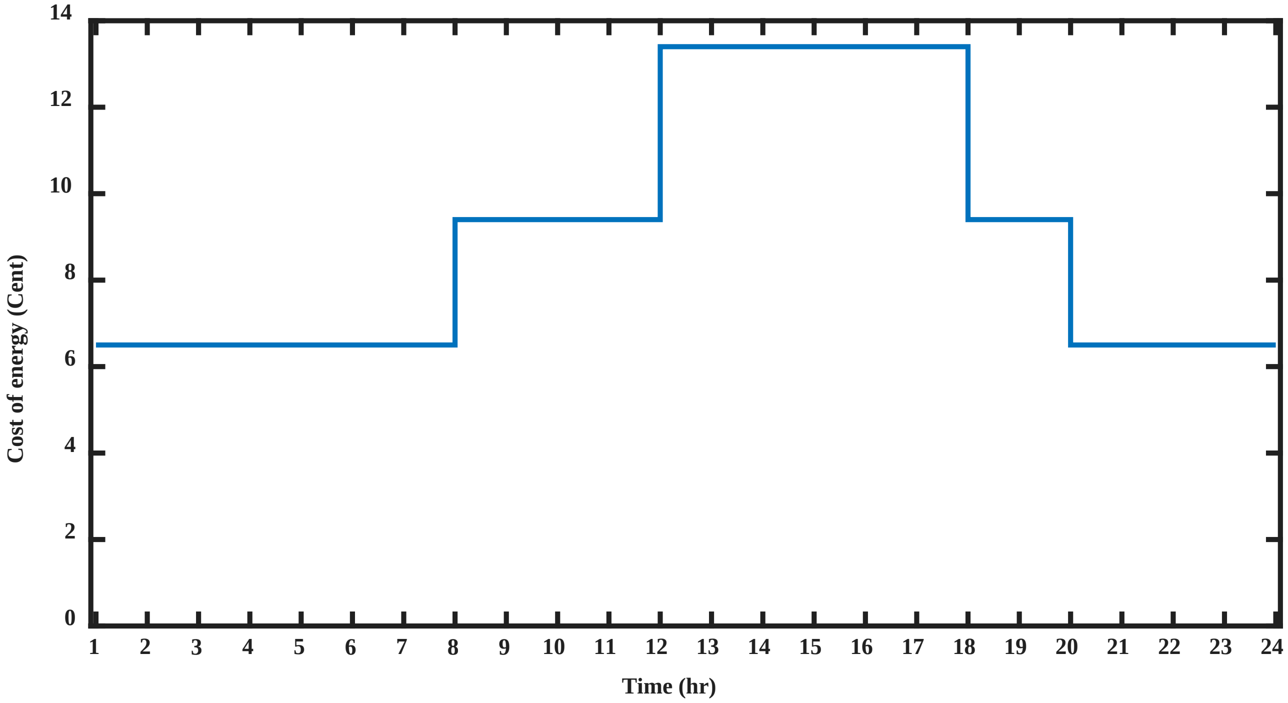
- *Objective function = min* $(f_1 + f_2 + f_3)$
- where f_1 is the cost of electric energy consumption, f_2 is the cost of pump maintenance and f_3 is the cost of demand charges.

- $f_1 = \sum_{i=1}^{np} \sum_{j=1}^{24} P_{ij} * c_{e_j}$
- $f_2 = c_d * P_{max}$
- $f_3 = \sum_{i=1}^{np} c_m * Sw_{max_i}$

Regional Water Network Model



Ontario Daily Energy Tariff

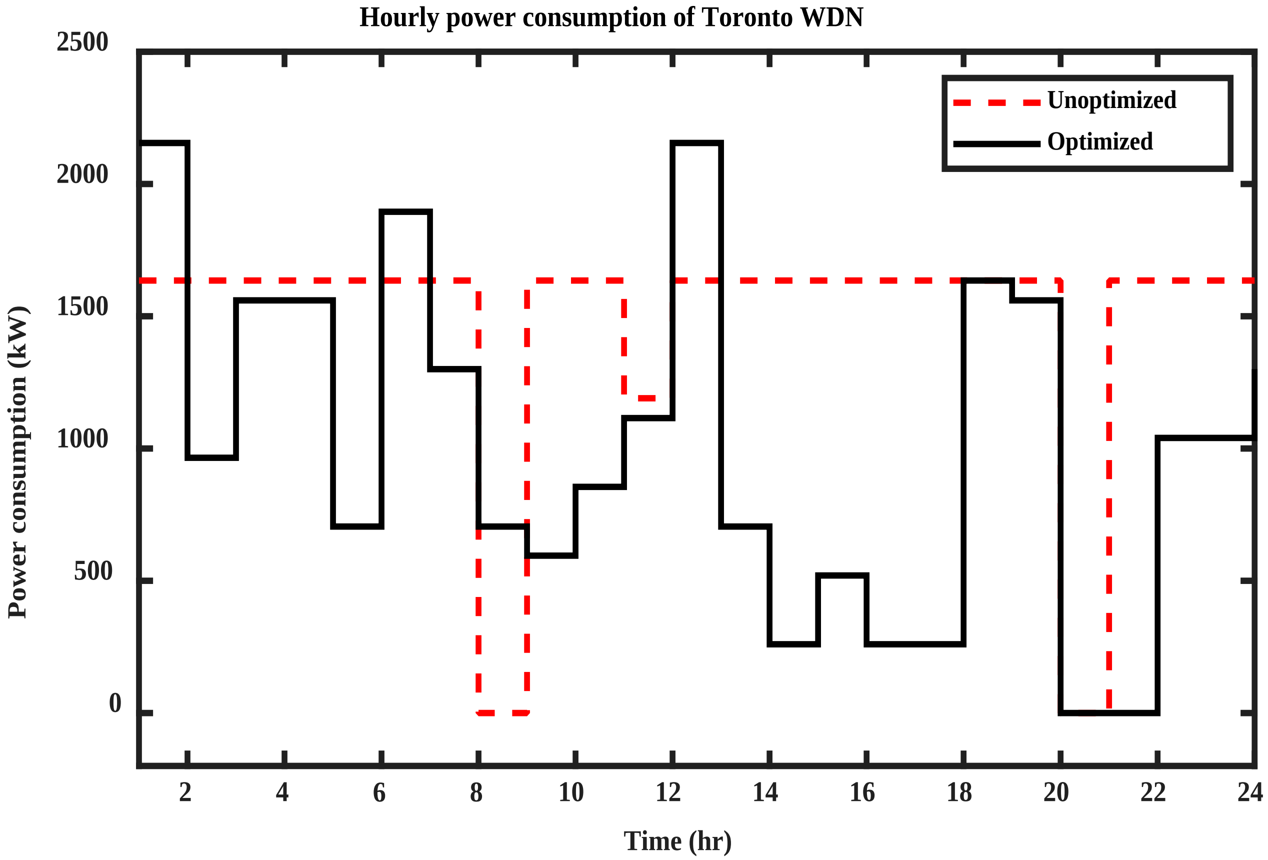


Optimization Results

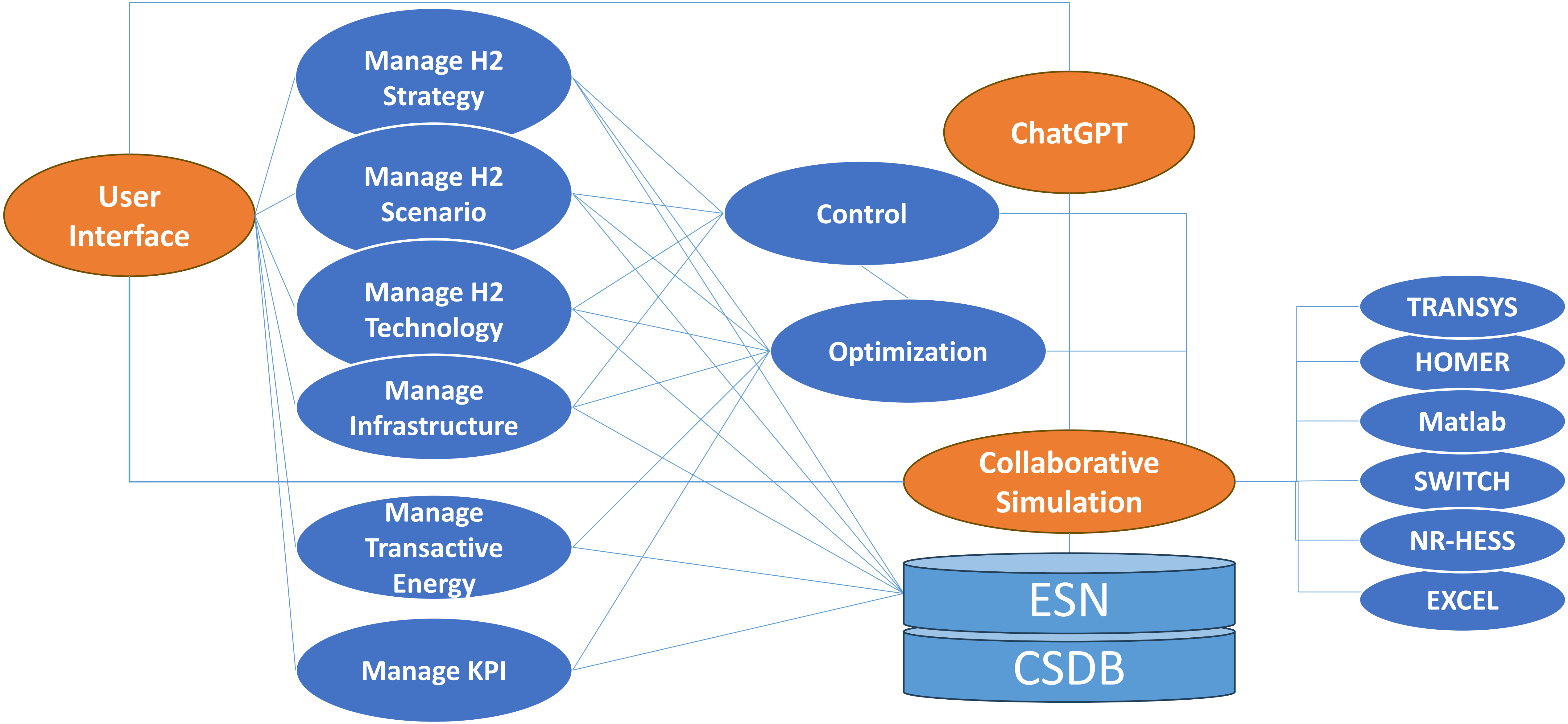
Pump	#1	#2	#3	#4	#5	#6	#7
Power (kW)	595	445	260	260	595	740	330
Water Flow (m^3/hr)	1800	1440	828	828	1800	2240	1000

Tank	1	2	3
Lower limit (m)	6.5	6.5	6
Upper limit (m)	9	8.5	9

Daily Power Consumption of Toronto Water Pump Stations



Integrated Collaborative Simulation for Regional Planning and Optimization of Hydrogen Deployments Strategies



Case study 2: Starting to include fuel cell vehicles

30%

70%

Durham Region

Main KPIs

Region KPIs
CO2 emissions (tons/year)
Operating costs ($/year)
Power demand (MWh/year)
Water demand (ML/year)

Zone KPIs
CO2 emissions (tons/year)
Operating costs ($/year)
Power demand (MWh/year)
Water demand (ML/year)

Power plants KPIs
CO2 emissions (tons/year)
Operating costs ($/year)
Generated power (MWh/year)
Capital costs ($)

Hydrogen plant/s KPIs
Generated hydrogen (kg/year)
Operating costs ($/year)
Capital costs ($)

Water plants KPIs
Operating costs ($/year)
Processed water (ML/year)

System architecture

Must be updated every time new modules are developed/changed

Source code Location: Github

https://github.com/ElenaVH/switch_E

Code is private: only accessible to our team

Two Installation options

Google collab:
- Easy start, installation of 2-3 minutes
- Installation required on every use
- Information should be saved constantly in case collab limit is exceeded

switch

Local:
- Initial installation is complex
- Installation required one time (except when there are code updates)
- Information storage is flexible

Modifying input data

Manually

From user interface (currently not implemented

- carbon_policies.csv
- financials.csv
- fuel_cost.csv
- fuels.csv
- gen_build_costs.csv
- gen_build_predetermined.csv
- gen_info.csv
- load_zones.csv
- loads.csv
- modules.txt
- non_fuel_energy_sources.csv
- periods.csv
- switch_inputs_version.txt
- timepoints.csv
- timeseries.csv
- water_demand.csv
- water_plants_info.csv

Interpreting output data

Manually

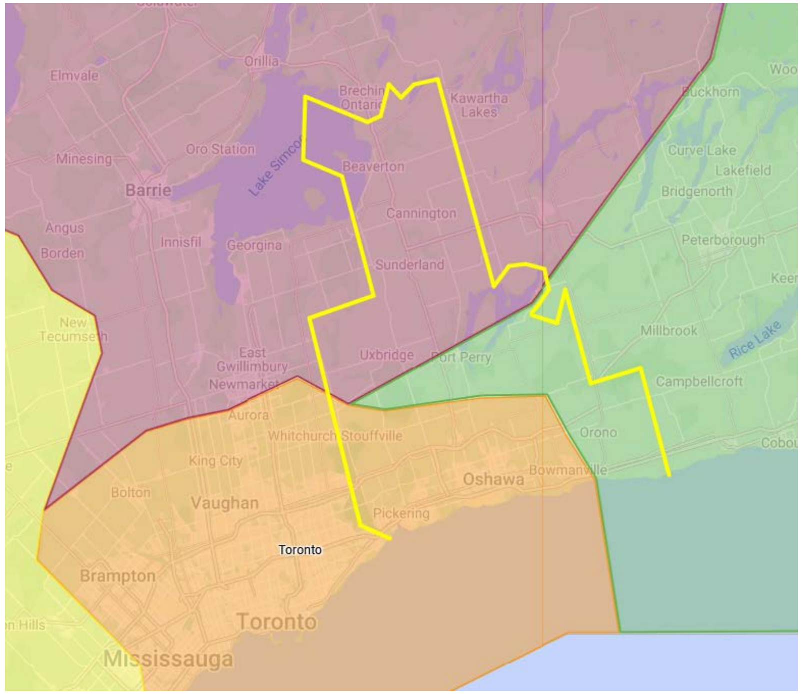
From user interface (currently not implemented

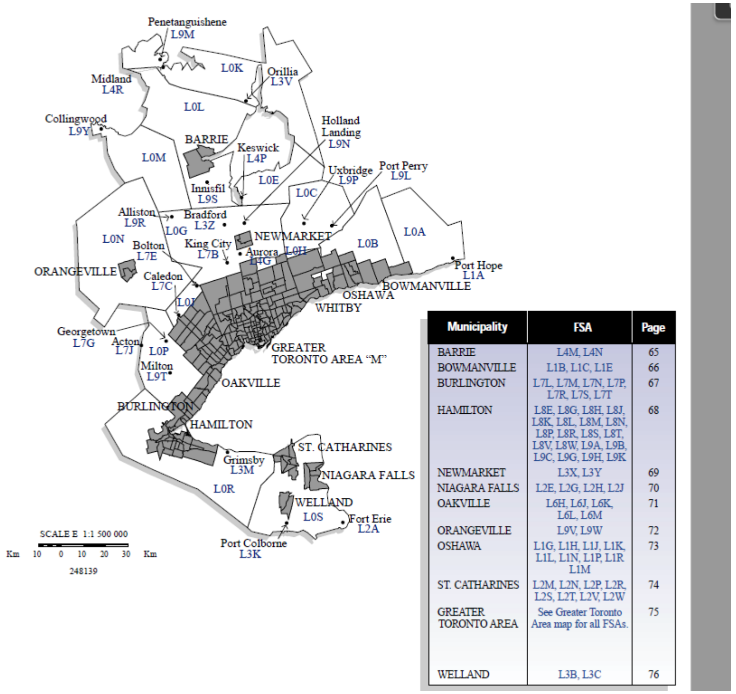
- BuildGen.csv
- BuildHydrogenP.csv
- BuildMinGenCap.csv
- cost_components.csv
- costs_itemized.csv
- dispatch.csv
- dispatch_annual_summary.csv
- dispatch_annual_summary_fuel.pdf
- dispatch_annual_summary_tech.pdf
- dispatch_hydrogen.csv
- dispatch_water_wide.csv
- dispatch_wide.csv
- dispatch_zonal_annual_summary.csv
- DispatchBaseloadByPeriod.csv
- DispatchGen.csv
- DispatchHPlant.csv
- DispatchWater.csv
- electricity_cost.csv
- emissions.csv
- gen_build.csv
- gen_cap.csv
- gen_project_annual_summary.csv
- GenFuelUseRate.csv
- h_plant_project_annual_summary.csv
- hydrogen_balance.csv
- hydrogen_build.csv
- hydrogen_cap.csv

Data preprocessing: Power

Power separation proportional to population density

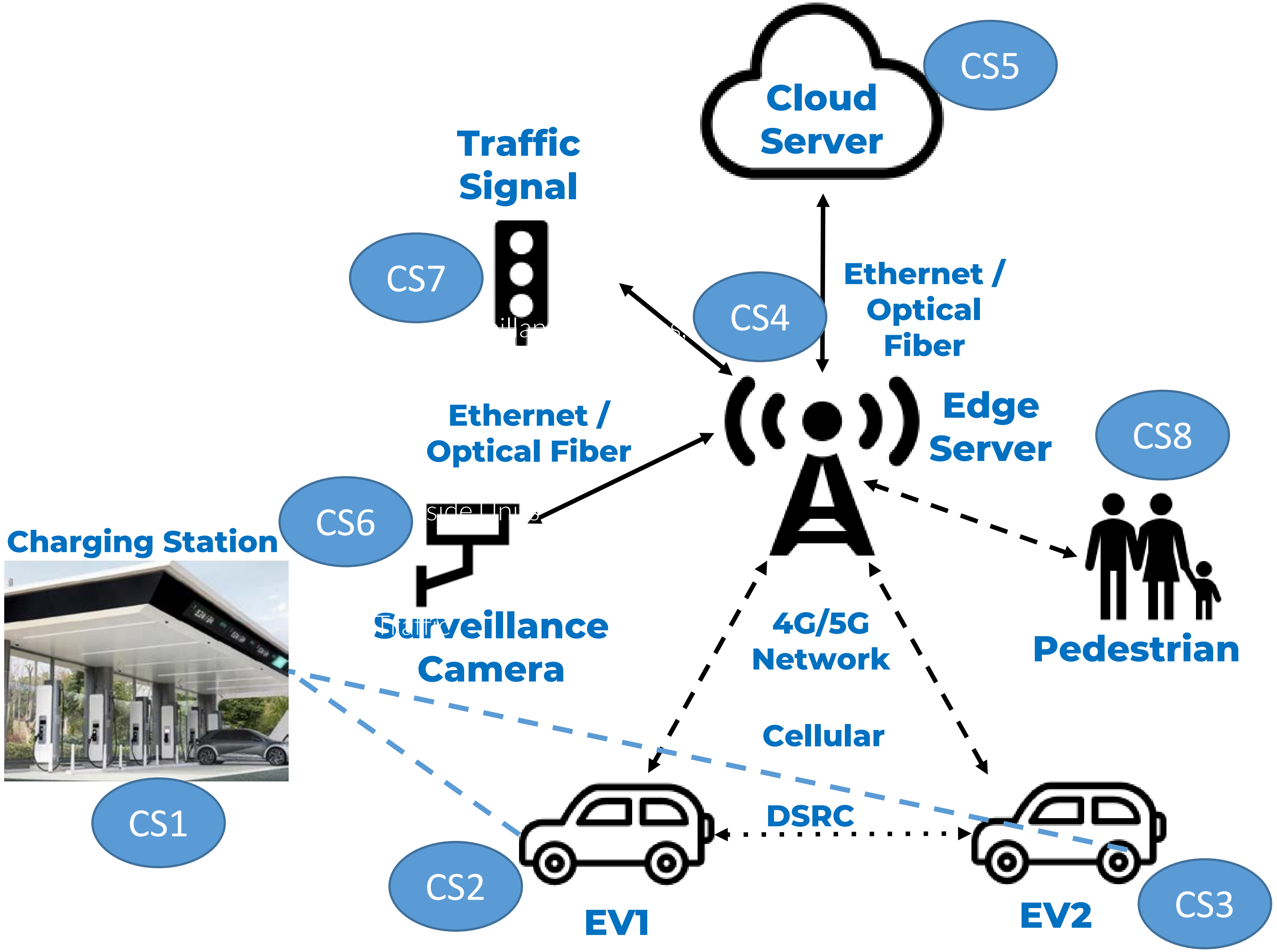
Population in Toronto, East and Essa areas vs population in Durham region: Select applicable FSAs,



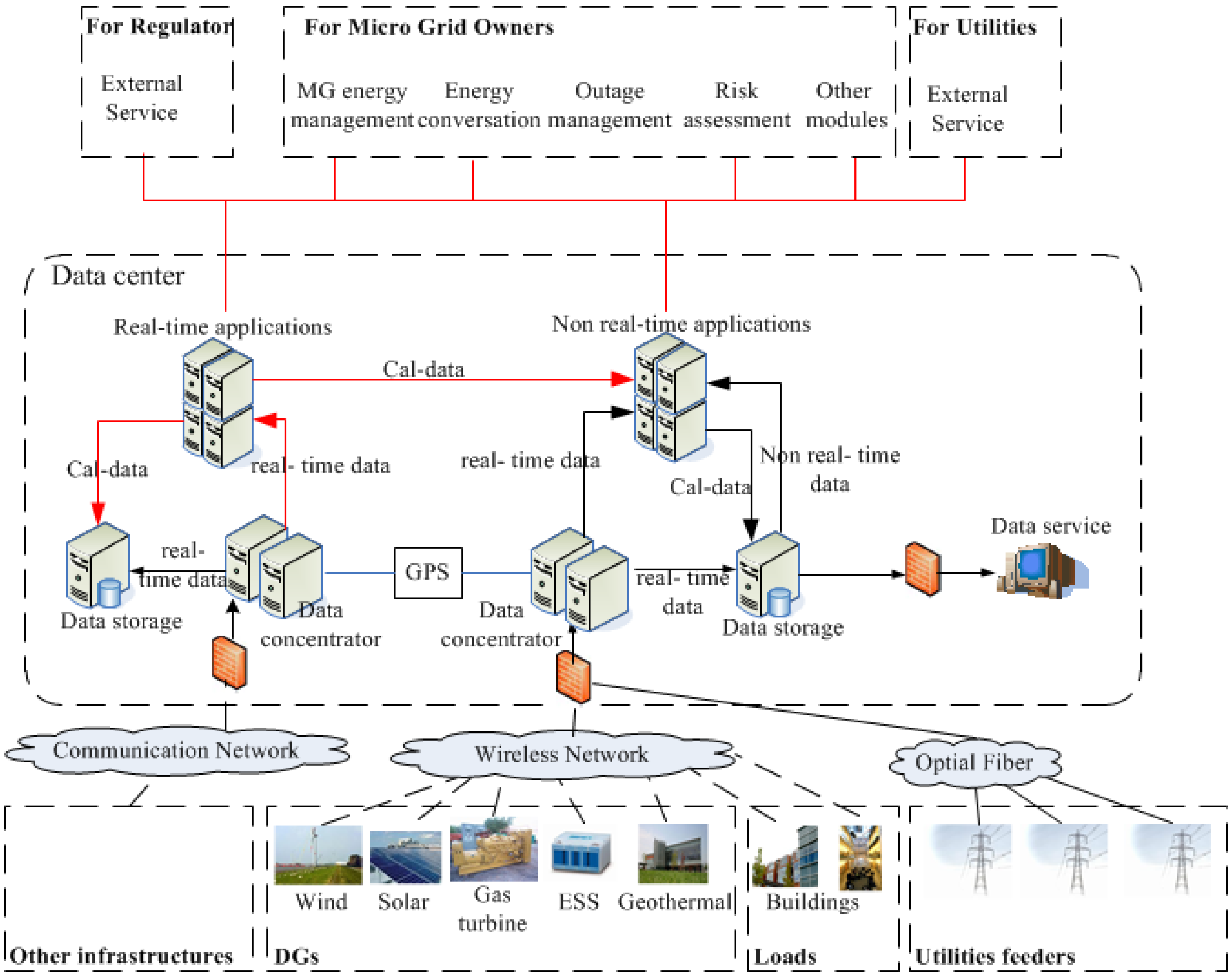


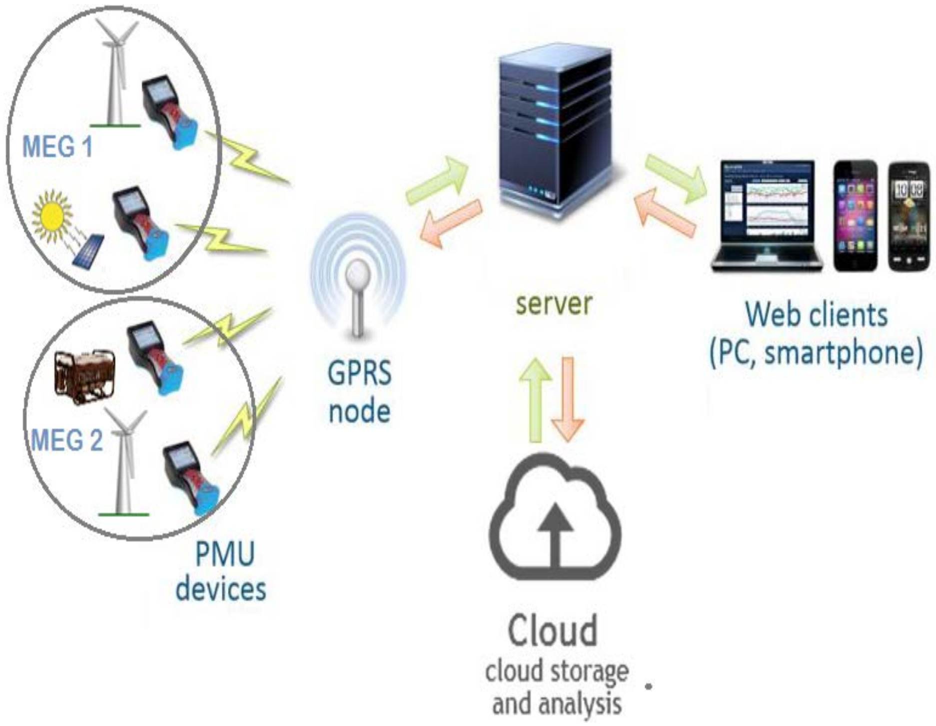
	A	B	C	D	E	F	G	H	I	J	K	L
1	CENSUS_Y	DGUID	ALT_GEO_	GEO_LEVEL	GEO_NAME	TNR_SF	TNR_LF	DATA_QUALITY_	CHARACTE	CHARACTERISTIC	CHARACTE	C1_COUNT_TOTAL
2	2021	2021A001	A0A	Forward sortation area	A0A	3.3	4.2	0	1	Population, 2021	1	44930
3	2021	2021A001	A0A	Forward sortation area	A0A	3.3	4.2	0	2	Population, 2016	1	
4	2021	2021A001	A0A	Forward sortation area	A0A	3.3	4.2	0	3	Population percentage change, 2016 to 2021		
5	2021	2021A001	A0A	Forward sortation area	A0A	3.3	4.2	0	4	Total private dw	2	26102
6	2021	2021A001	A0A	Forward sortation area	A0A	3.3	4.2	0	5	Private dwellings	3	19752

Digital Architecture for Transactive Mobility

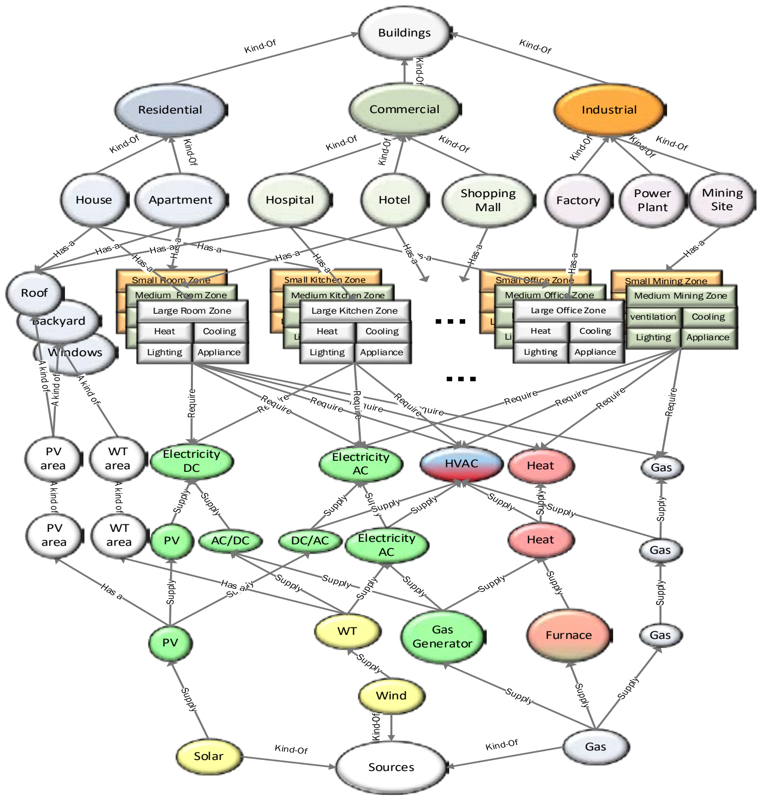


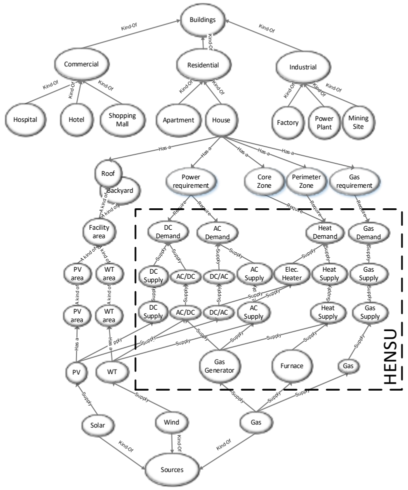
Integrated Energy-Water-Food-Health-Transportation Data Center (Efficiency, Conservation, Safety, Reliability)



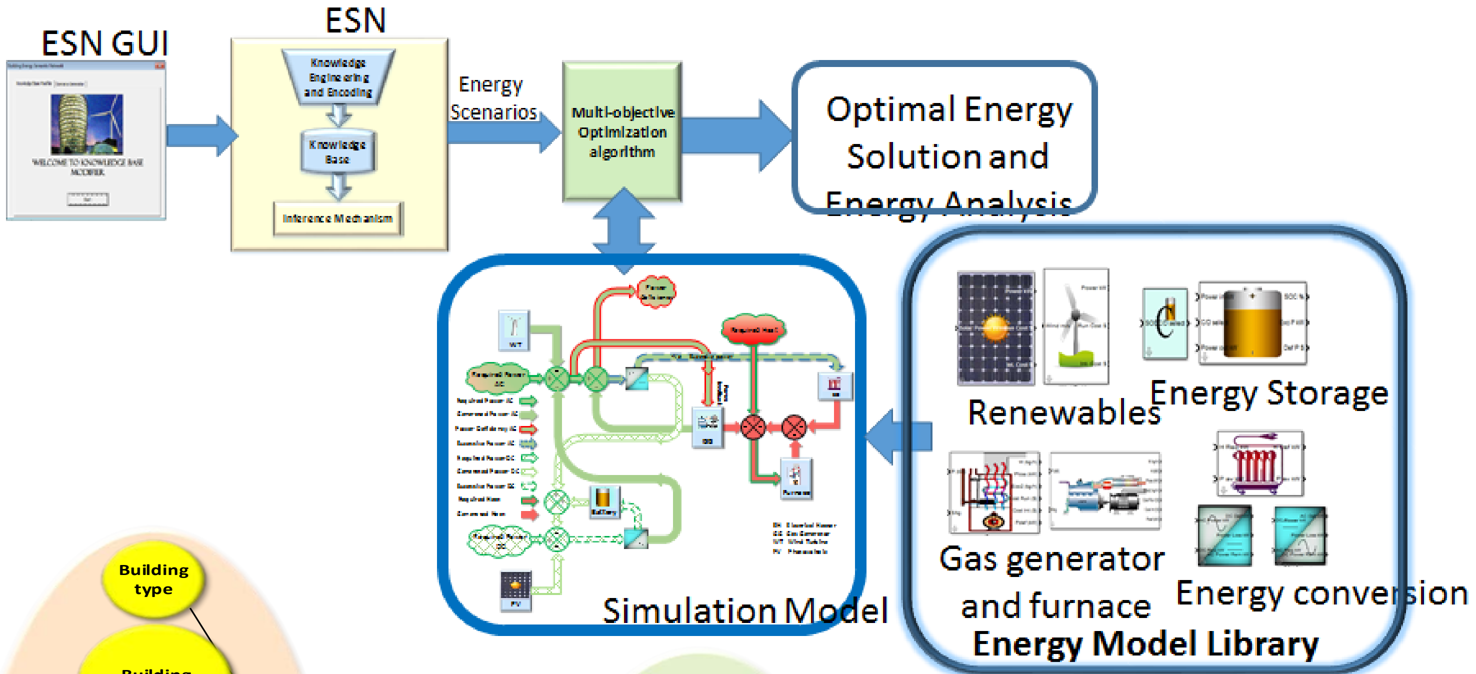


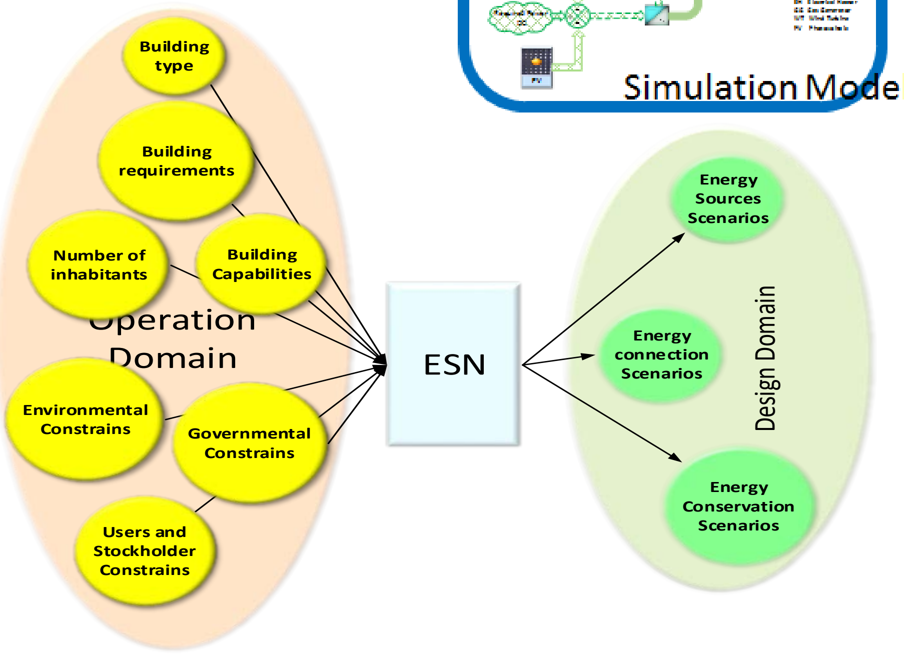
AI for Smart Energy-Water-Food-Health-Transportation Infrastructures



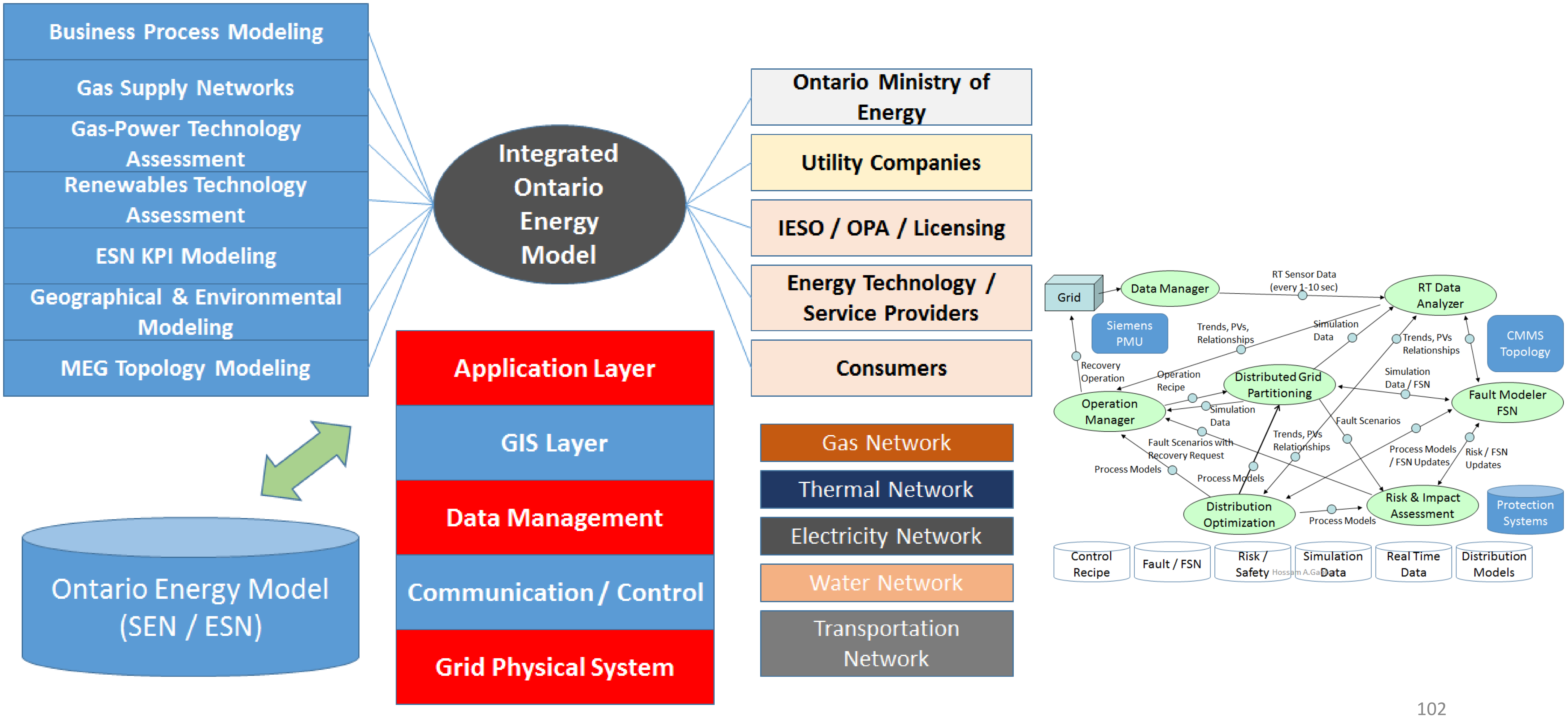


$$C^i = \begin{bmatrix} c^i_{1,1} & \cdots & c^i_{1,J_{i-1}} \\ \vdots & c^i_{j,k} & \vdots \\ c^i_{J_i,1} & \cdots & c^i_{J_i,J_{i-1}} \end{bmatrix}_{J_{i-1}\times J_i}$$

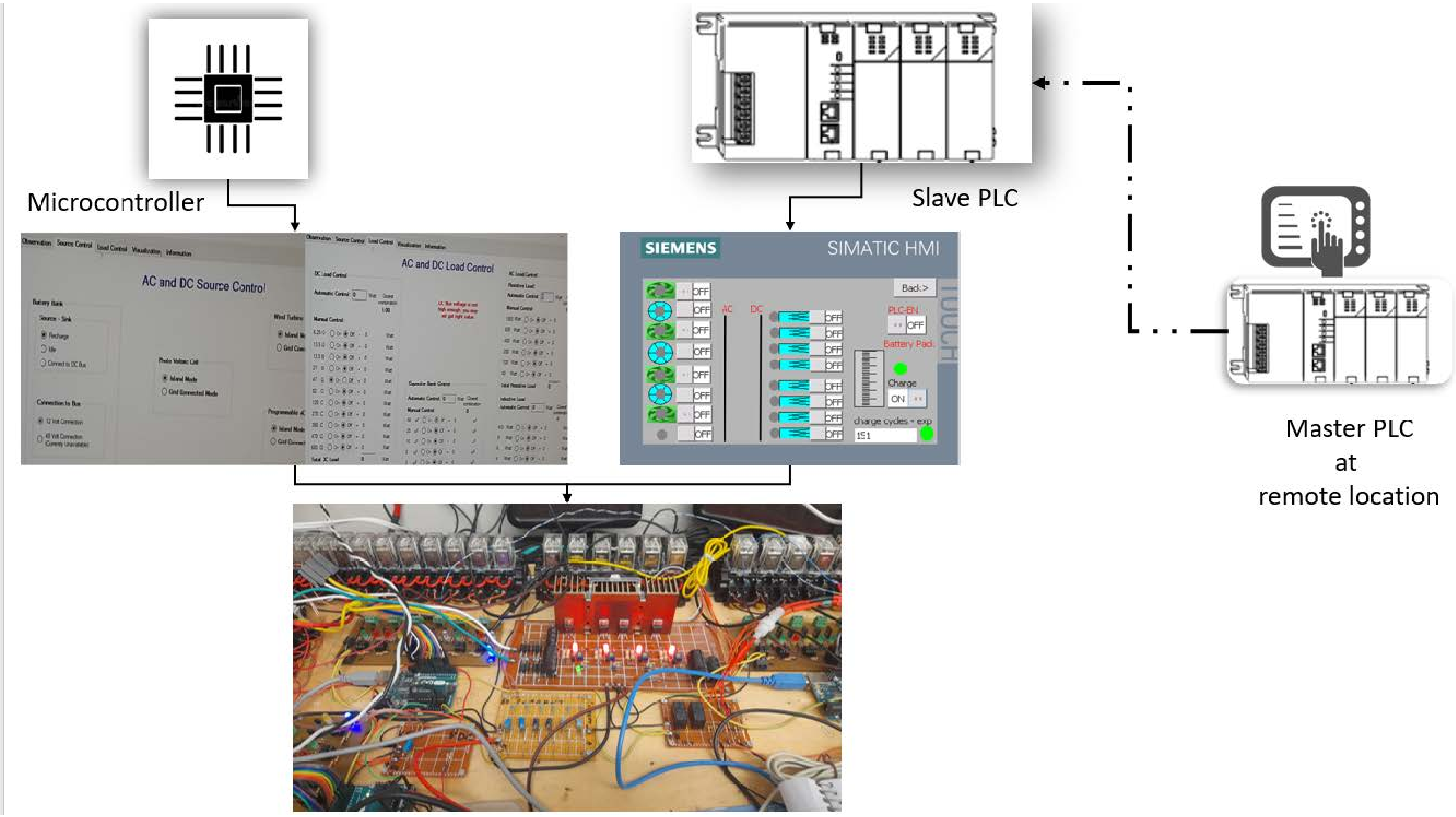




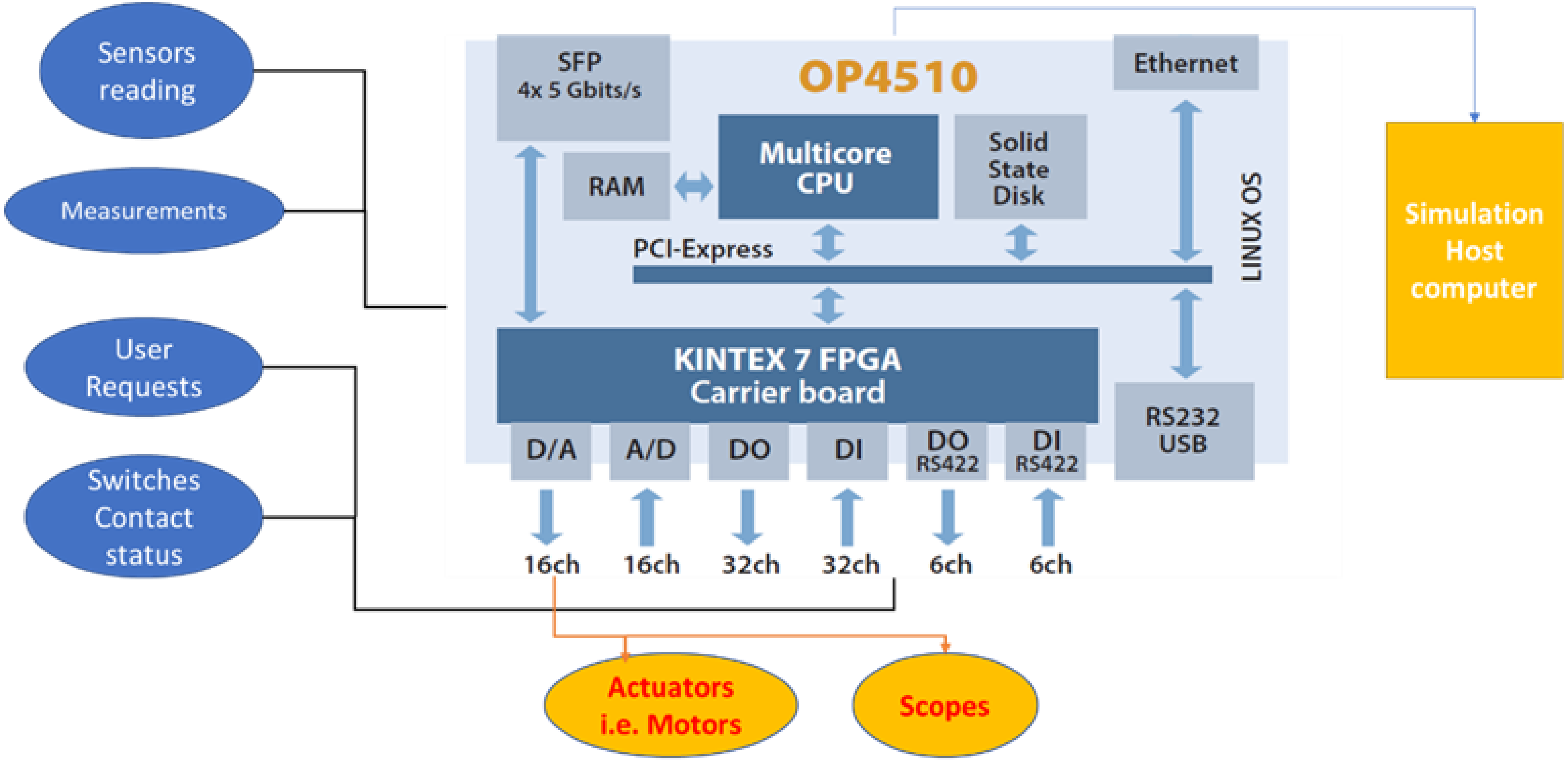
Integrated Modeling & Simulation for Smart Energy-Water-Food-Health-Transportation Grids Planning, Control, and Optimization



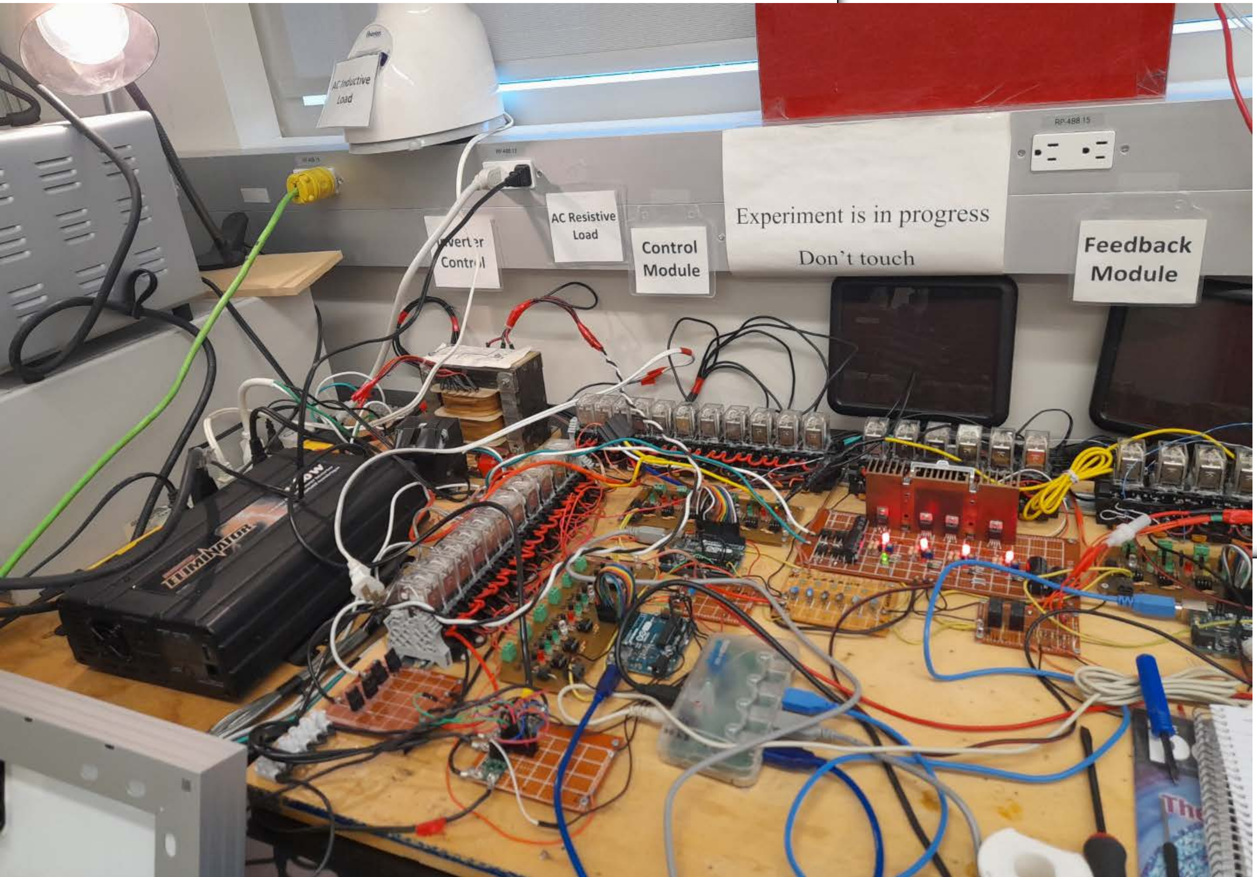
The Resilient Design of the Microgrid

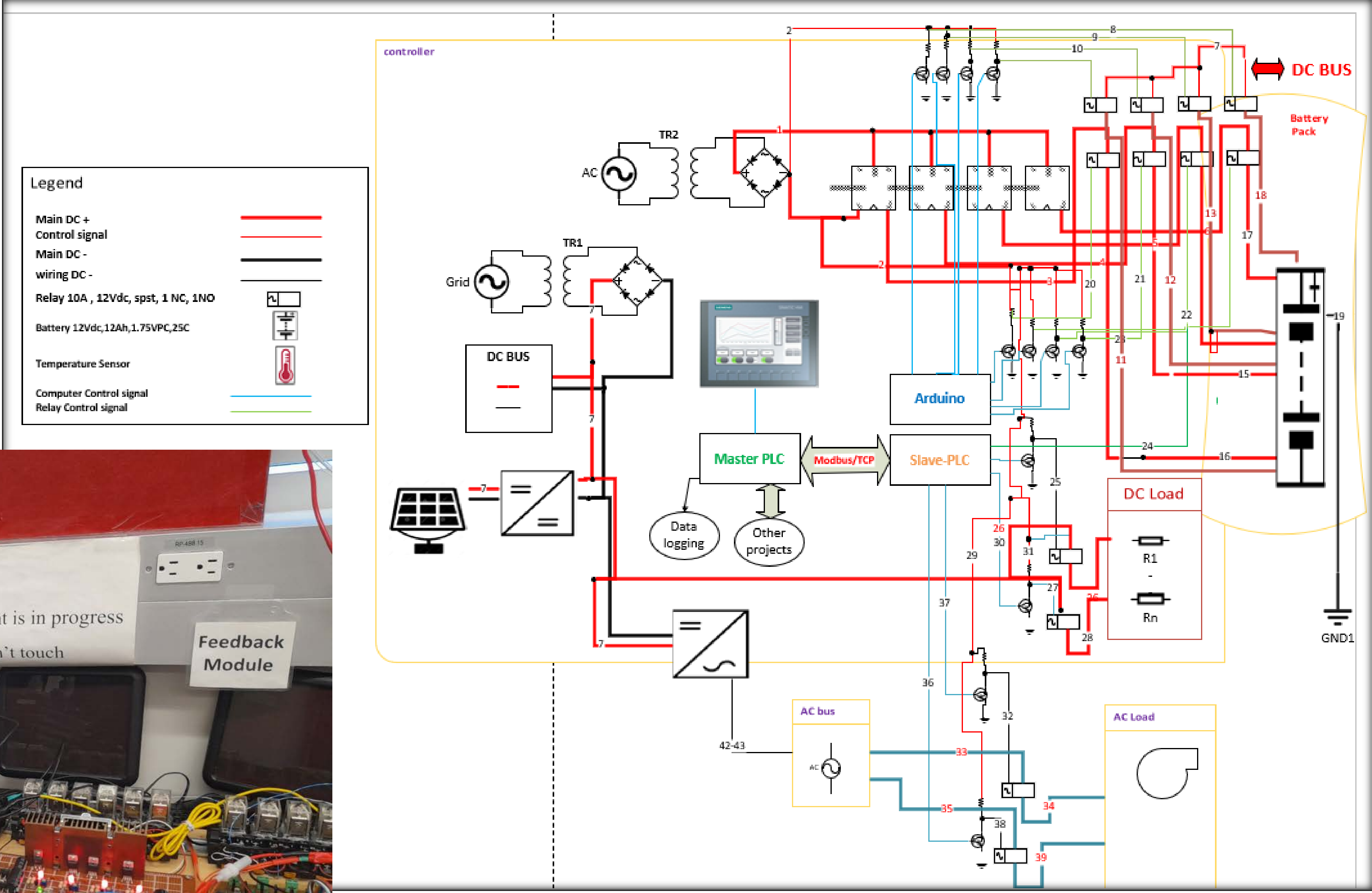


Real-time Co-simulation for Microgrid Applications



Lab Demonstration of Microgrid with FCS





H2VPRO – Novel Hydrogen Generation Technology

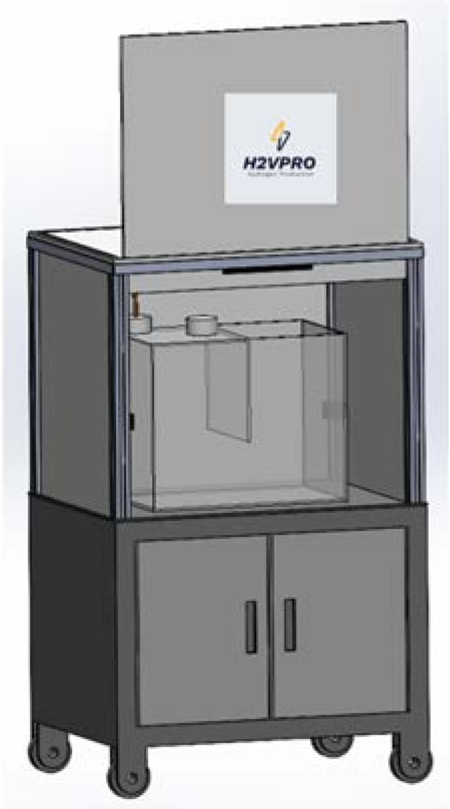
GPROSYS.COM
GPROSYS Green Production Systems (GPROSYS) Corp.

H2VPRO Specification

Type	Alkaline Electrolysis
Dimension	$30 \times 40 \times 50\ cm$
Electrode	Ni 99.9%
Electrical input	Voltage 3.6 V Current 10.8 A
H_2 Purity	99.5%
Temperature/Pressure	Ambient (22oC)/Atmospheric
Efficiency	94.3%

H2VPRO Productivity

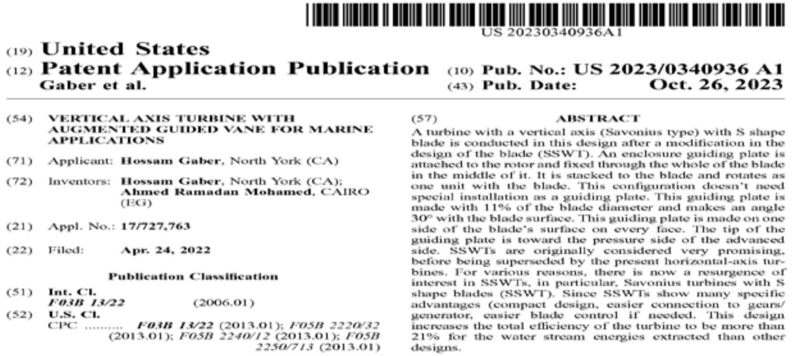
Consumed Power W	H_2 mL/min	H_2 kg/hr.	H_2 kg/day	H_2 kg/year
39	71	0.0004	0.0085	3.1174



Key Features & Summary Description of SSWT

GPROSYS.COM
GPROSYS Green Production Systems (GPROSYS) Corp.

- This patent is concerned with the ability to install a vertical axis turbine as a hydrokinetic turbine on both the board of maritime transports and shoreline infrastructures. The patent is establishing a new Savonius turbine with a vertical axis concept S shape water turbine (SSWT), which consists of a simple design with higher efficiency at low wind and water speeds than other turbines. In addition, this design presents a compact size, self-starting, ease of installation and maintenance, and independence concerning water flow direction.


US 20230340936A1

(19) United States
(12) Patent Application Publication
Gaber et al.

(10) Pub. No.: US 2023/0340936 A1
(43) Pub. Date: Oct. 26, 2023

(54) VERTICAL AXIS TURBINE WITH AUGMENTED GUIDED VANE FOR MARINE APPLICATIONS

(71) Applicant: **Hossam Gaber**, North York (CA)

(72) Inventors: **Hossam Gaber**, North York (CA); **Ahmed Ramadan Mohamed**, CAIRO (EG)

(21) Appl. No.: 17/727,763

(22) Filed: Apr. 24, 2022

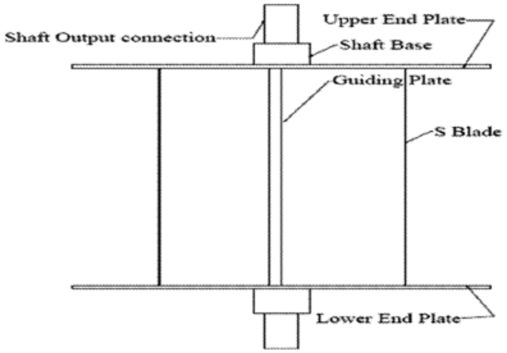
Publication Classification

(51) Int. Cl.
F03B 13/22 (2006.01)

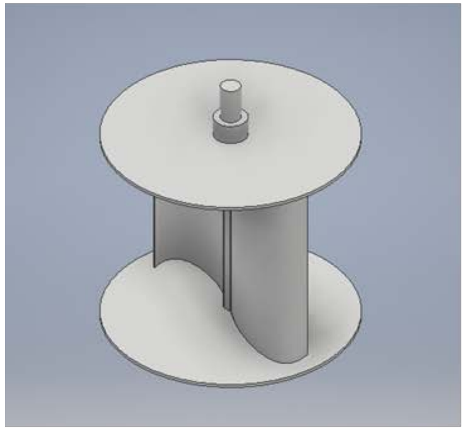
(52) U.S. Cl.
CPC *F03B 13/22* (2013.01); *F05B 2220/32* (2013.01); *F05B 2240/12* (2013.01); *F05B 2250/713* (2013.01)

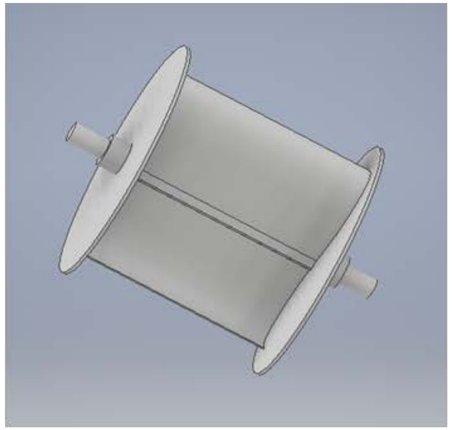
(57) **ABSTRACT**

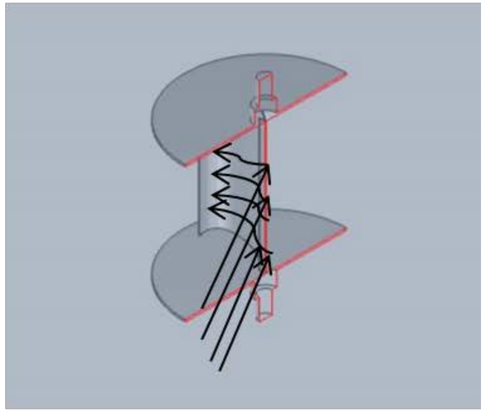
A turbine with a vertical axis (Savonius type) with S shape blade is conducted in this design after a modification in the design of the blade (SSWT). An enclosure guiding plate is attached to the rotor and fixed through the whole of the blade in the middle of it. It is stacked to the blade and rotates as one unit with the blade. This configuration doesn't need special installation as a guiding plate. This guiding plate is made with 11% of the blade diameter and makes an angle 30° with the blade surface. This guiding plate is made on one side of the blade's surface on every face. The tip of the guiding plate is toward the pressure side of the advanced side. SSWTs are originally considered very promising, before being superseded by the present horizontal-axis turbines. For various reasons, there is now a resurgence of interest in SSWTs, in particular, Savonius turbines with S shape blades (SSWT). Since SSWTs show many specific advantages (compact design, easier connection to gears/generator, easier blade control if needed. This design increases the total efficiency of the turbine to be more than 21% for the water stream energies extracted than other designs.

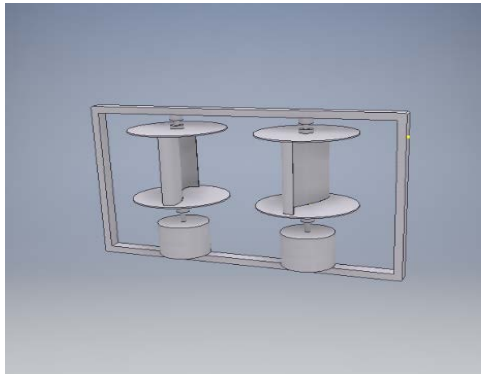


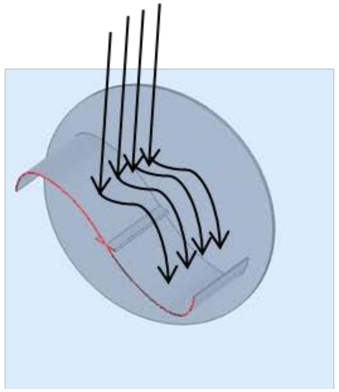
2D Item Components for SSWT

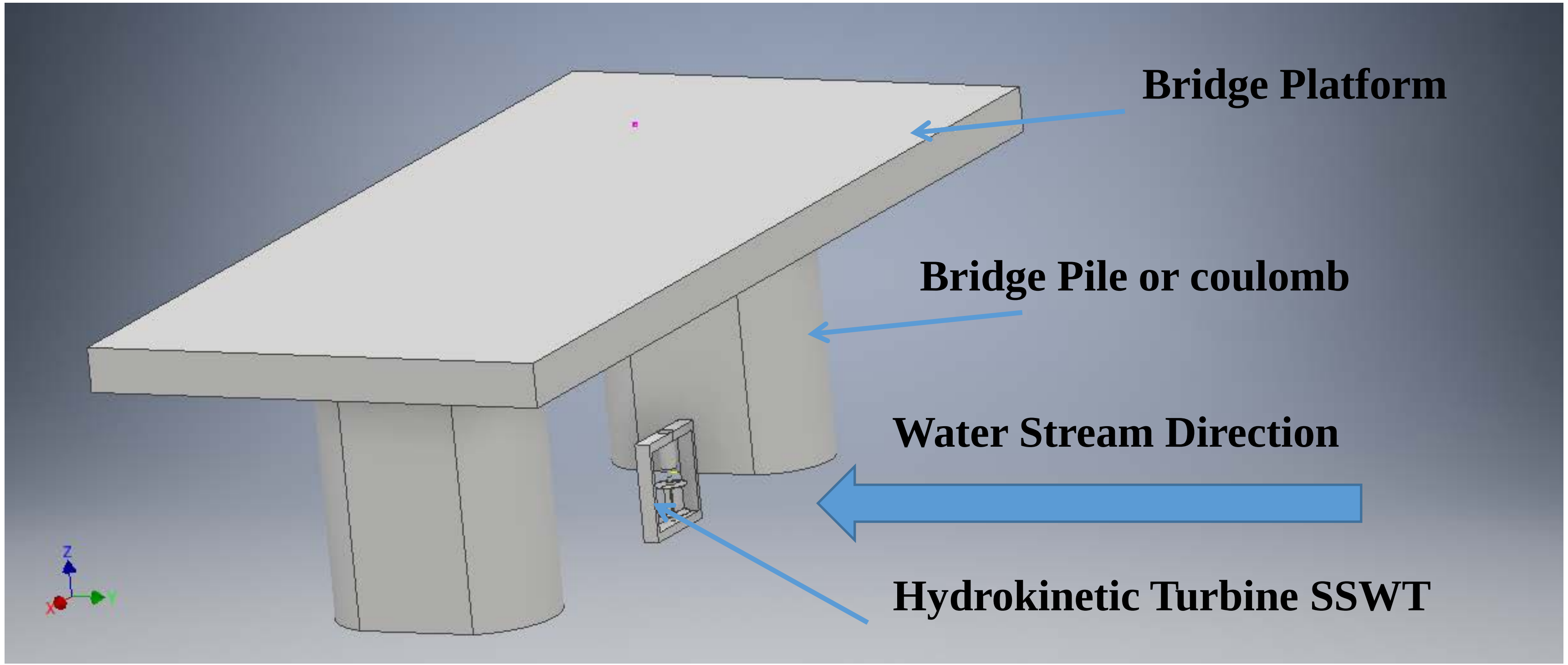




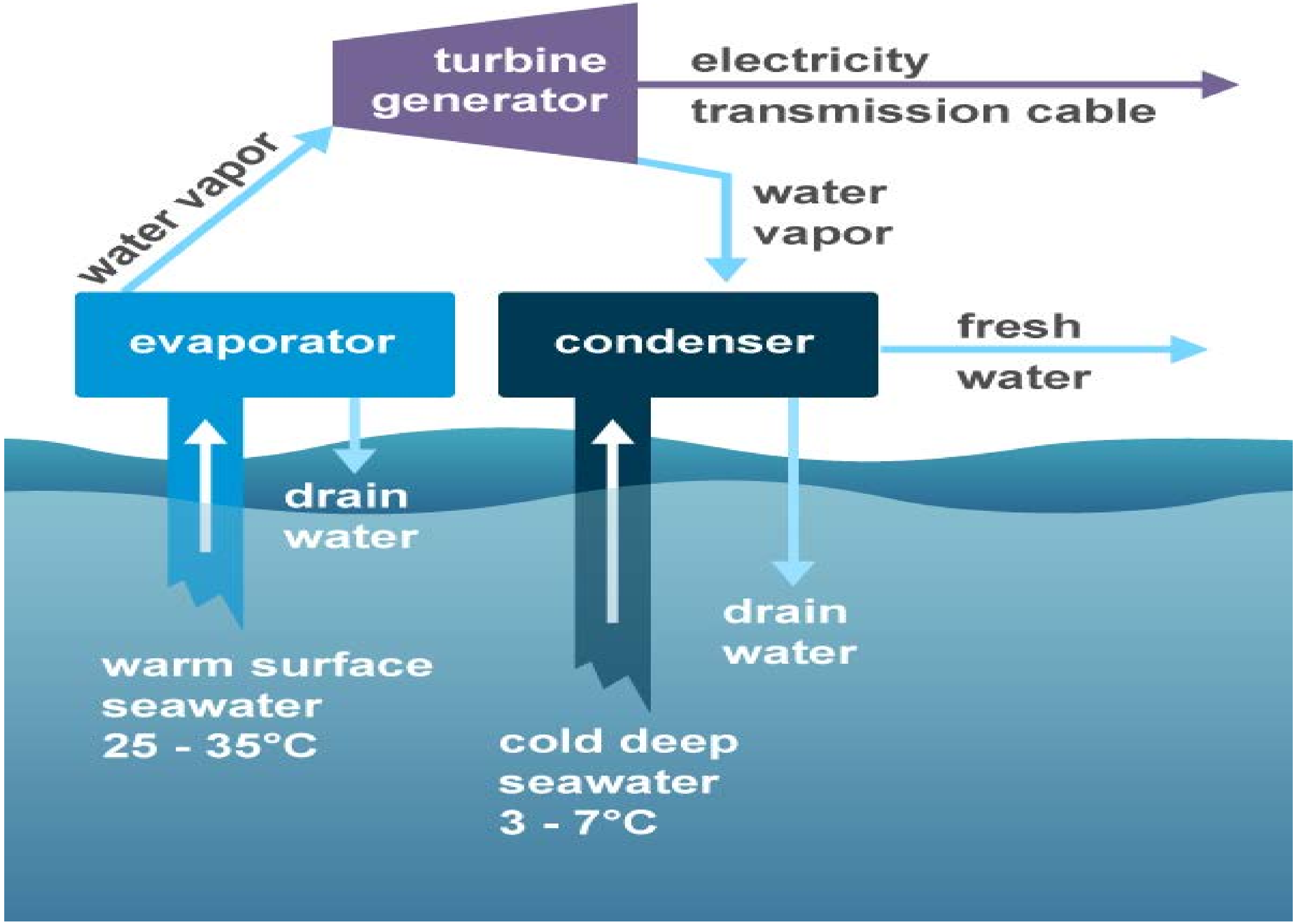






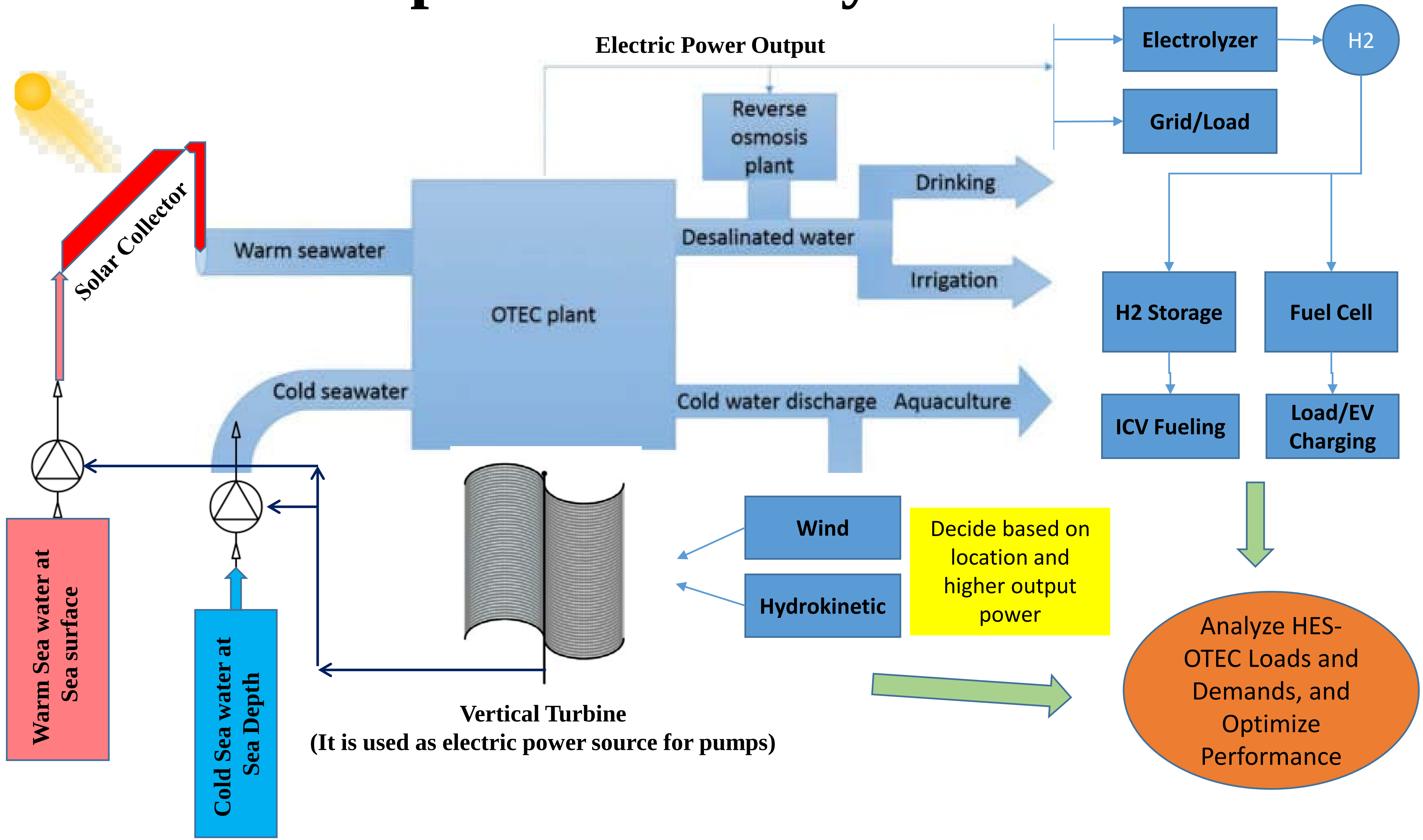

Bridge Platform
Bridge Pile or coulomb
Water Stream Direction
Hydrokinetic Turbine SSWT

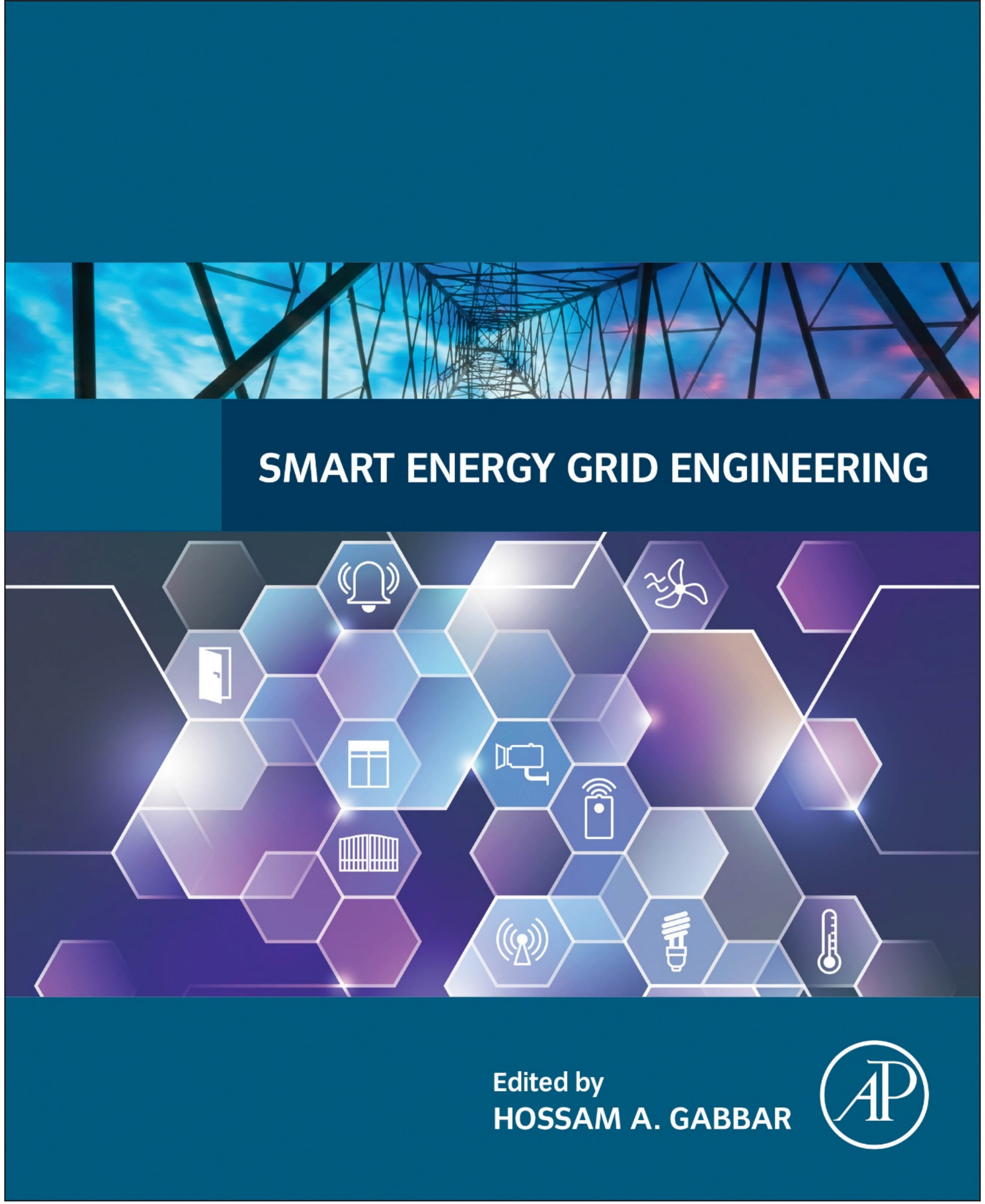
The Conventional OTEC System



https://www.eia.gov/energyexplained/hydropower/ocean-thermal-energy-conversion.php

The Proposed OTEC System





UNIVERSITY OF ONTARIO INSTITUTE OF TECHNOLOGY OSHAWA | CANADA

Energy Safety and Control Lab

- IEEE SEGE: http://sege-conference.com/index.html
- Smart Energy Grid Engineering Book: http://store.elsevier.com/Smart-Energy-Grid-Engineering/Hossam-Gabbar/isbn-9780128053430/

IEEE Press Series on Systems Science and Engineering

MengChu Zhou, Series Editor

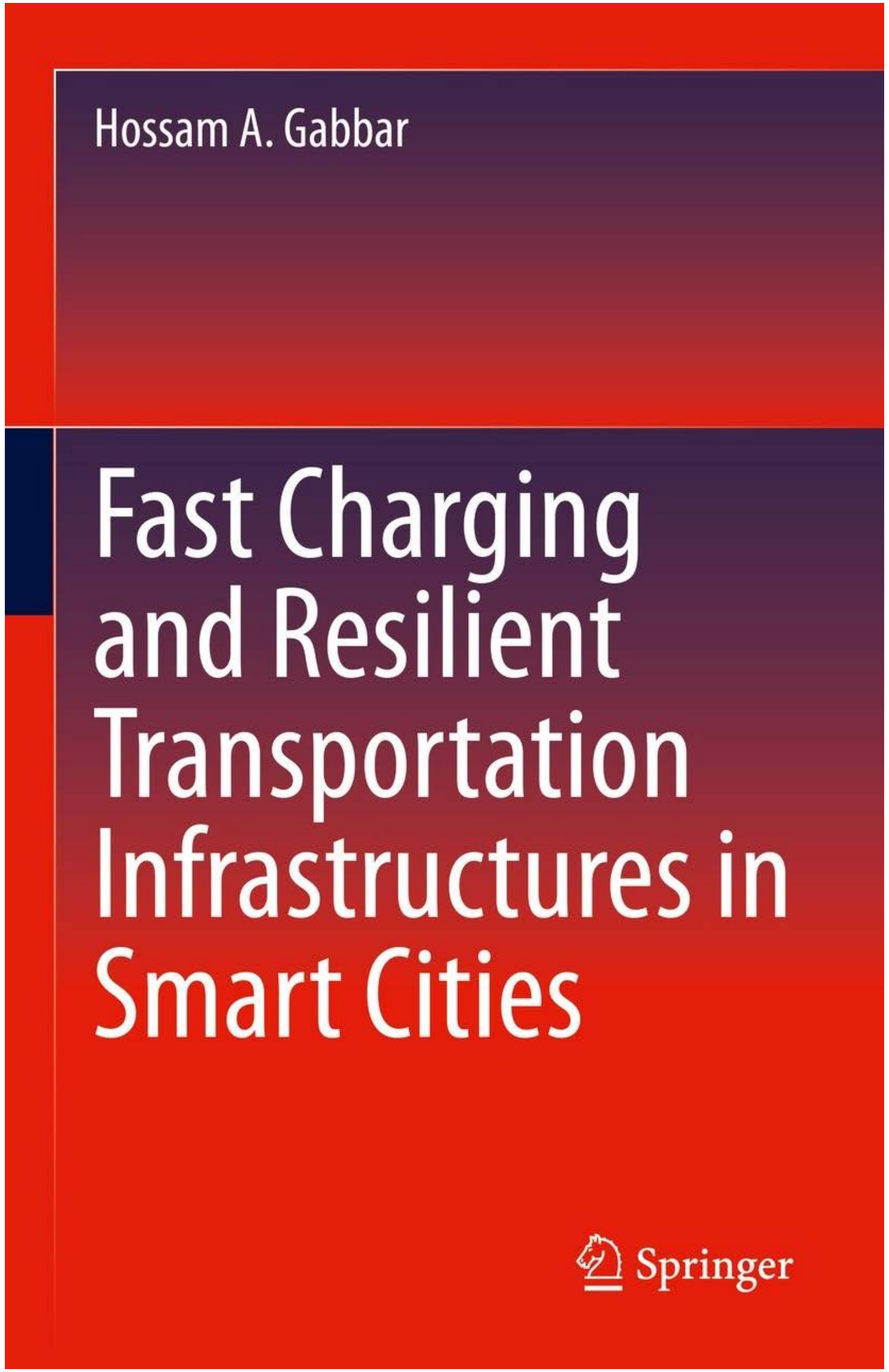
Energy Conservation in Residential, Commercial, and Industrial Facilities

Hossam A. Gabbar

IEEE PRESS

WILEY

ISBN: 978-3-031-09500-9



SEGE

HOME ABOUT SEGE CALL FOR PAPERS FOR AUTHORS HISTORY CONTACT
SPANS

the 12th

SEGE 2024

Ontario Tech University
Oshawa, Canada

August 18-20, 2024

2024 IEEE the 12th International Conference on Smart Energy Grid Engineering

Welcome Message

It is our great pleasure to invite you to join our International Conference on Smart Energy Grid Engineering (SEGE), which is sponsored by Toronto Section NPS Chapter and hosted by Ontario Tech University. This event will provide unique opportunity to have fruitful discussions about smart energy grid infrastructures, technologies, engineering design methods, and best practices that address industrial challenges. The event includes large number of speakers and quality papers that cover energy generation, transmission and distribution infrastructures, energy storage, electrification, information and communications, and security. 2023 11th International Conference on Smart Energy Grid Engineering will be held during **August 13-15** in 2023. We look forward to welcoming you at **Ontario Tech University, Oshawa, Canada.**

Dr. Hossam Gabbar
Founder and General Chair of IEEE SEGE
Ontario Tech University
Oshawa, Ontario, Canada

Hosted by

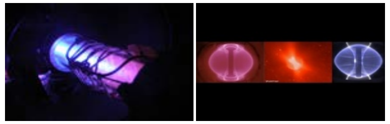
OntarioTech UNIVERSITY

Sponsored by

IEEE Advancing Technology for Humanity — TORONTO Section est. 1903

IEEE PES Power & Energy Society®

Thank You



UNIVERSITY OF ONTARIO
INSTITUTE OF TECHNOLOGY
OSHAWA | CANADA

APEL
Advanced Plasma Engineering Laboratory

Advanced Plasma Engineering Lab

OntarioTech UNIVERSITY

Smart Energy Systems Lab

S L E S