Collaborative Energy Conservation in a Microgrid

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KBFSC

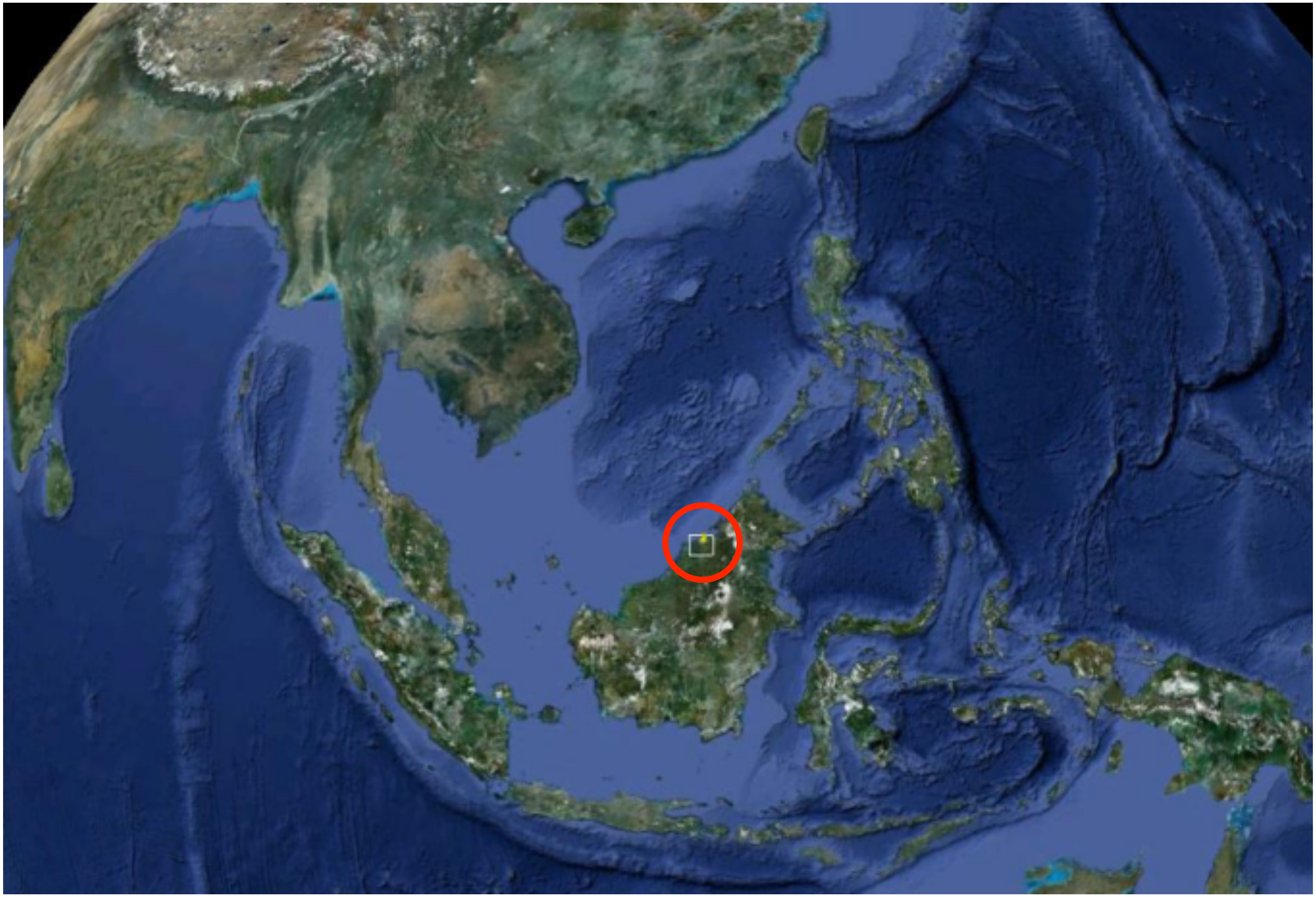
Kuala Belalong Field Studies Centre

In Brunei, a country in SE Asia, close to Malaysia

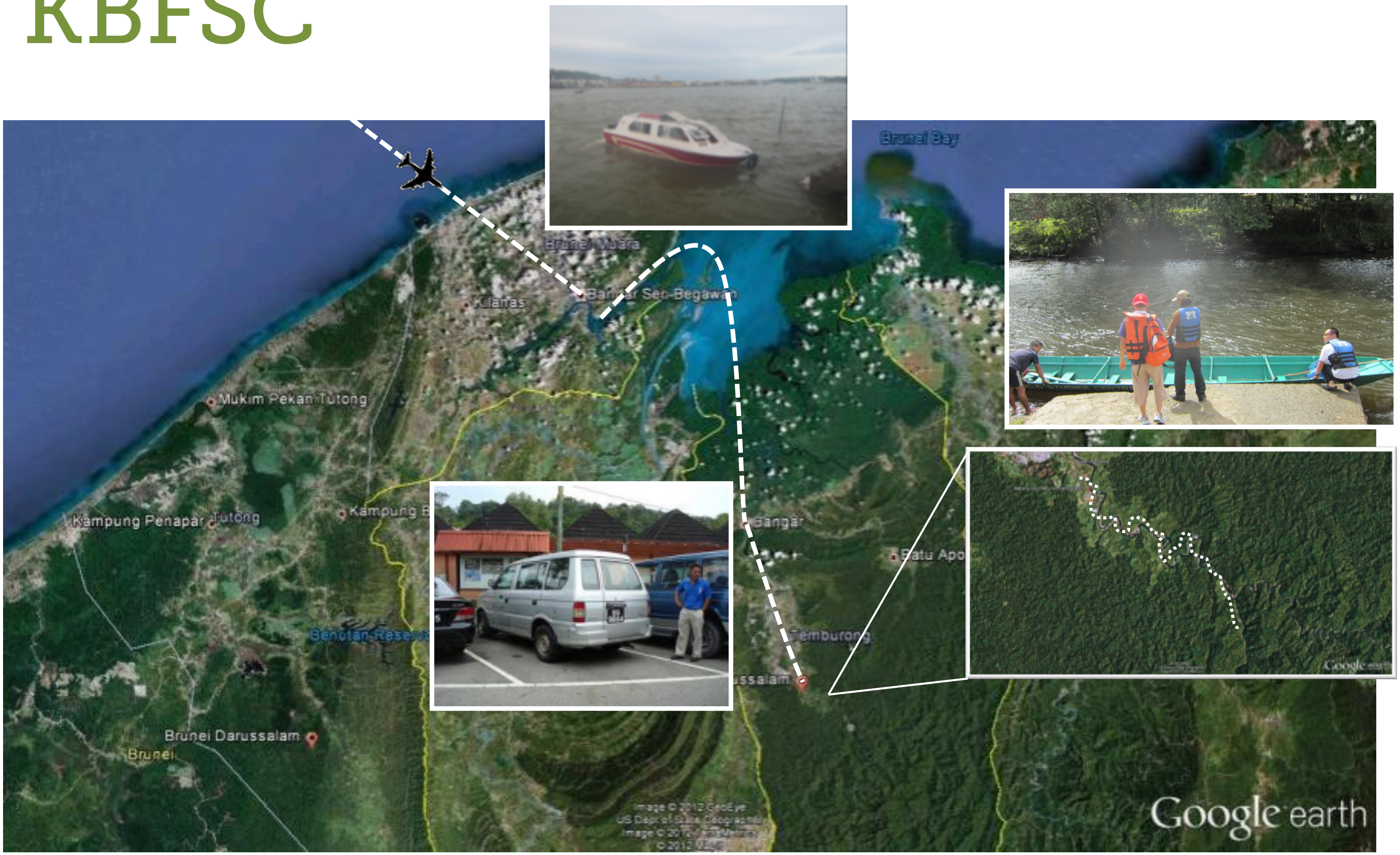
A research centre located in a tropical evergreen rainforest

Visited by biologists and ecologists from all over the world.

KBFSC



KBFSC



India → Bandar Seri Begawan → Bangar → Temburong → KBFSC

1 day of travel with 4 different modes of transportation

State-of-the-art

40 occupants (30 researchers+10 staff)

Primary Appliances: lights, fans

Secondary Appliances: dryer, washer, heater, lab equipment

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No direct grid connection

3 diesel generators (DG) for 5 buildings

DG hours: 6-9am and 4-11pm (~10 hrs)

DG consumption: ~30 L/day

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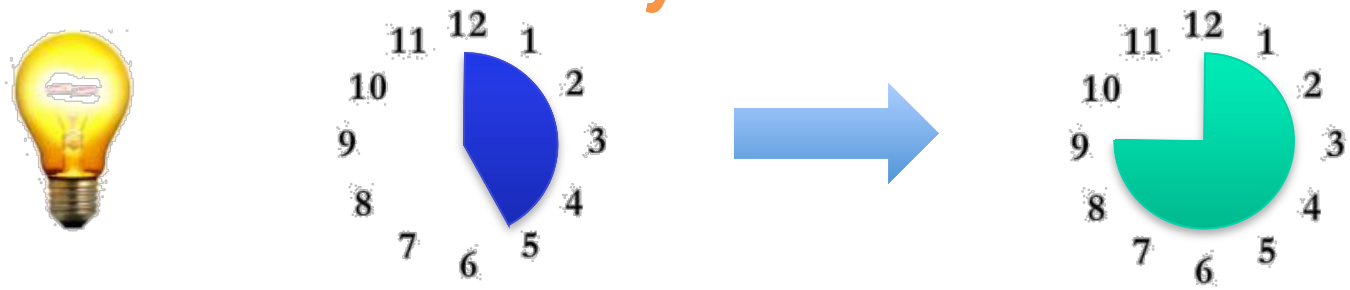
Transporting diesel is difficult

Objective

Increase Power Availability



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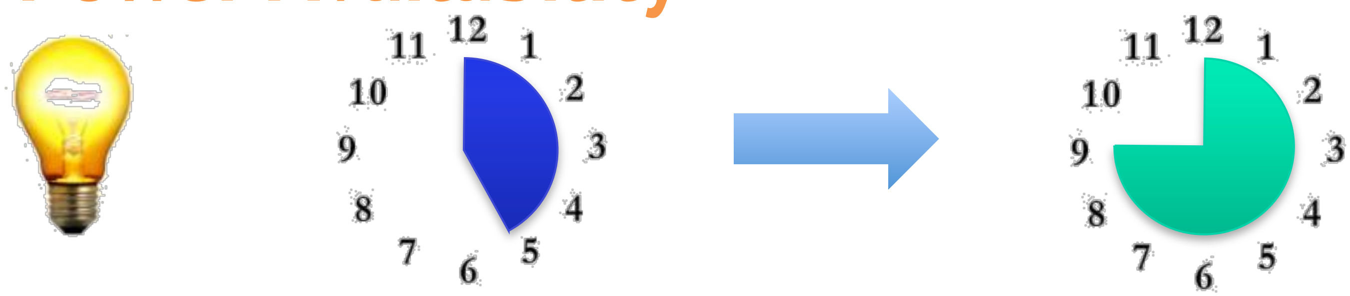
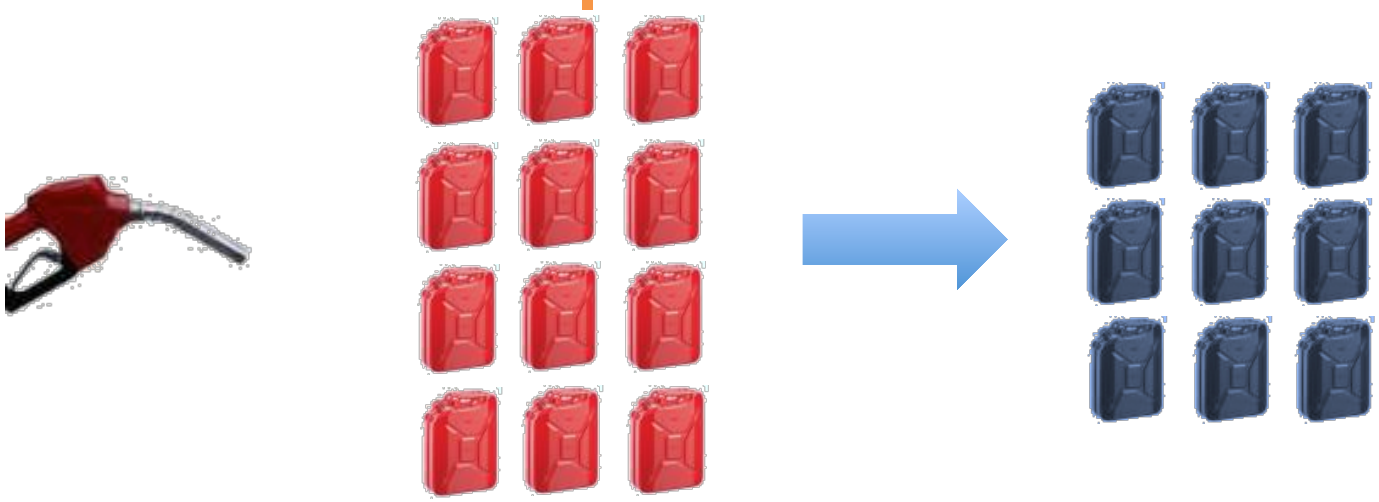


Reduce Diesel Consumption



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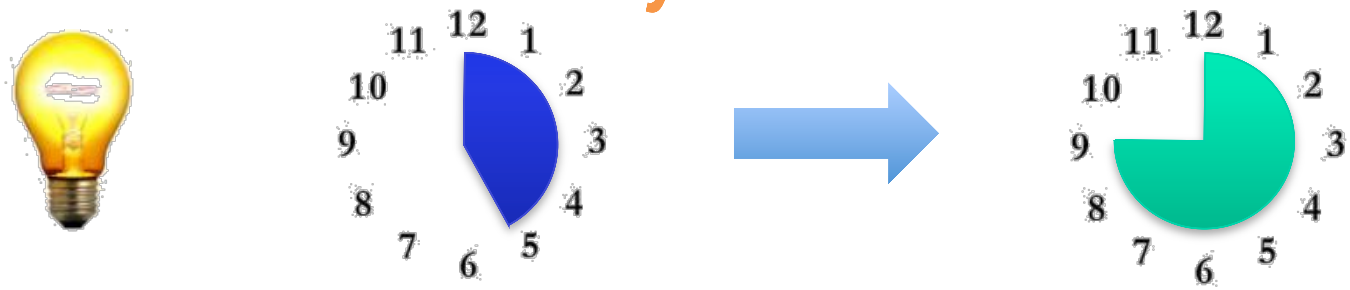

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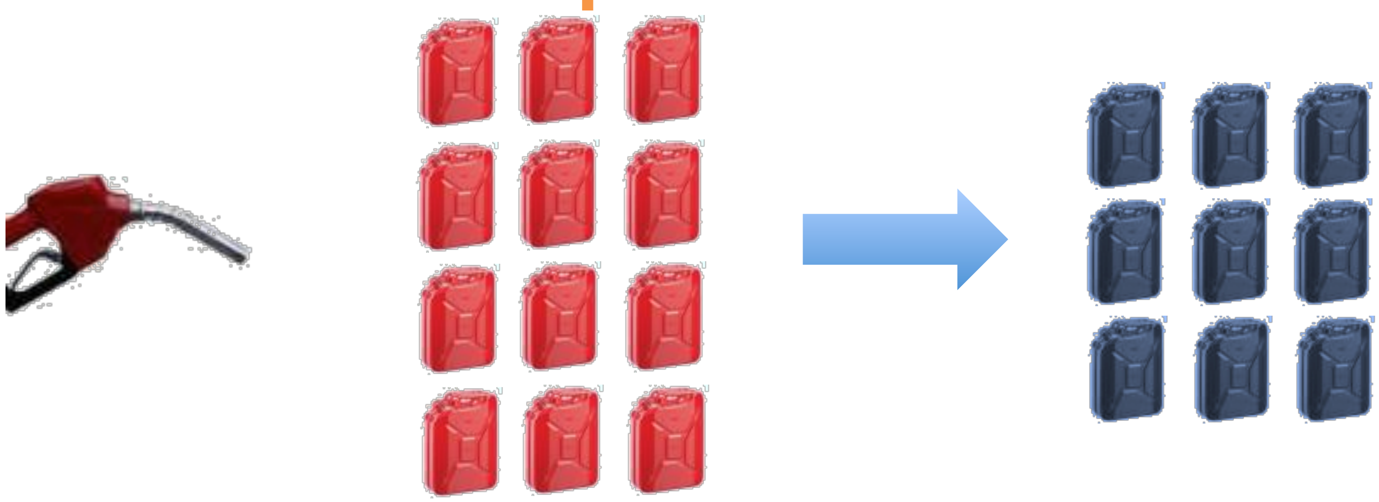


Minimize Visitor Inconvenience

Further Constraints

Wind speed **too low**

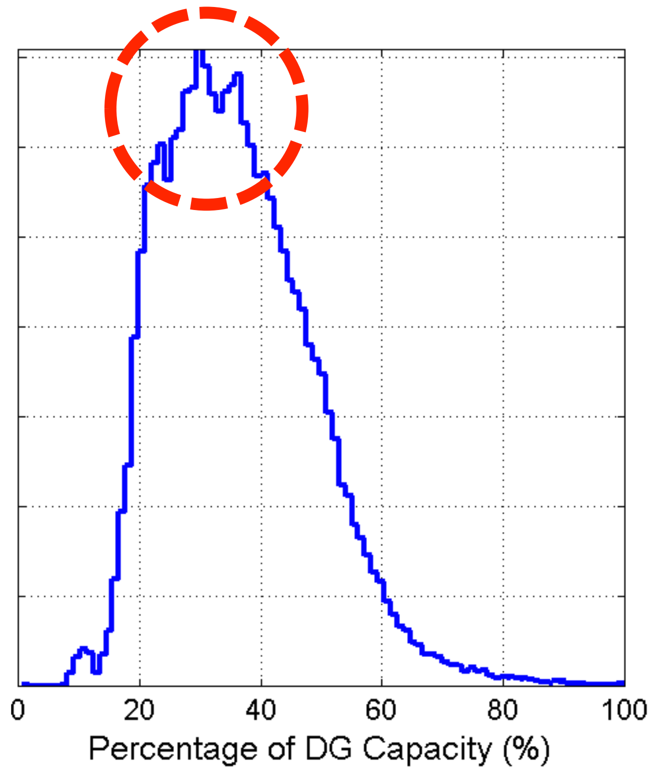
Only about **1-2 hrs** of direct sunshine per day

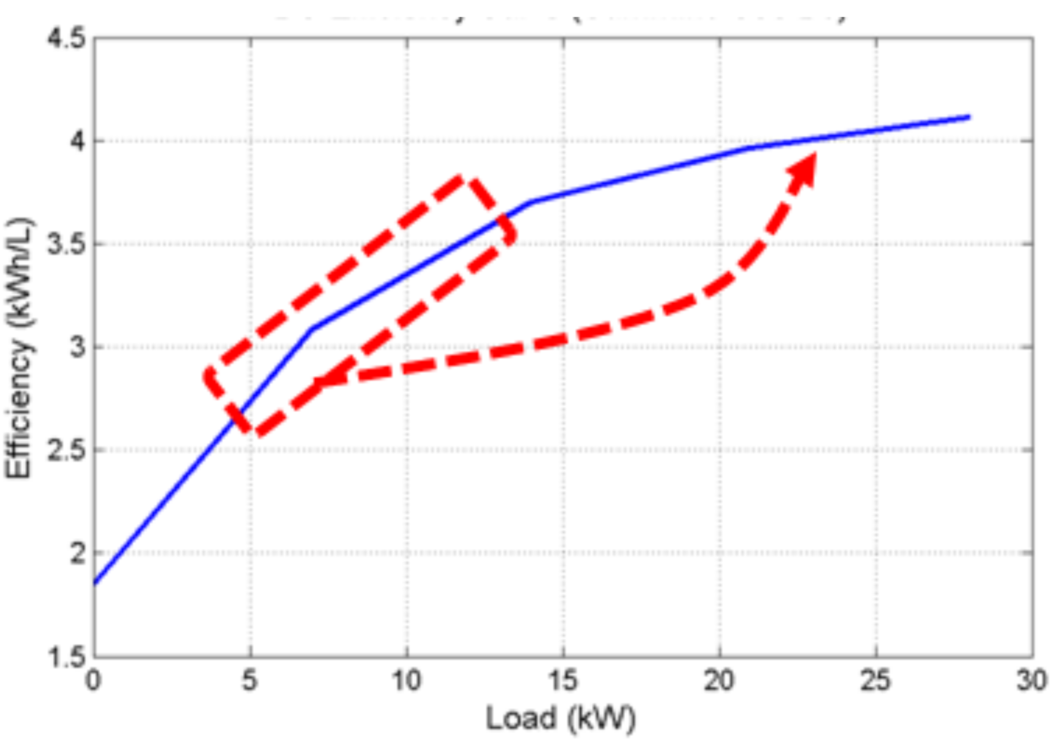
River **too shallow**

State-of-the-art Analysis

Underutilized DG

- Loaded to only 30% of its capacity
- DG fuel efficiency characteristics is non-linear
- At KBFSC, DG is sized for worst load





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Fixed (unrequired) DG hours

- DG being ON even with no (or small) loads
- Increasing DG hours can lead to inadvertent wastage, while decreasing DG hours can lead to visitor inconvenience

Inconvenient DG hours

No DG = No load (not even fans or lights)

Solution

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Battery bank

To supply power to small but convenience (*primary*) loads, such as lights and fans

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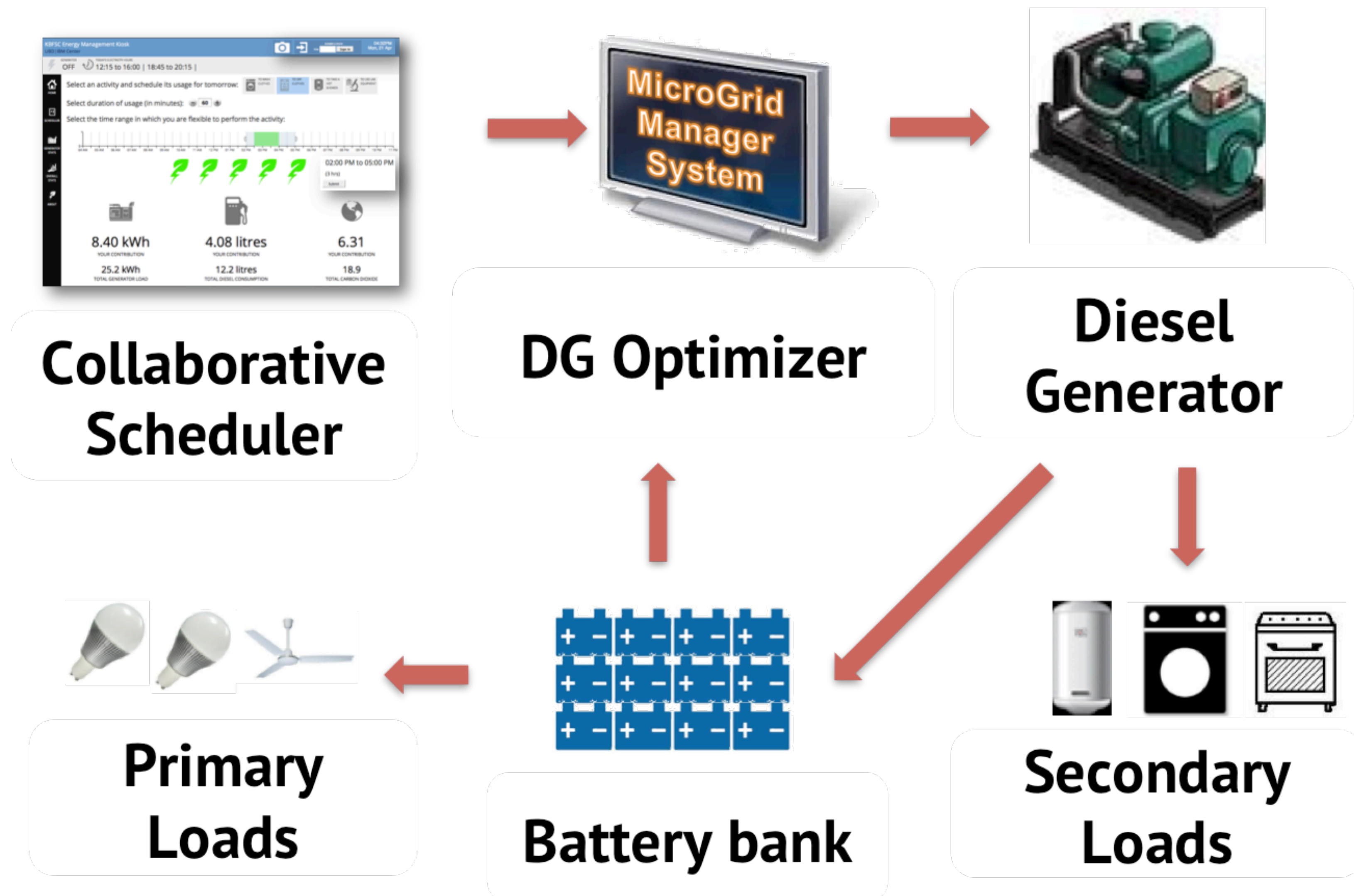
Provides visitor a UI to choose when they want to use a particular *secondary* appliance

DG Optimizer

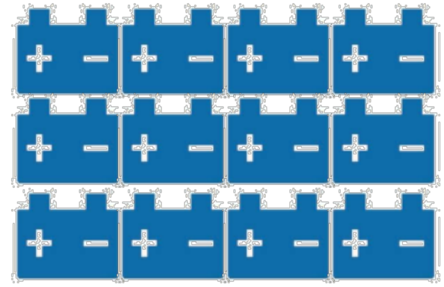
A software that uses load of secondary appliances and battery status, to suggest optimal DG hours

Solution



8.40 kWh
4.08 litres
6.31
25.2 kWh
12.2 litres
18.9
MicroGrid Manager System
Collaborative Scheduler
DG Optimizer
Diesel Generator
Primary Loads
Battery bank
Secondary Loads

I. Battery Bank



Supply power to small *primary loads*

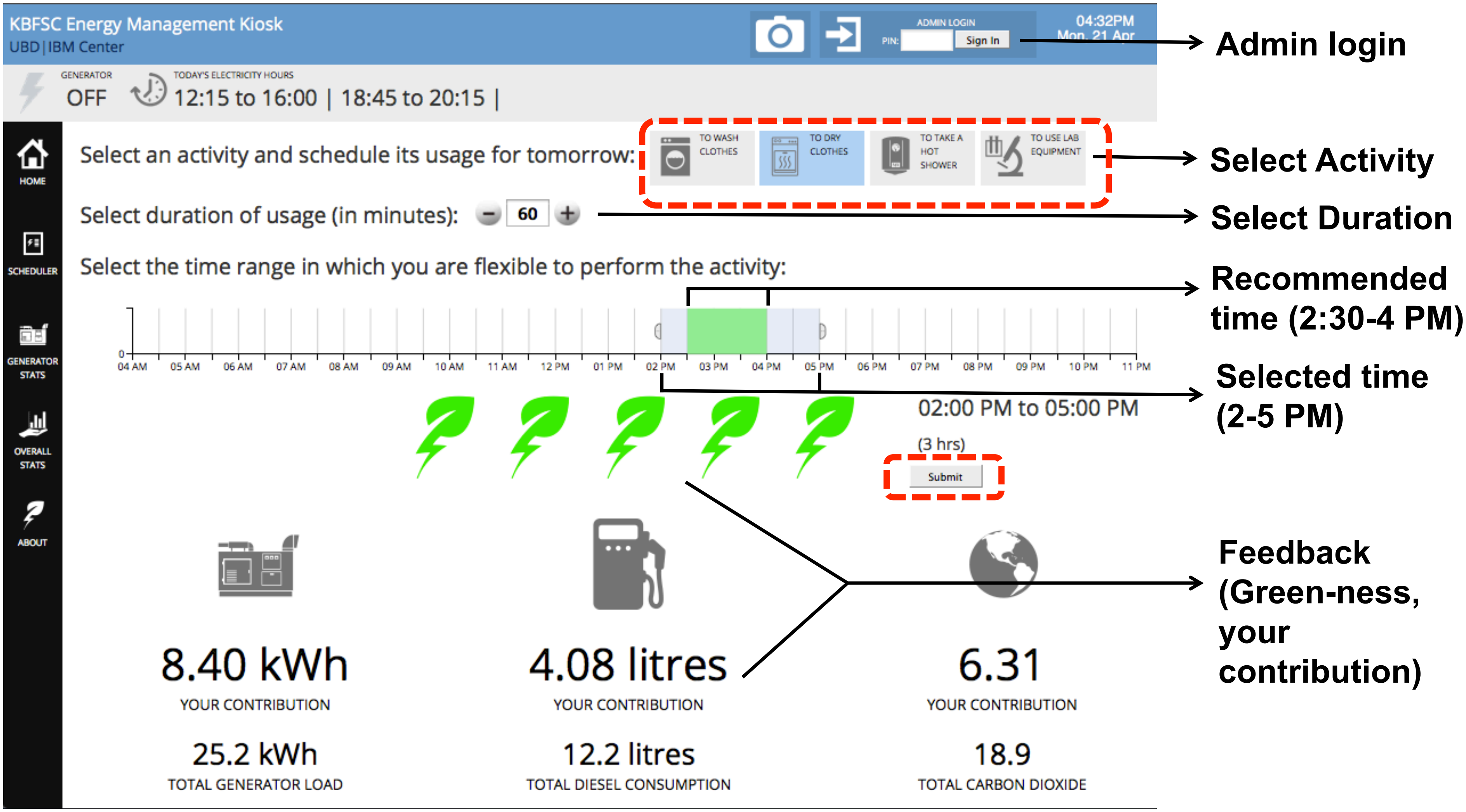
Lead acid batteries were deployed

Extra advantage:

High loaded DG is efficient

Battery bank can act as load aggregator

II. Collaborative Scheduler



Walk-up-and-use kiosk | Minimal interaction

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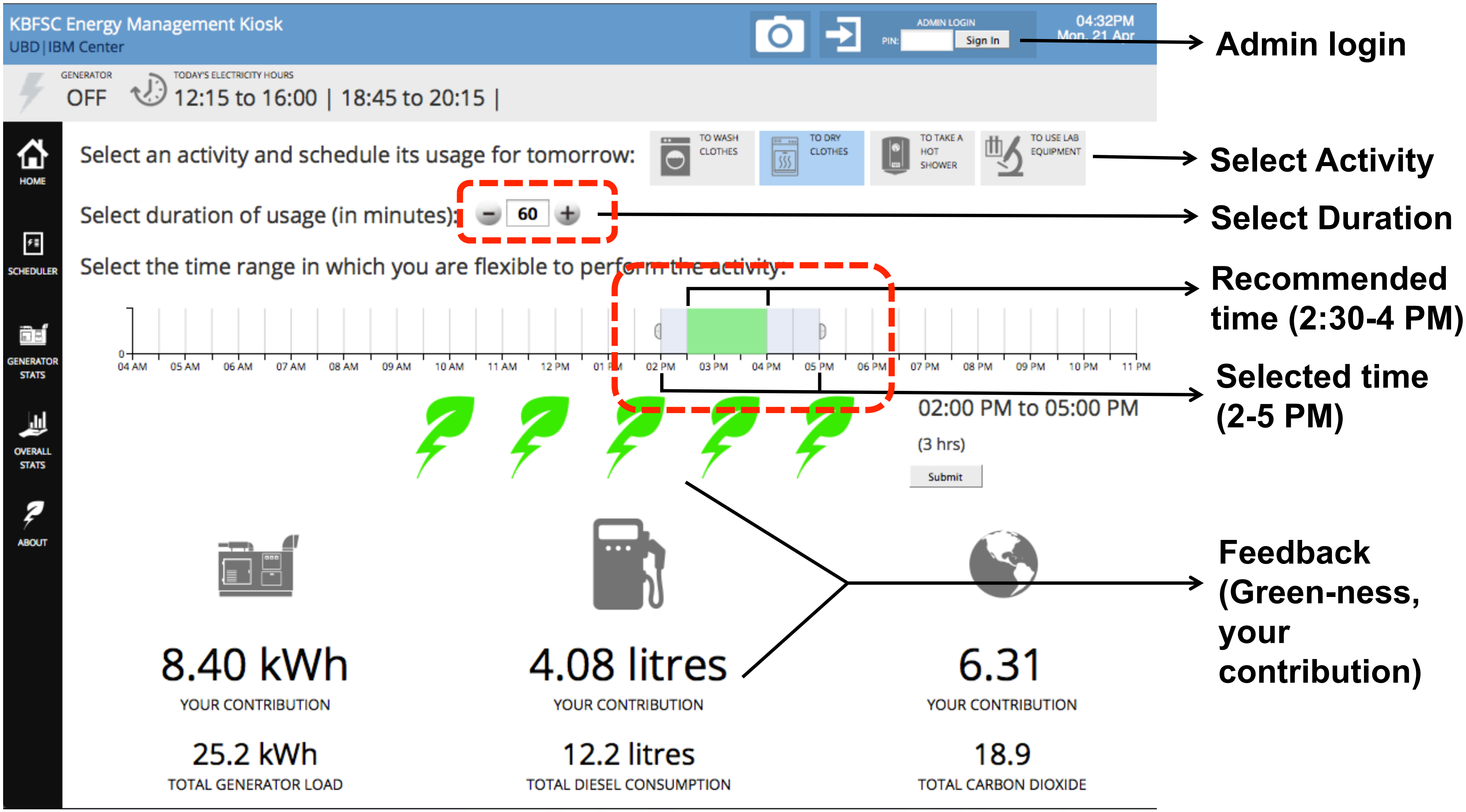
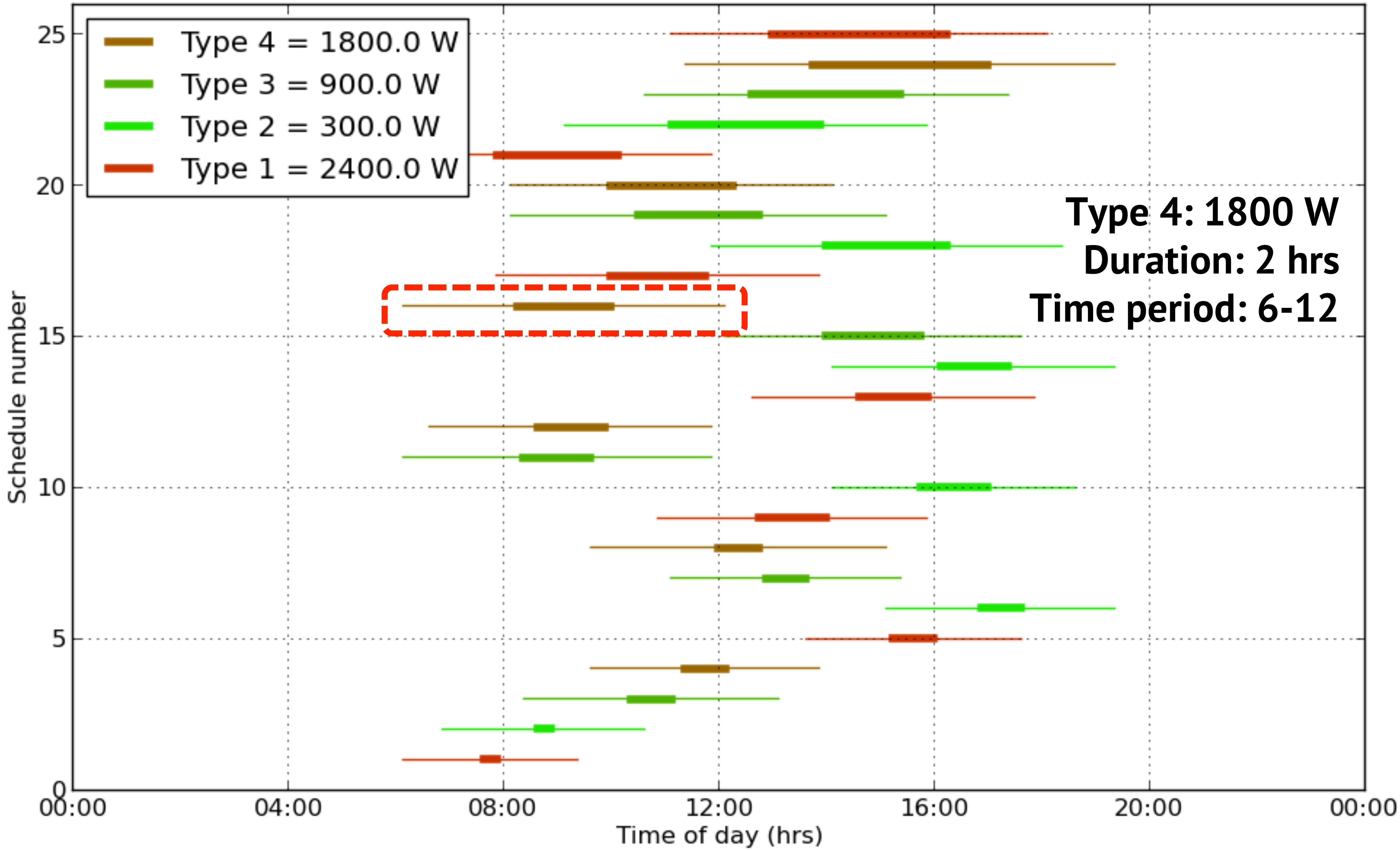


Walk-up-and-use kiosk | Minimal interaction | Minimal learning curve

II. Collaborative Scheduler



Type 4: 1800 W
Duration: 2 hrs
Time period: 6-12

III. DG Optimizer

Problem Schedule running time of each request
Compute DG running schedule

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Compute DG running schedule

Objective Minimize the diesel consumption

Input Scheduling requests

- power rating, usage duration, selected time period

Current battery charge level

III. DG Optimizer

Step 1: Schedule running time of each request

DG efficiency is highest when DG is loaded close to its capacity

Heuristic: Run as many appliance as possible, at any given time (Bin Packing problem).

a. Start with the most constrained appliance (with minimal padding between usage duration and selected time period).
b. Schedule successive appliances by maximizing the overlap with already scheduled appliances.

III. DG Optimizer

Step 2: Compute DG running schedule

Use the aggregate power profile generated in Step 1.

Objective function: $J = \sum_{1}^{N} u_i \left[F_B(c(i)) + F_S(i) + (1 - u_{i-1}) F_{start} \right]$

{0,1}
Binary decision at time i

Fuel usage by Battery

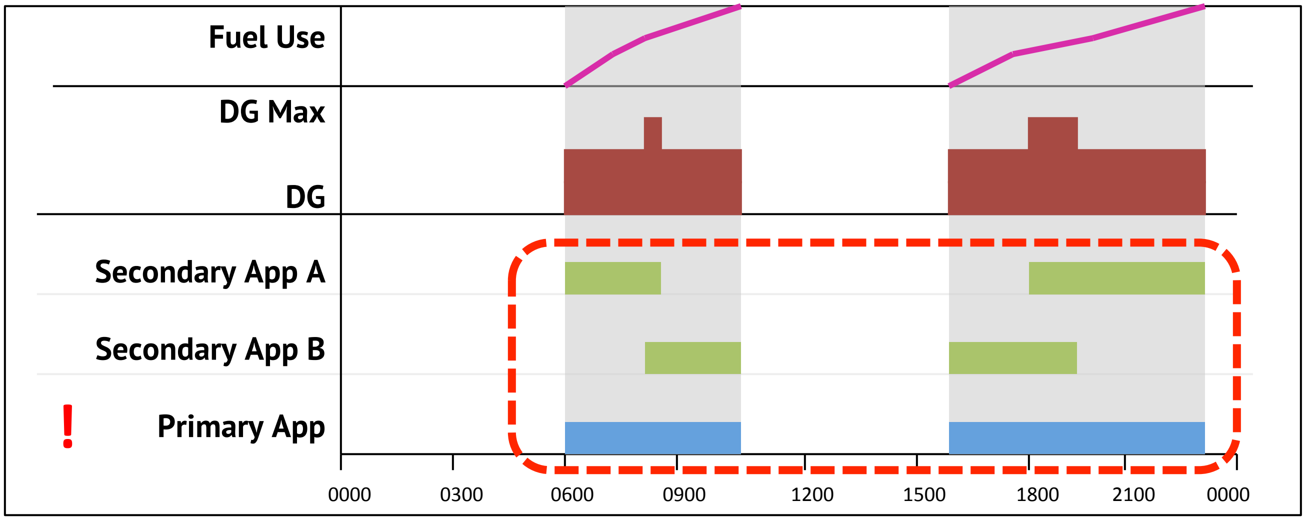
$c(i)$: State of battery charge at time i

Fuel usage by secondary appliances

Spool-up Cost

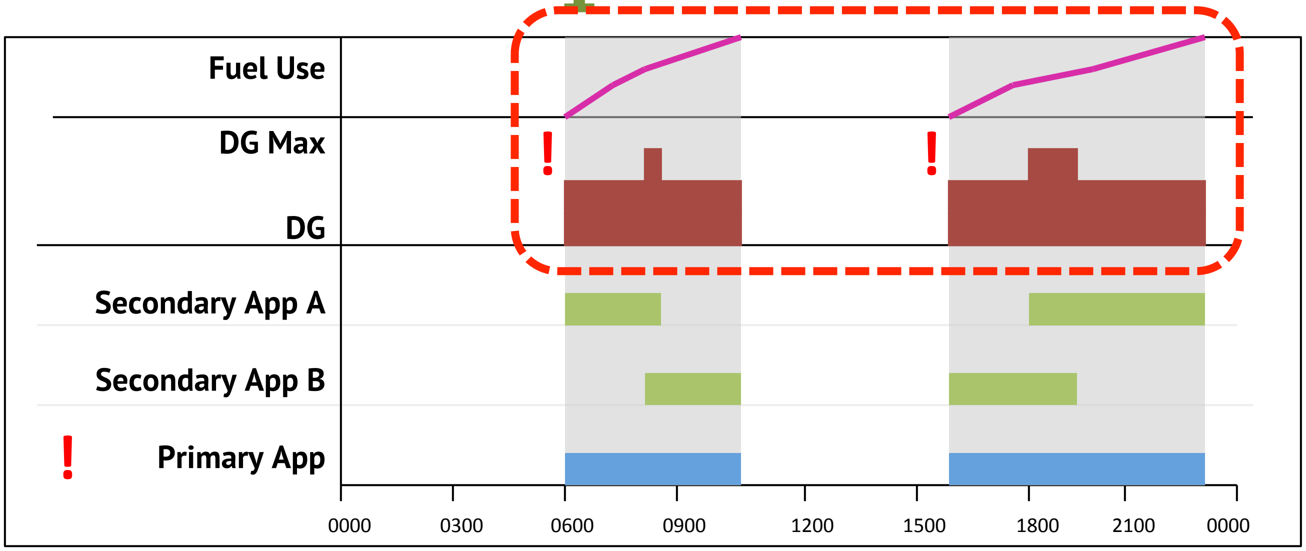
This formulation is solved using DP approach (full algorithm in paper)

III. DG Optimizer



Original Scenario

III. DG Optimizer



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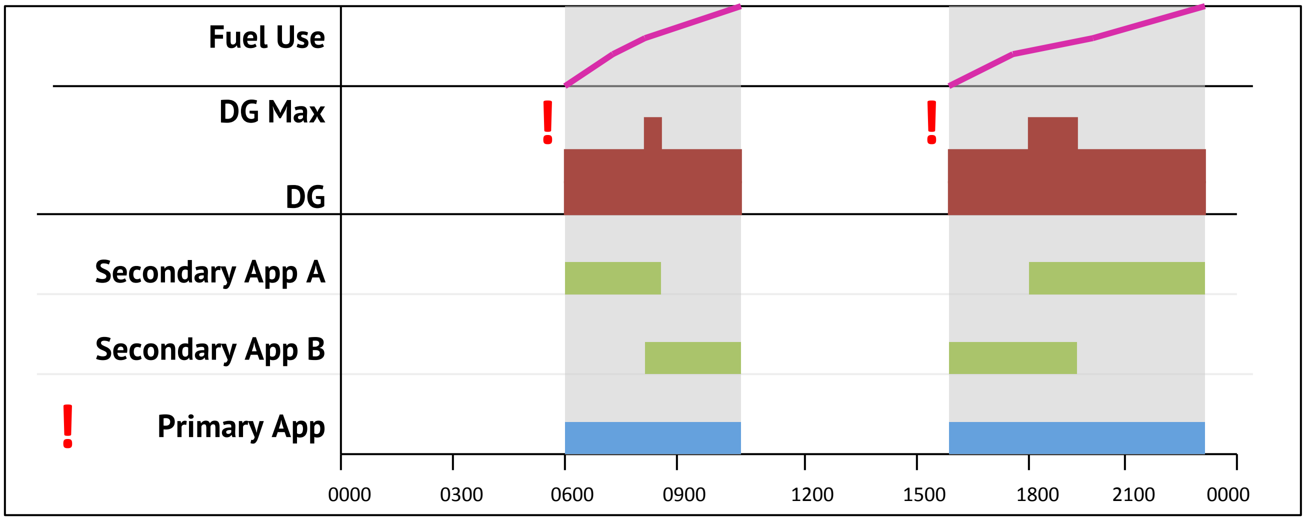

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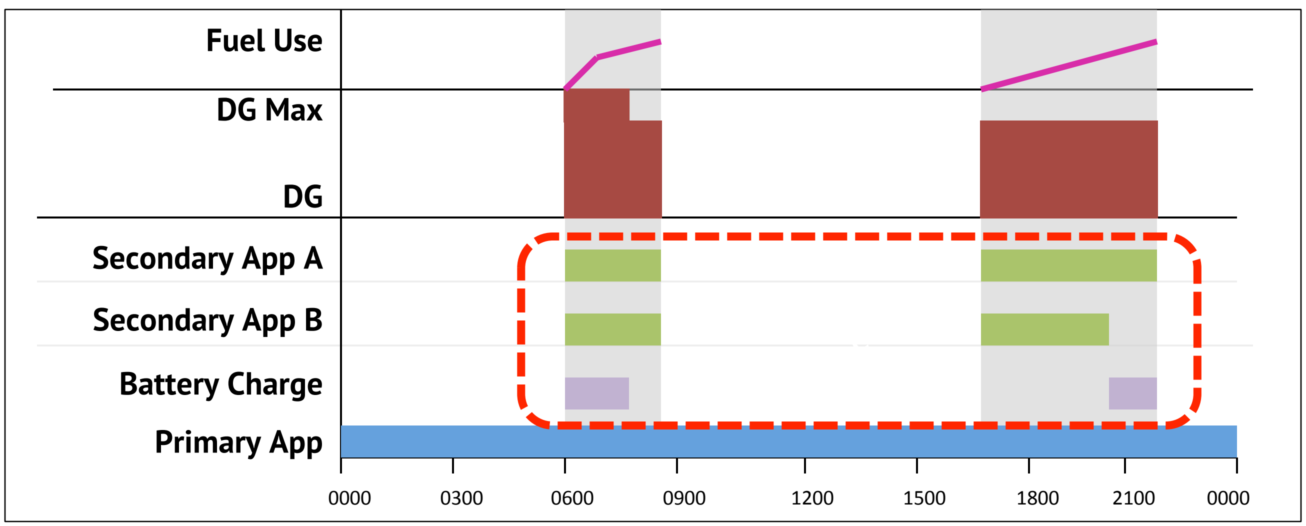

Altered Scenario

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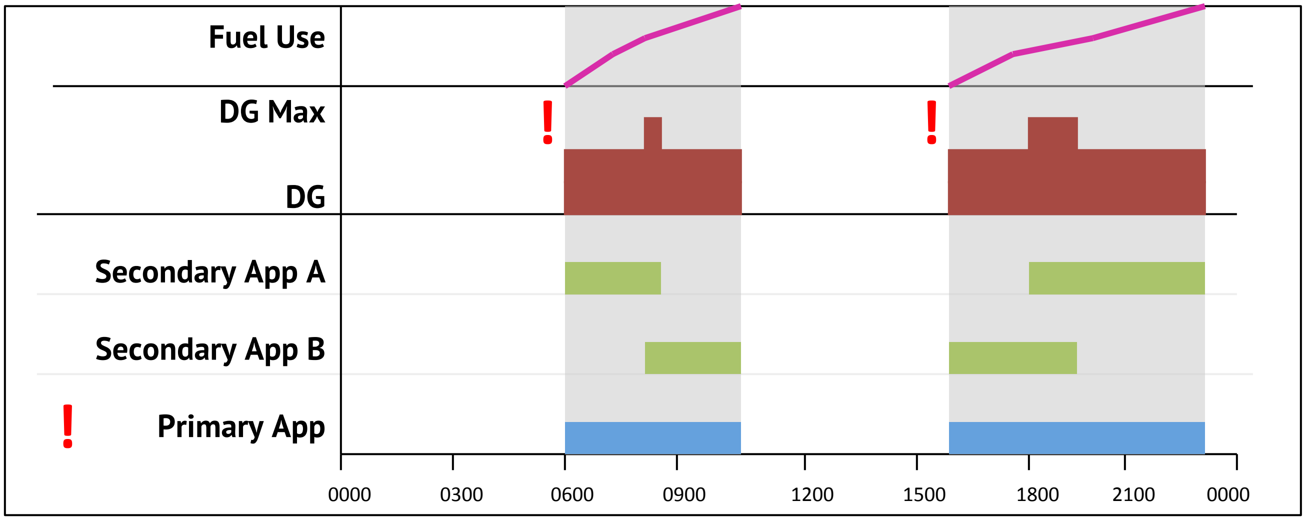

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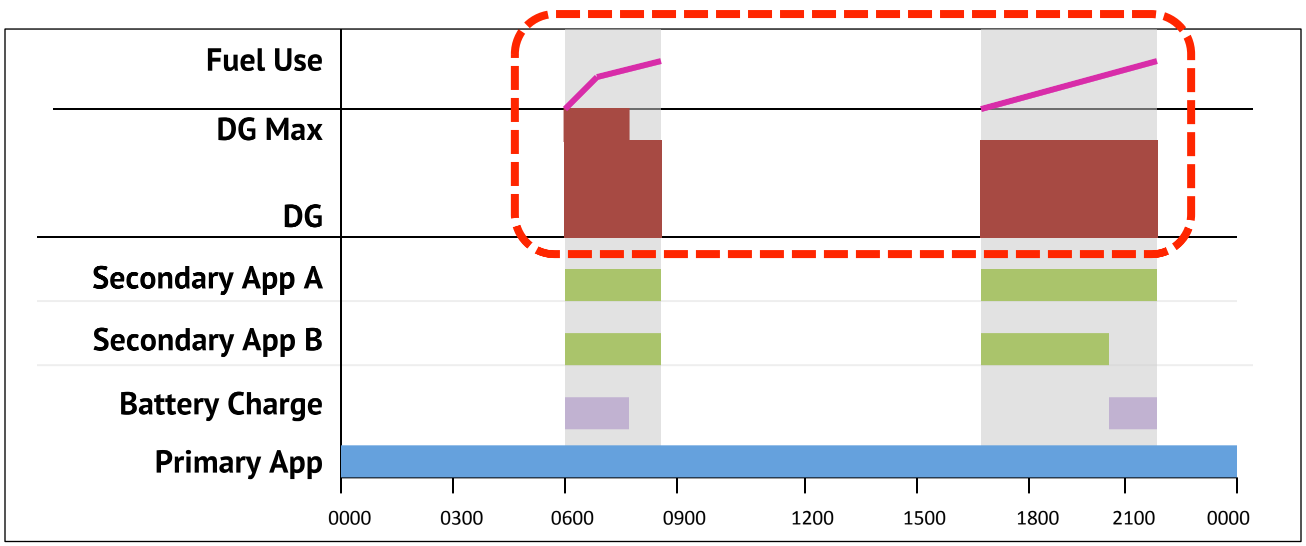

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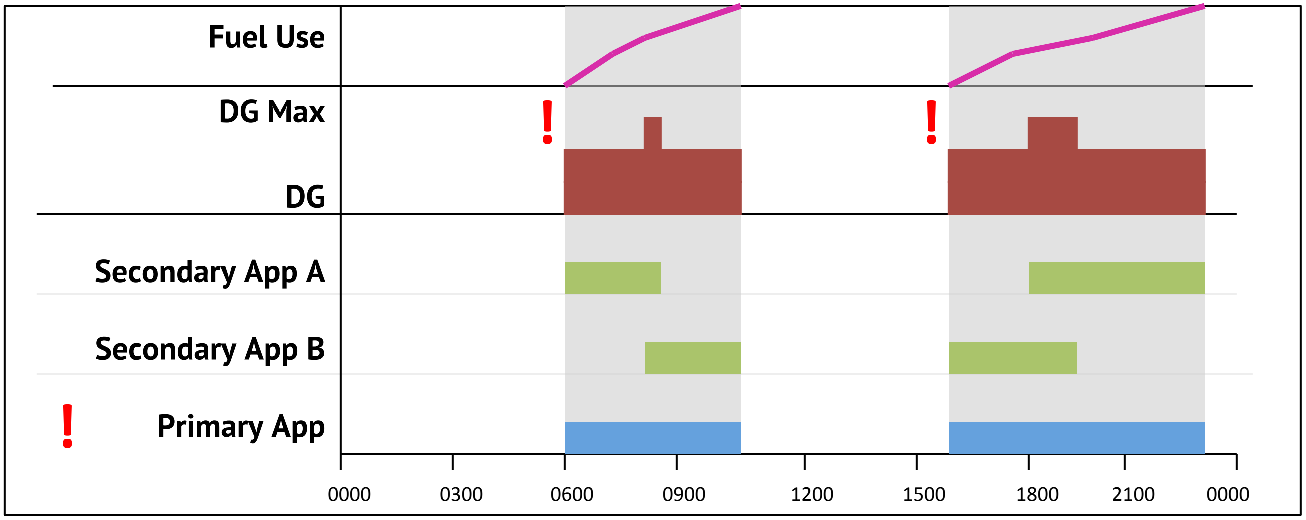

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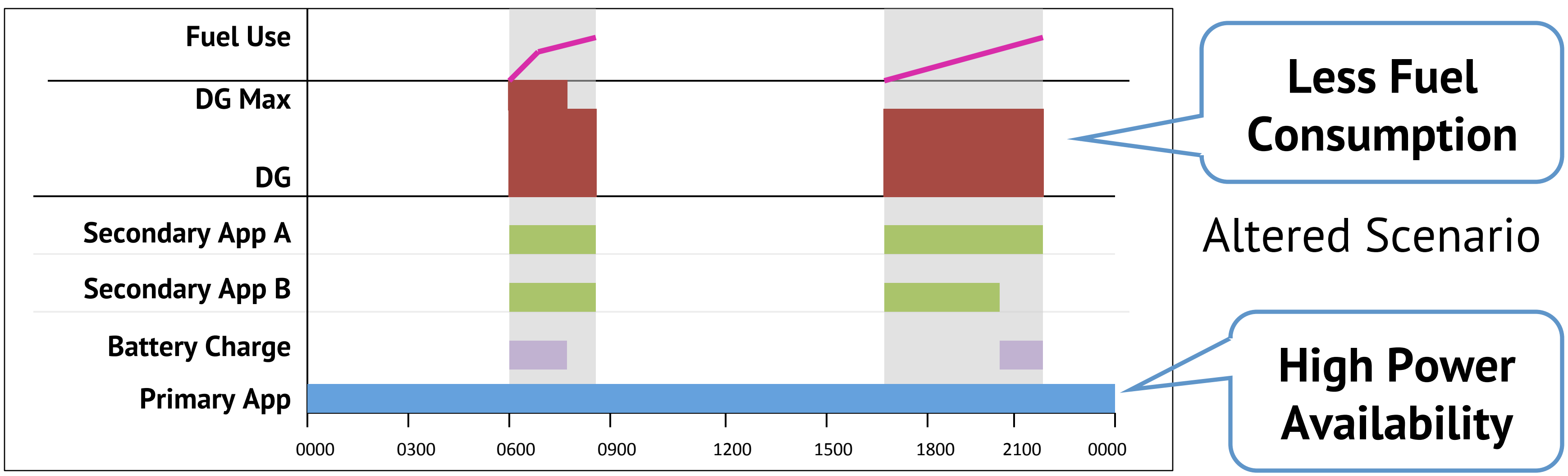

Altered Scenario

Results

Only DG	Run DG whenever there is non-zero demand (state-of-the-art)
Hybrid	Run all appliances from battery; run DG optimally to recharge the battery
C Hybrid	Run primary appliances from battery, and secondary appliances from DG

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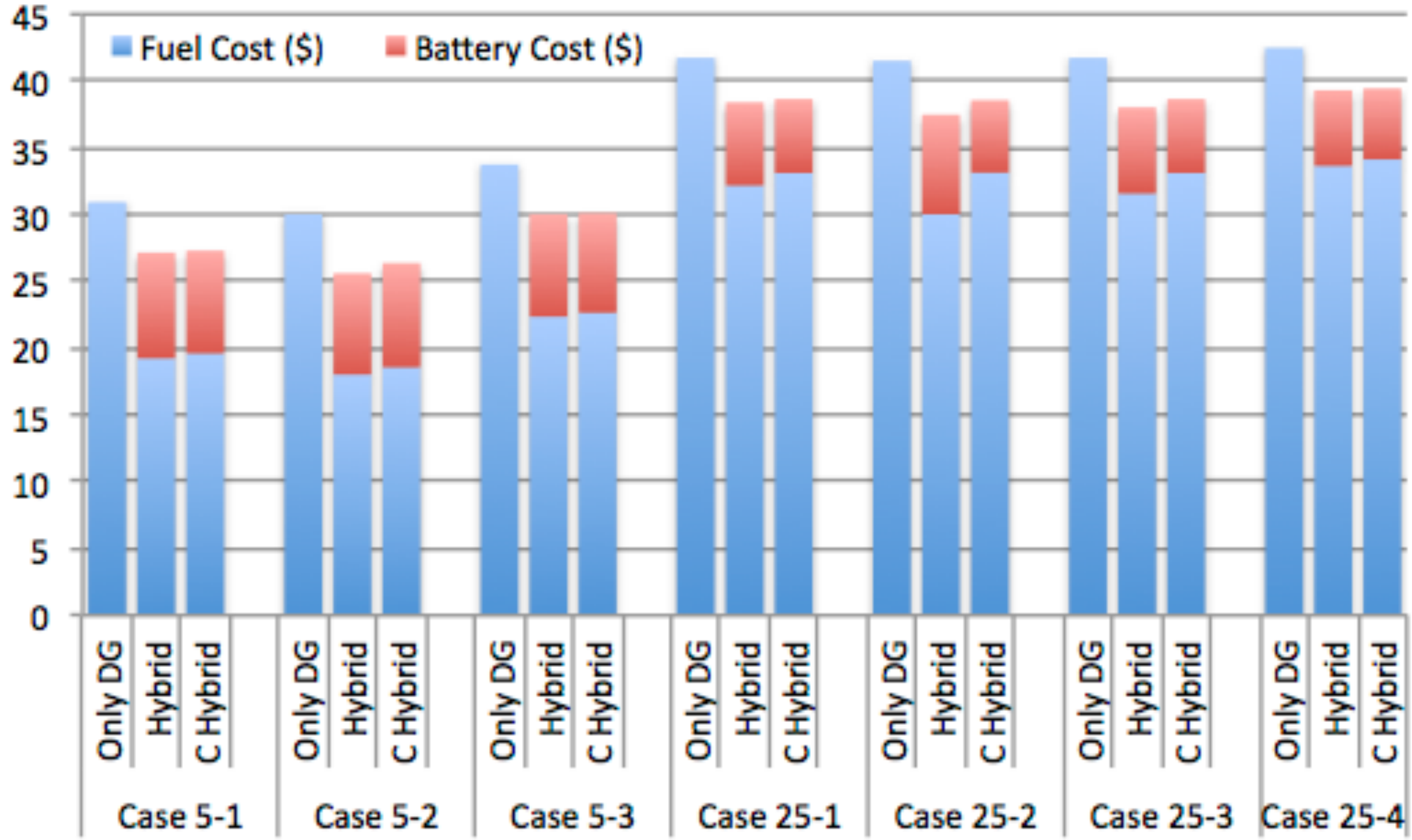


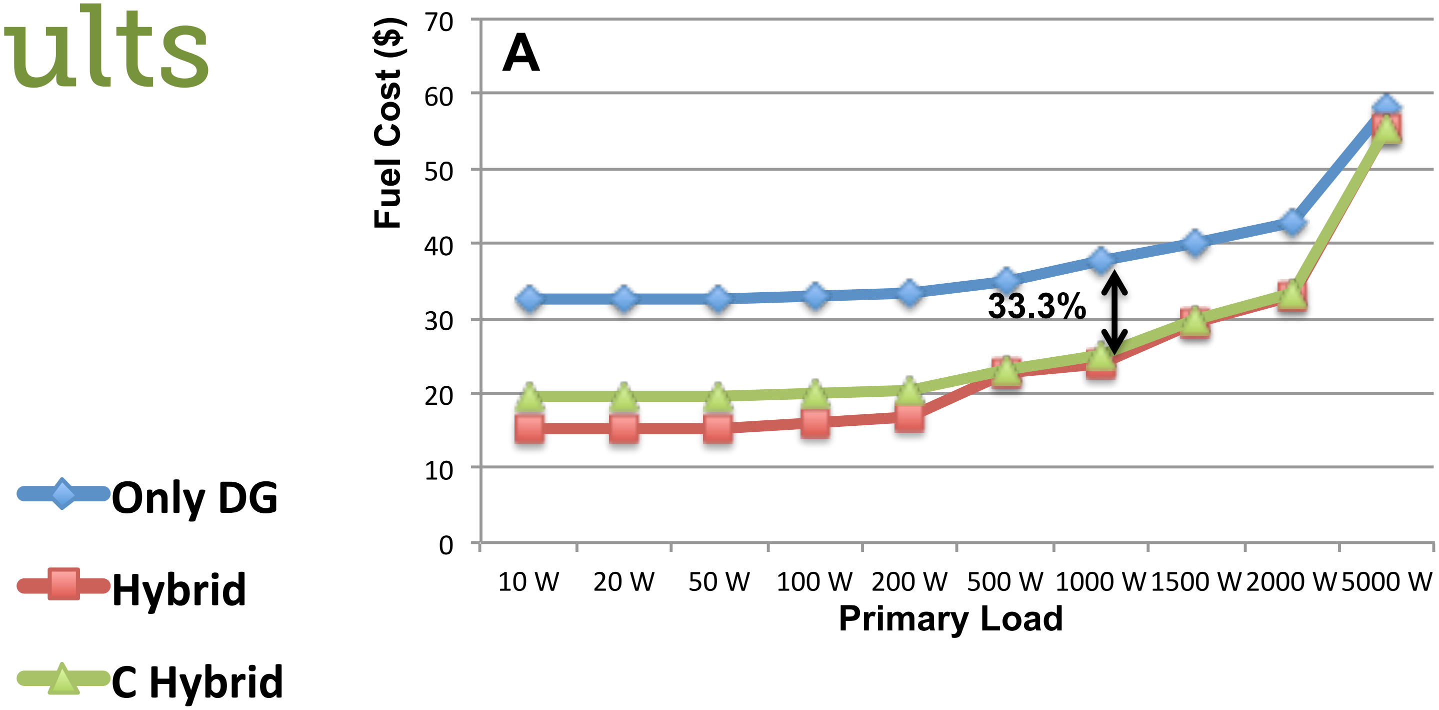
Results

C Hybrid performs almost as good as pure Hybrid

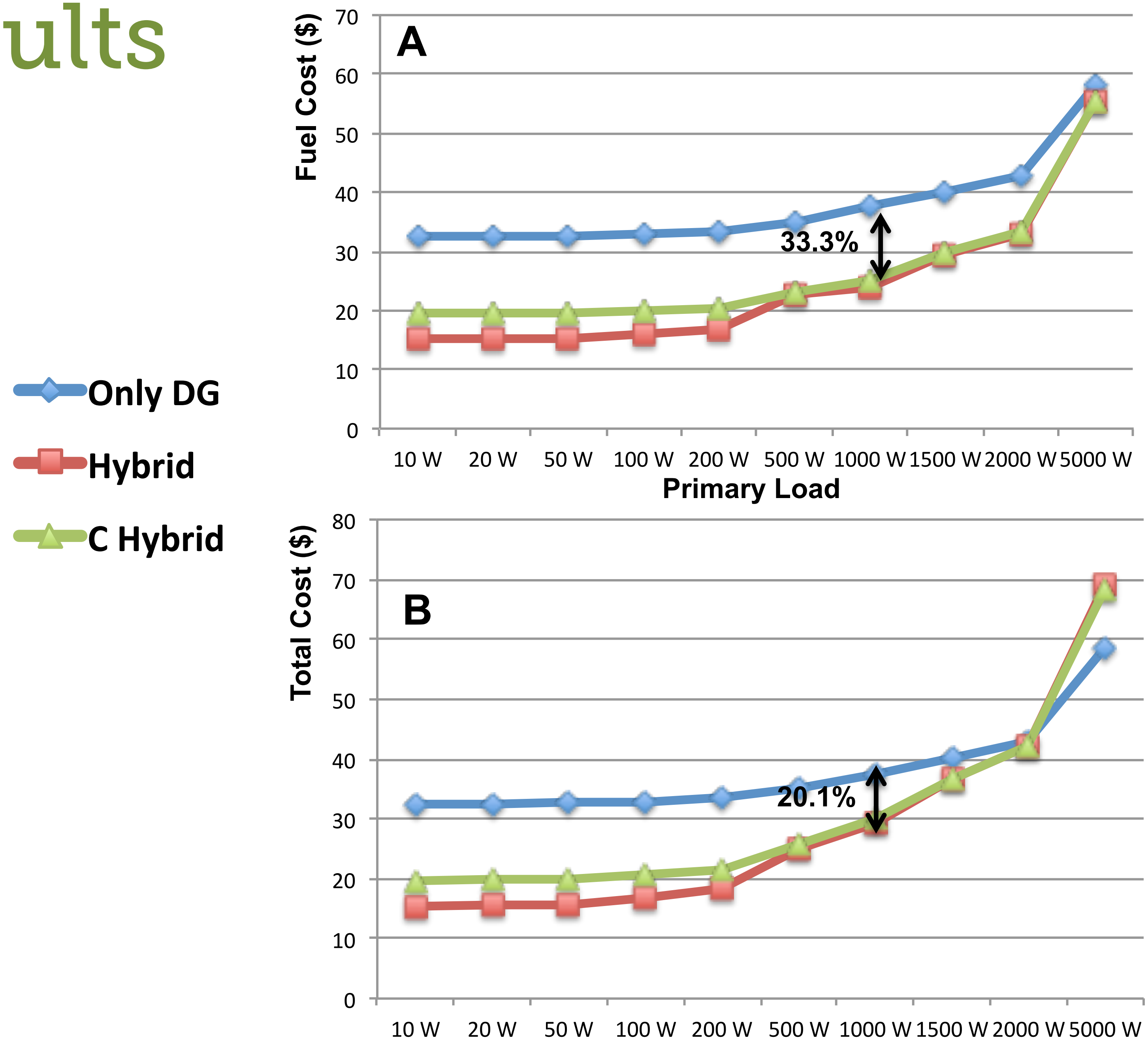
Hybrid: both primary and secondary loads run from the battery, and DG is used only to recharge the battery

- Higher wear and tear of the battery
- As electricity is freely available from the battery at any time of the day, users may tend to be less economical in their usage

Results


A
Fuel Cost ($)
70
60
50
40
30
20
10
0
33.3%
10 W
20 W
50 W
100 W
200 W
500 W
1000 W
1500 W
2000 W
5000 W
Primary Load
Only DG
Hybrid
C Hybrid

Results



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100 W
200 W
500 W
1000 W
1500 W
2000 W
5000 W
Primary Load
B
Total Cost ($)
80
70
60
50
40
30
20
10
0
20.1%
10 W
20 W
50 W
100 W
200 W
500 W
1000 W
1500 W
2000 W
5000 W

Summary

Solution designed for reducing diesel consumption at KBFSC, a remote ecological field study centre in Brunei

The system consists of

- a **battery bank** to increase power availability to primary loads
- a **collaborative scheduler** for access to power for secondary loads
- a **DG optimizer** ensures that the DG run at the appropriate times to minimize diesel consumption while keeping the batteries charged and meeting user needs

Simulations modeled on real data suggest that our system:

- provides **uninterrupted power**, oppose to 10 hours in the past
- **reduces diesel consumption** by 33.3% and total cost by 20.1%

Thank You!

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Neha Sengupta

Zainul Charbiwala

Deva P. Seetharam

Kushan U Tennakoon — Institute for Biodiversity & Environmental Research

Rodzay bin Haji Abdul Wahab

Liyanage Chandratilak De Silva — Universiti Brunei Darussalam