

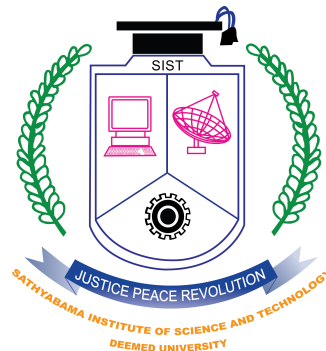
SUSTAINABLE GARMENT FACTORY BUILDING FOR WARM AND HUMID CLIMATE

A Thesis

Submitted in partial fulfillment of the requirements for the award of
Master of Architecture degree in Sustainable Architecture

by

S.SUGANYA (40890018)



**DEPARTMENT OF ARCHITECTURE
SCHOOL OF BUILDING AND ENVIRONMENT**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade "A" by NAAC

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119

MAY 2022



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DEPARTMENT OF ARCHITECTURE

BONAFIDE CERTIFICATE

This is to certify that this Report is the bonafide work of **S.SUGANYA (20S895015)** who carried out the Thesis entitled "**SUSTAINABLE GARMENT FACTORY BUILDING FOR WARM AND HUMID CLIMATE**" under our supervision from January 2022 to May 2022.

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Submitted for Viva voce Examination held on 6 May,2022

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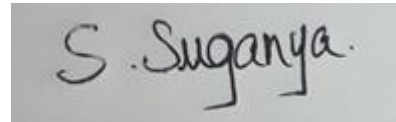
External Examiner

DECLARATION

I **S.SUGANYA** hereby declare that the Thesis Report entitled “**SUSTAINABLE GARMENT FACTORY BUILDING FOR WARM AND HUMID CLIMATE**” is done by me under the guidance of **AR.MADHUMITA** (Internal) and **AR. KRITHIKHA MUTHUKRISHNAN** (External) at Sathyabama Institute of Science and Technology is submitted in partial fulfillment of the requirements for the award of Master of Architecture degree in Sustainable Architecture

DATE: 6 MAY 2022

PLACE: CHENNAI

A rectangular box containing a handwritten signature in black ink. The signature appears to be 'S. Suganya'.

SIGNATURE OF THE CANDIDATE

ACKNOWLEDGEMENT

I am pleased to acknowledge my sincere thanks to Board of Management of **SATHYABAMA** for their kind encouragement in doing this Thesis project and for completing it successfully. I am grateful to them.

I convey my thanks to **Dr. Devyani Gangopadhyay, Dean and Head of the department, Dept. of Architecture, School of Building and Environment**, for providing me necessary support and details at the right time during the progressive reviews.

My special thanks to **Dr. Suresh Kuppusamy**, our Design chair and **Ar. Krithikha Muthukrishnan** , (External guide) and **Ar. Sheetal Amraotkar** (Thesis Coordinator) for their valuable comments and guidance during the project work.

I would like to express my sincere and deep sense of gratitude to my Project Guide **Ar. Madhumitha** for her valuable guidance, suggestions and constant encouragement which paved way for the successful completion of my project work.

I wish to express my thanks to all Teaching and Non-teaching staff members of the Department of Architecture who were helpful in many ways for the completion of this Thesis.

ABSTRACT

India's industrial sector is an important contributor to the country's economic growth, and it is set to grow in scale as the government pushes for greater indigenous manufacturing. But while industries are a key facet of our country's economic development, they are also extremely energy intensive. Most industrial processes continue to be powered by traditional fuels and the sector accounts for approximately one-fourth of India's total greenhouse gas (ghg) emissions. Reducing the energy intensity of key industrial sectors can result in a drastic decrease in emissions and improvement in air quality.

TABLE OF CONTENTS

CHAPTER No.	TITLE	PAGE No.
	ABSTRACT	v
	LIST OF TABLES	xii
	LIST OF FIGURES	xiii
1	INTRODUCTION	1
1.1	INTRODUCTION	9
1.2	AIM	9
1.3	RESEARCH QUESTIONS	9
1.4	OBJECTIVE	9
1.5	NEED FOR THE STUDY	9
1.6	SCOPE AND LIMITATIONS FOR THE STUDY	10
2	LITERATURE REVIEW	11
2.1	INTRODUCTION	11
2.2	A CASE STUDY ON INDUSTRIAL ECOLOGY ,INDIA	
2.3	IE IN APPAREL MANUFACTURING-8 : LAYOUT PLANNING	

- 2.4 DESIGN APPROACH OF ENERGY EFFICIENT READY MADE
GARMENT FACTORY IN VIEW OF THERMAL COMFORT
- 2.5 AN APPROACH FOR REDUCING ENERGY CONSUMPTION IN FACTORIES
BY PROVIDING SUITABLE ENERGY EFFICIENCY MEASURES

3 CASE STUDY

- 3.1 STAR GARMENT INNOVATION CENTRE,SRI LANKA
- 3.2 PT- UNGARAN SARI GARMENTS,INDONESIA
- 3.3 FCI[BD] -DEPZ,SAVAR,DHAKA
- 3.4 INFERENCE FROM CASE STUDIES

4 ANALYSIS AND RESULTS

65

- 4.1 PASSIVE STRATAGIES FROM MAHONEY TABLE
- 4.2 PLANNING STRATAGIES
- 4.3 CODES AND STANDARDS
- 4.4 CLIMATE STUDY
- 4.5 DESIGN RECOMMENDATONS FOR INDUSTRIAL BUILDING
- 4.6 SPACE REQUIREMENTS
- 4.7 SITE PLAN
- 4.8 ANALYSIS FOR SITE PLANNING
- 4.9 DETAILED PLAN
- 4.10 ANALYSIS FOR DETAILED PLAN

4.11 ITERATION AND PLANNING

4.12 ITERATION ANALYSIS

5 SUMMARY AND CONCLUSION 26

REFERENCES 148

APPENDICES 158

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

India's industrial sector is an important contributor to the country's economic growth, and it is set to grow in scale as the government pushes for greater indigenous manufacturing. But while industries are a key facet of our country's economic development, they are also extremely energy intensive. Most industrial processes continue to be powered by traditional fuels and the sector accounts for approximately one-fourth of India's total greenhouse gas (ghg) emissions. Reducing the energy intensity of key industrial sectors can result in a drastic decrease in emissions and improvement in air quality.

1.2 AIM

To design the sustainable garment factory building for warm and humid climate.

1.3 RESEARCH QUESTIONS

- What are factors affecting the thermal comfort of the occupants in the garment factory?
- What are the energy efficient approaches for the garment factory?
- What are the environmental focus area of the garment factory building?

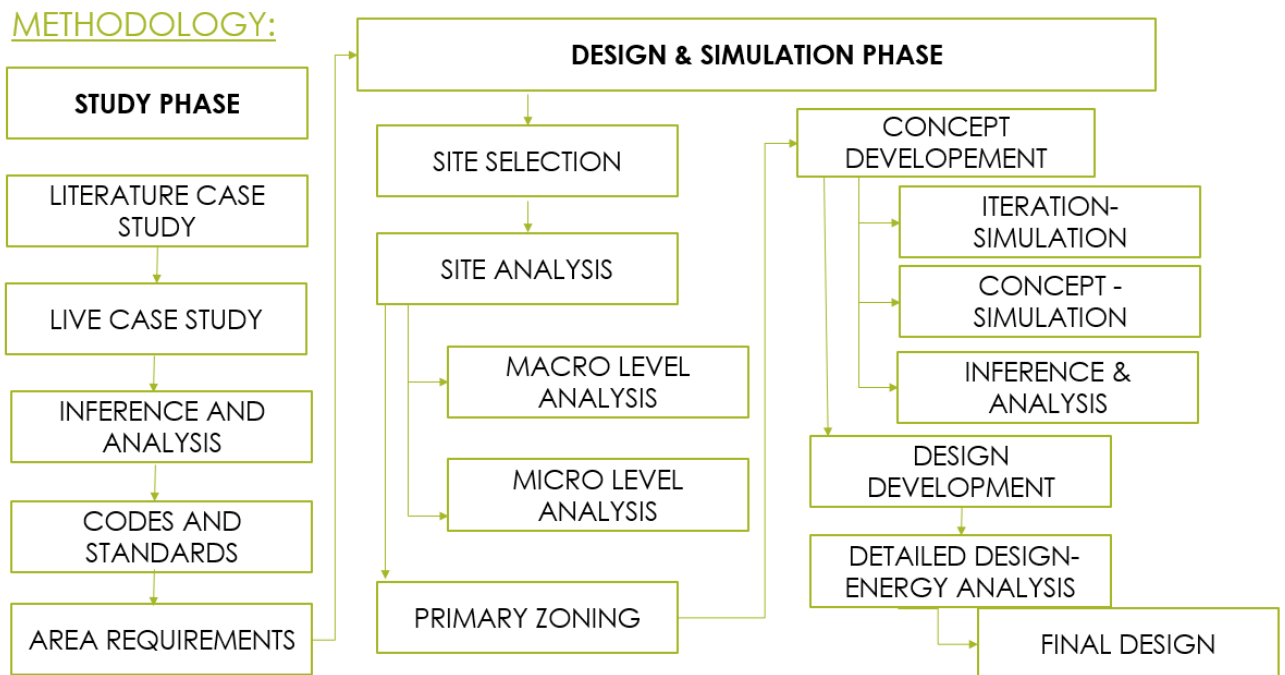
1.4 OBJECTIVE

- To identify and design according to the factors affecting the thermal comfort of the occupants in garment factory.
- To identify the energy efficient approaches for the garment factory.
- To identify the environmental focus area for the garment factory.

1.5 LIMITATIONS

- Design only for the warm and humid climatic zones.
- Design according to the ECBC standards.

1.6 METHODOLOGY



CHAPTER 2 LITERATURE STUDY AND CASE STUDY

2.1 A case study on Industrial Ecology, India- Case Study of The Textile Industry In Tirupur

The entire town's economic activity is centered on the manufacture of cotton knitwear: for use as banians (mostly sold in the Indian market), and for use as T shirts (mostly exported).

MAJOR ISSUES IN TIRUPUR TEXTILE INDUSTRY

1. Water
2. Fire wood
3. Solid waste

Water:

Water is a major requirement of the industry. As the area is dry and much of the groundwater is polluted, over half the water required by the industry is brought in by trucks from groundwater sources at distances of over 50 km. The industrial effluents are drained out untreated into a dry river. The effluents accumulate at a reservoir, built originally for irrigation, around 15 km away. A substantial part of the effluent leaches into the ground through its passage to the reservoir. The water is saline, highly colored and contains toxic dyes. The entire agricultural operations in the neighborhood have been badly affected by the groundwater contamination.



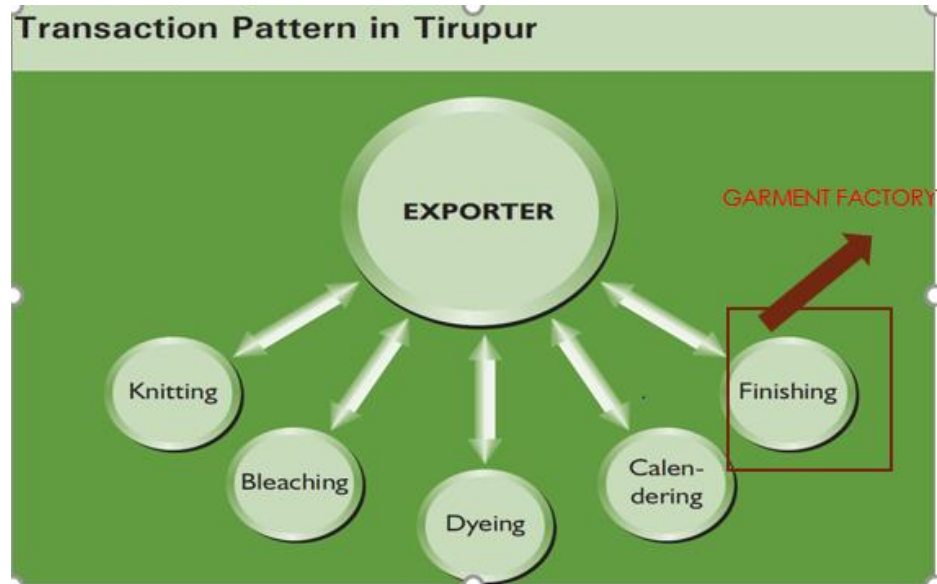
Fig 2.1 Nine traditional common effluent treatment plants (ETP)

Firewood:

The consumption of firewood by the industry is over 437,760 tonnes per year. The steam calendering industry uses over half of this quantity, for steam generation. The bleaching and dyeing industry uses the rest. It would be possible to substantially reduce the consumption by improving the design of the boilers. A central steam generating system could also be considered. Alternatively, a system of substitution of the fuel could be worked out—such as pre-heating with solar energy.

Solid waste:

Nearly 40 tonnes of combustible solid waste are generated every day by the textile industry. This comprises paper and textile scrap (rags and threads).



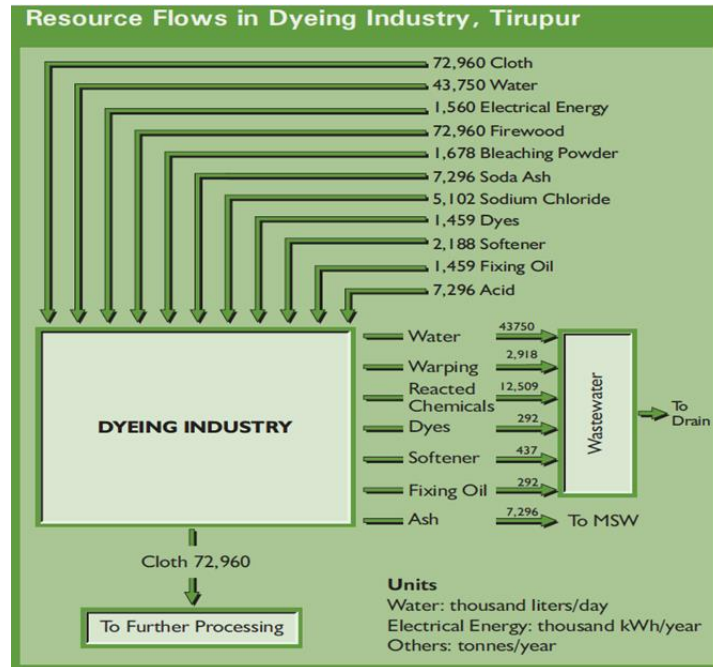
Dyeing: natural dyeing or artificial dyeing

Calendering: After bleaching/dyeing, the fabric is passed through steam heated rollers in the steam calendering machines.

Finishing: After calendering, the fabric is ready to be made into garments in the finishing units. These units use electrically operated stitching machines and electric irons. Some of the processes like embroidery require sophisticated computer controlled machines.

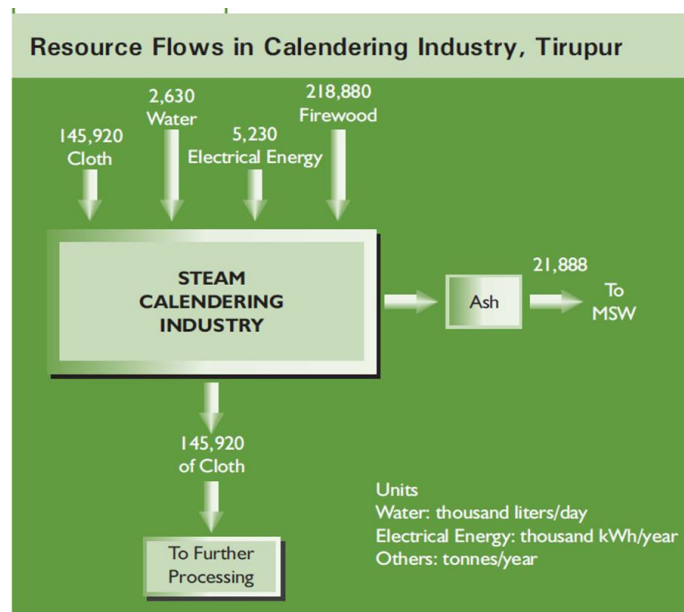
Bleaching/Dyeing:

- Total fabric bleached per year : 72,960 tonnes
- Fabric bleached by machine : 58,368 tonnes (assuming 80% of total fabric bleached by machine, and 20% hand bleached which does not need any power)
- Power consumption per tonne : 26.78 kWh
of fabric bleached
- Consumption per year : 1,560,000 kWh (1.56 million kWh)



Calendering:

- Average consumption per tonne : 35.8 kWh
- Total fabric calendered : 145,920 tonnes
- Total annual consumption : 5,230,000 (5.23 million kWh)



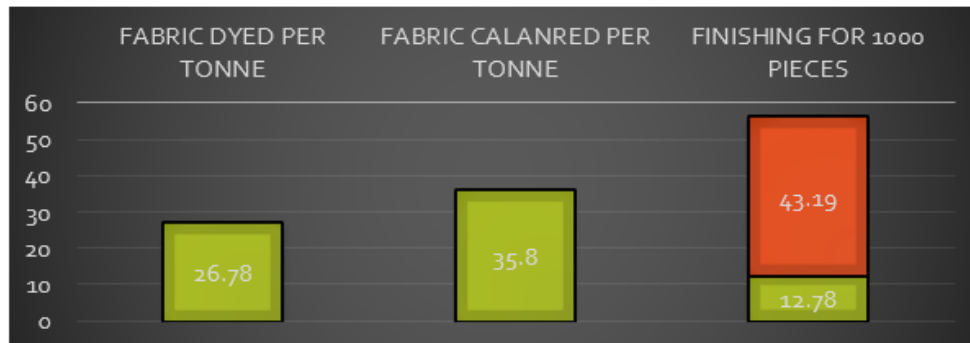
FINISHING: CUTTING+STITCHING+IRONING

Cutting & Stitching

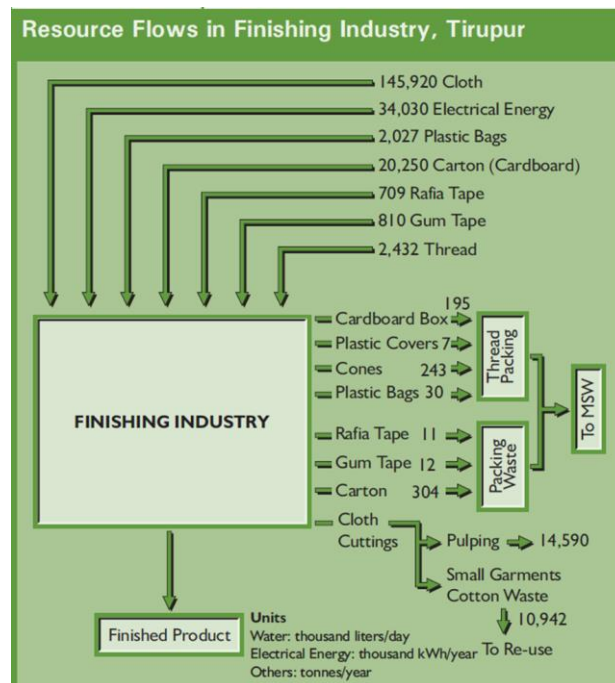
- Total production : 608 million pieces
- Average consumption : 12.78 kWh per 1,000 pieces
- Total annual consumption : 7,780,000 Kw (7.78 million kWh)

Pressing/Ironing

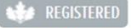
- Total production : 608 million pieces
- Consumption per 1,000 pieces : 43.19 kWh
- Total annual consumption : 26,260,000 kWh (26.26 million kWh)
- Total Finishing (stitching + ironing) : 34,040,000 kWh (34.04 million kWh)



Power consumption per tonne [Unit : kwh]



LEED rated and registered garment factories in Tirupur:

Anugraha Fashion Mill Pvt Ltd 📍 Tiruppur, TN IN	2020-01-06 Anugraha Fashion Mill Pvt Ltd. Industrial Manufacturing / 100,869 sq ft	 REGISTERED LEED v4 O+M EB
Knit Gallery 📍 Tiruppur, TN IN	2019-10-28 KNIT GALLERY Office / 96,338 sq ft	 PLATINUM CERTIFIED LEED NC 2009 88 pts
SAGS APPARELS 📍 Tiruppur, TN IN	2019-10-24 SAGS APPARELS Industrial Manufacturing / 23,197 sq ft	 PLATINUM CERTIFIED LEED v4 O+M EB 86 pts
Teemage Precast Corporate Office Building 📍 Tiruppur, TN IN	2014-01-09 Teemage Builders P Ltd Office / 25,280 sq ft	 REGISTERED LEED NC 2009
Ahill Apparel 📍 Tiruppur, TN IN	2011-01-01 40,475 sq ft	 SILVER LEED India NC

There are only 13 leed rated garment factories in india [source: the barriers and challenges for green garment factory:india]

2.2 IE in Apparel Manufacturing-8: Layout Planning

The key aim of every layout is to maximize utilization of available space in order to optimize the material flow, maintaining visibility or ease of supervision. The other benefits of a good layout may be improving on other productivity factors such as manpower, machine and lesser defects.

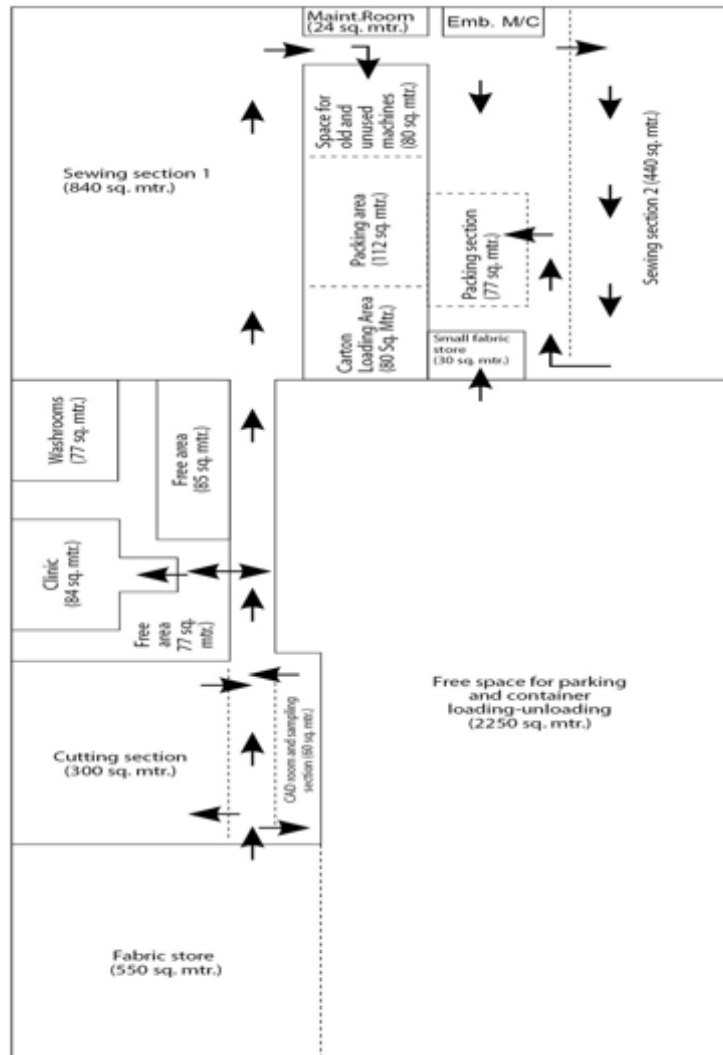
OBSERVED POINTS IN THE INITIAL LAYOUT:

Packing activity is happening at different places which may make the control difficult and may as well hamper the space utilization. A small fabric store is located near to Sewing Section 2, which is far from the main fabric store. This is resulting into an increased fabric movement while fabric is carried for cutting.

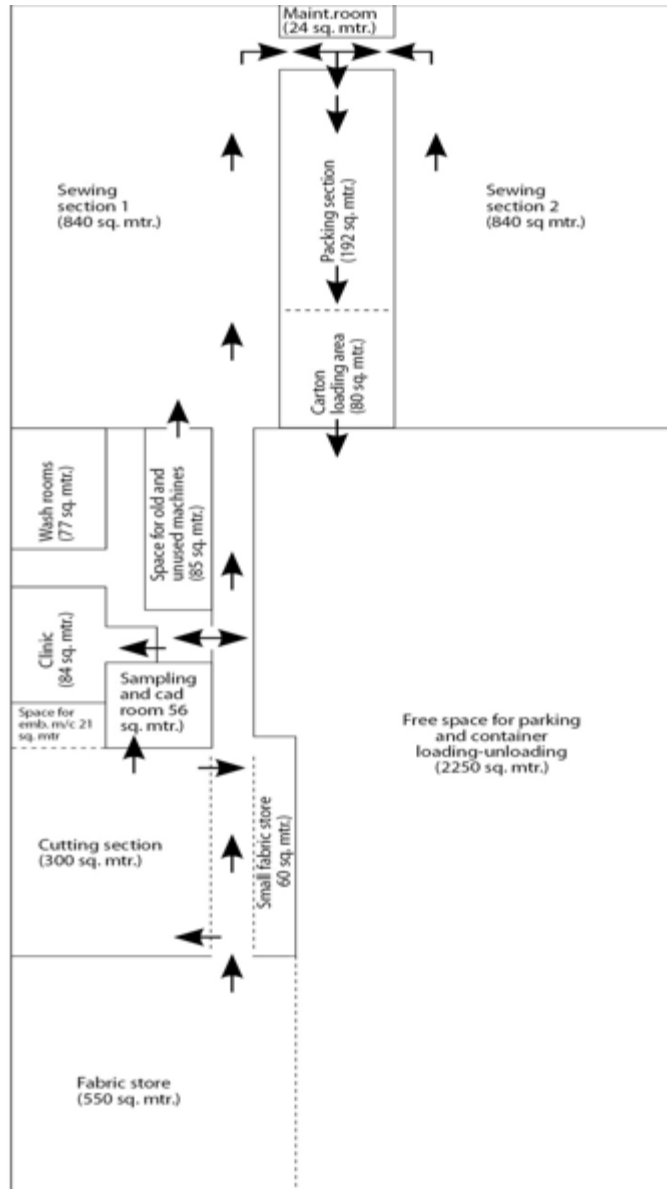
OBSERVED POINTS IN THE MODIFIED LAYOUT:

Embroidery section is located near to Sewing Section 2; due to this cut panels which are going to be embroidered have to travel comparatively more distance from cutting section before coming back for bundling. A good space is occupied by the old and unused machines. Embroidery section, CAD and sampling room have been moved near to the cutting section. This may bring improved control and less distance travelled in material movement. Old and unused machines have been relocated to the area near to clinic with a provision of gate opening towards Sewing Section 1. This has resulted in free space between Sewing Section 1 and Sewing Section 2. Small fabric store has been relocated from Sewing Section 2 (in the area earlier occupied by CAD and sampling room), near to

fabric store and cutting section. This will result into an easy fabric transaction while cutting as well as effective supervision. Packing which was happening at different places has been arranged to be at one place, between Sewing Section 1 and Sewing Section 2 with only 1 entry and exit points. The modifications done have resulted into an increased space availability in the Sewing Section 2 which can accommodate at least 90 additional sewing machines and mSewing Section 1 and Sewing Section 2 equal in terms of number of sewing machines accommodated.



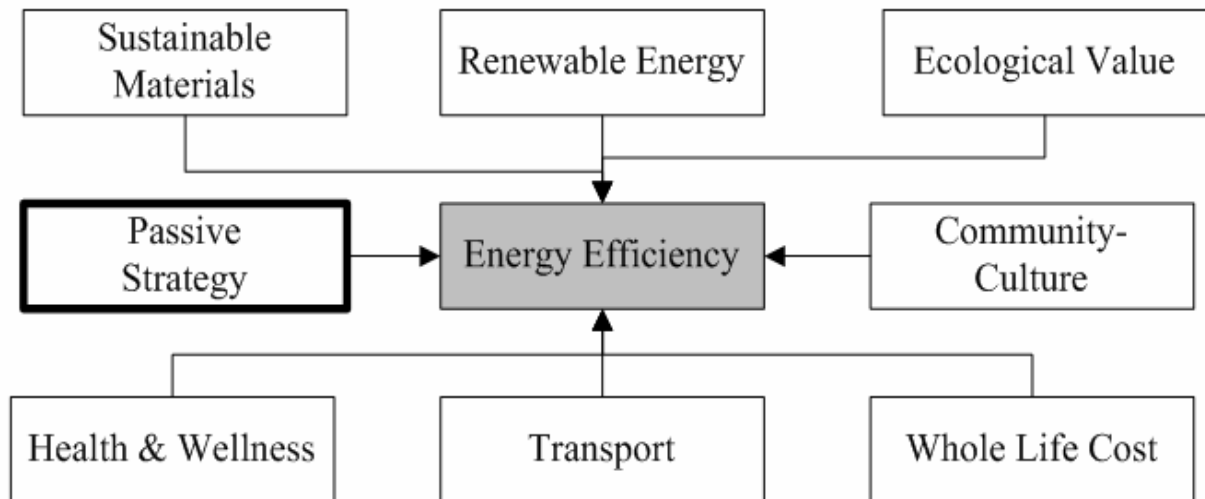
INITIAL LAYOUT OF THE FACTORY



MODIFIED FACTORY LAYOUT

TOPIC	AUTHOR	AIM	METHODOLOGY	INFERENCE
Design approach of energy efficient ready made garments factory in view of thermal comfort	Sajal Chowdhury* and Md. Rabiul Alam	The aim of this research is to investigate the energy efficient strategies that can be employed within RMG factories	- Theoretical study - Field survey - Data analysis - Energy efficient design considerations - Design formulation [THERMAL COMFORT]	- Detail analysis in view of thermal comfort level to make garment factory energy efficient by a design approach with the help of building simulation tools Enhanced daylight, color, building height and depth, material selection ,windows performance have often resulted in reduced thermal performance in a production space

Components of energy efficiency



- Passive design features are discussed to achieve thermal comfort level

Factors determining thermal comfort include:

1. Air temperature
2. Mean radiant temperature
3. Air movement / velocity
4. Relative humidity
5. Isolative clothing
6. Activity levels

- RMG factories are constructed by **steel structure in the upper portion** and **brick plaster in the lower portion**
- it is noticed that most of Ready Made Garments factories have less reflection about the **water conservation and water efficiency strategy**
- Garments Factories do not consider **building depth, building height, volume, equipment's and number of storey** which factors are very essential to make factory energy efficient



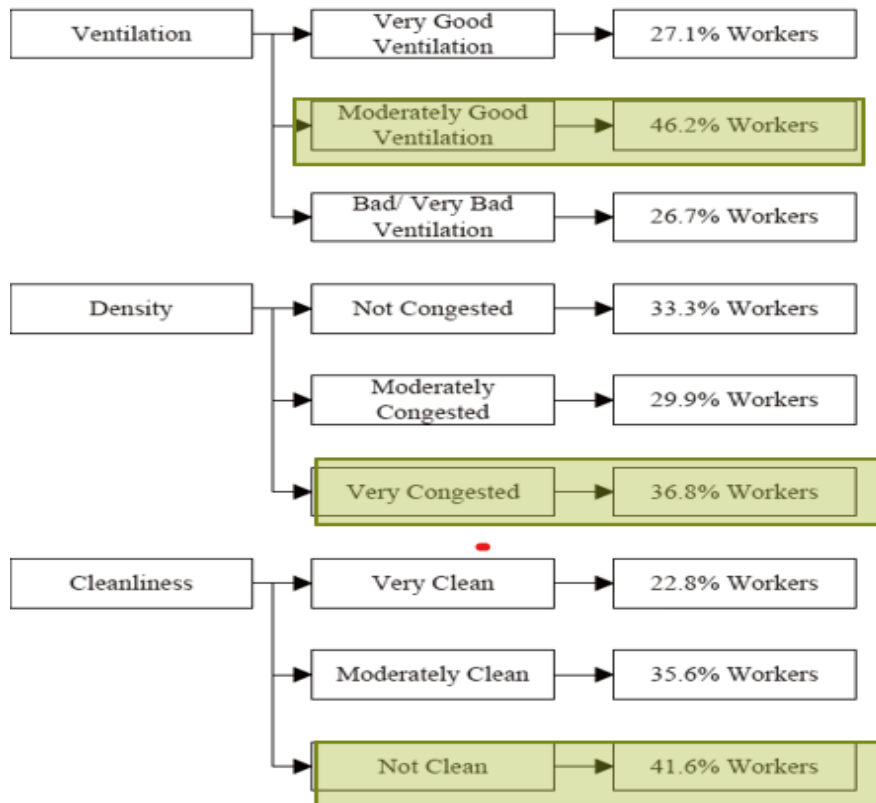
Worker besides the
Evaporative cooler



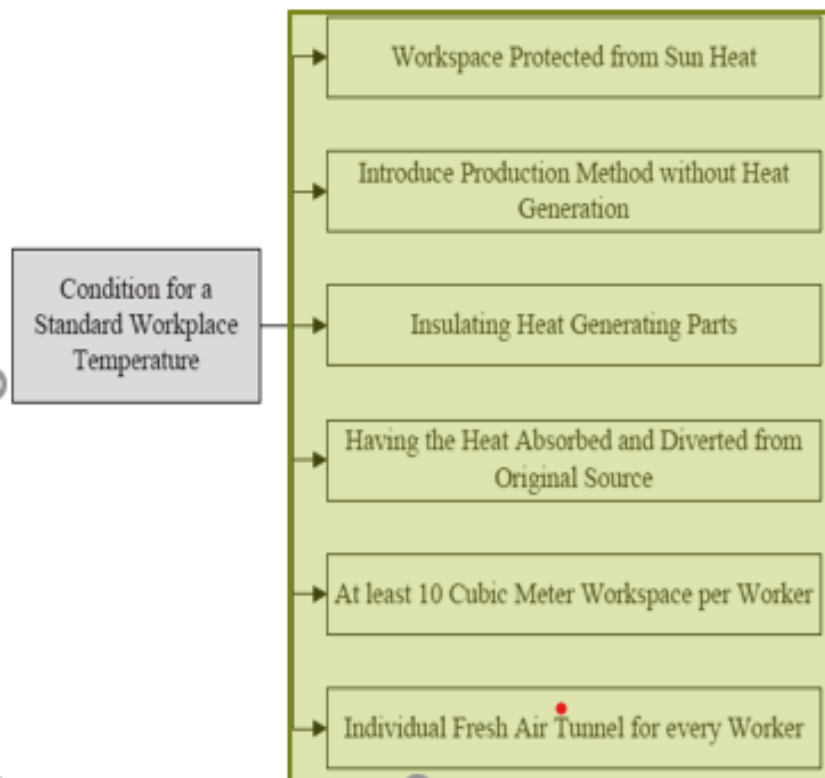
artificial lighting during day time

Nature of physical working condition and health condition of the RMG factories

- The factory buildings have no observation about the wall and window area ratio. It is observed that for **550 sqm** floor areas, it has only average **21% opening** which is not sufficient for natural cross ventilation system.

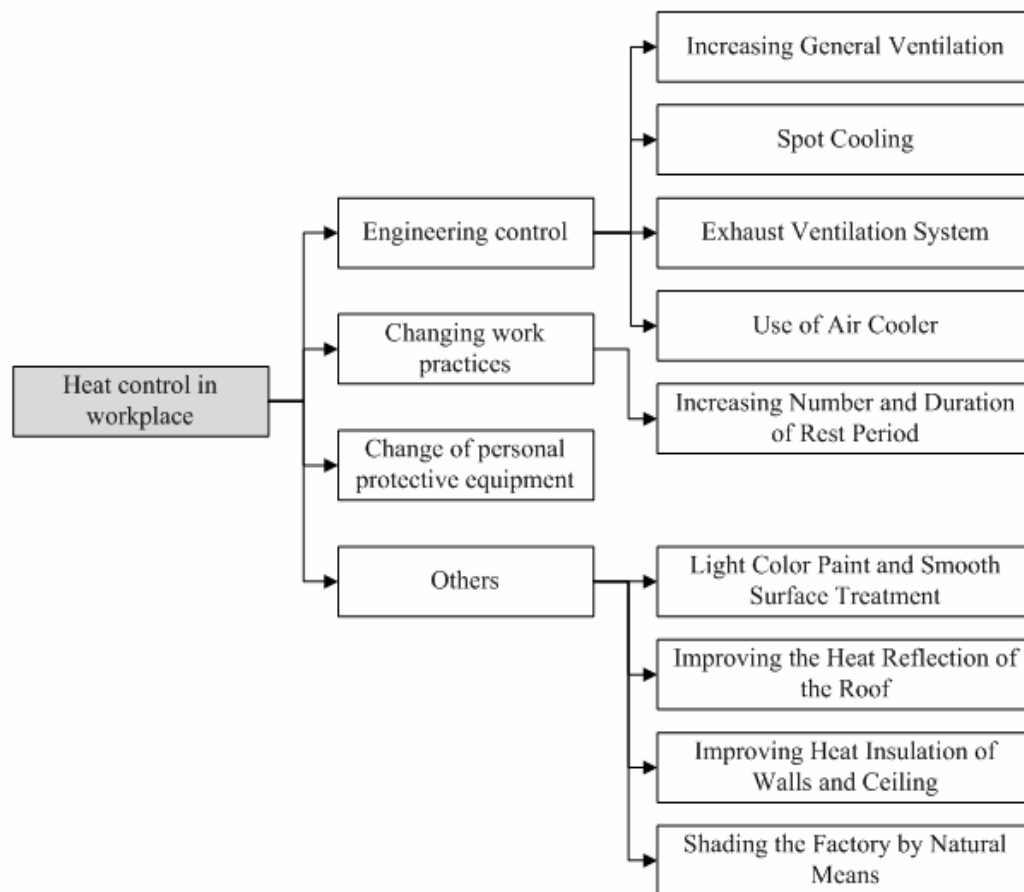


Condition for standard workplace



Space ratios of production areas

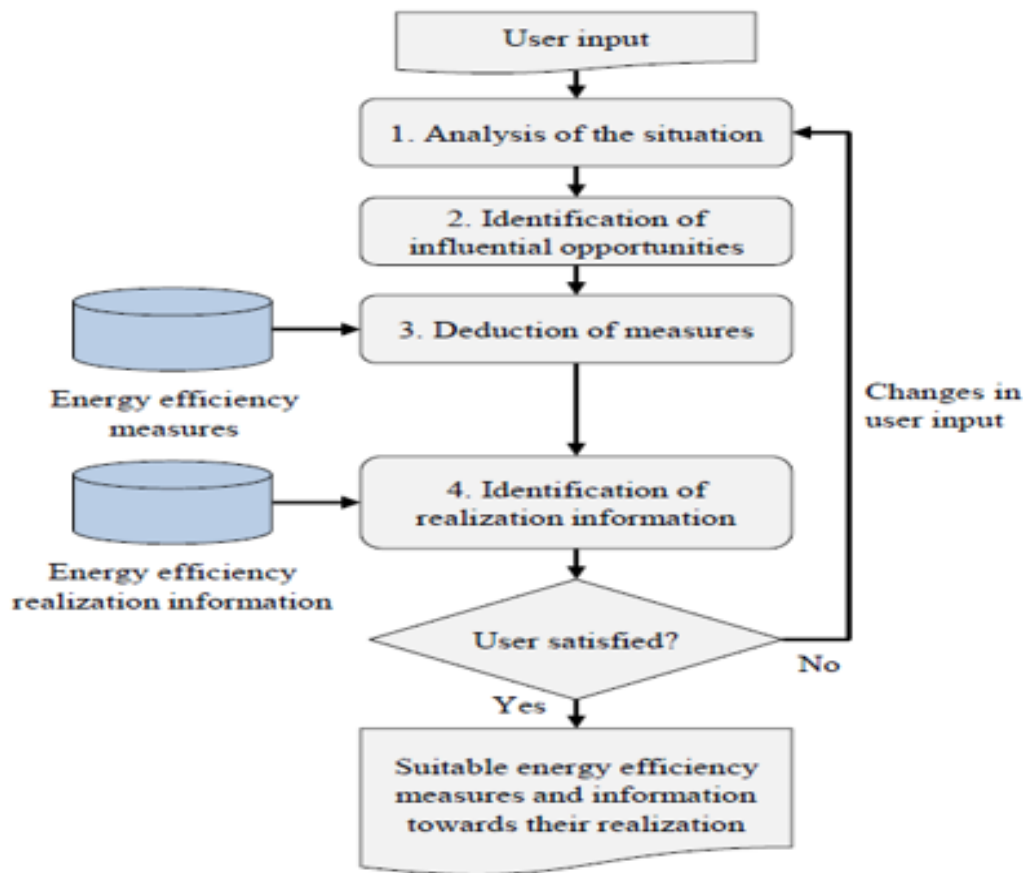
- **Sewing section is two times longer than the cutting and ironing section** to achieve the great impact from the environment.
- Standard comfort level can be achieved when the factory building's wall is constructed by **cavity or solid block** because it Creates **heat barrier from outdoor to indoor**.
- The height of the factory building is **6m to 8m**, it will give the maximum comfort level for the production area in which **150-200 workers work at a time in a single space** from 9.0 AM to 7.0pm.
- **Horizontal window with the shading device** has achieved the **good quality comfort range of temperature** and the minimum percentage of openings should be **25-35%** to achieve the **standard thermal comfort level for production space**.



TOPIC	AUTHOR	AIM	METHODOLOGY
An Approach for Reducing Energy Consumption in Factories by Providing Suitable Energy Efficiency Measures	Manuela Krones*, Egon Müller	The main aim of the research Need in developing an approach for the systematic Identification of energy efficiency measures without the high Efforts of acquiring energy consumption data	

Overview on existing types of tools for energy-efficient production

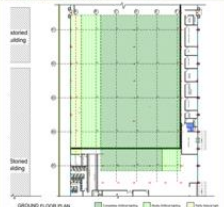
	Description	Example(s)
Energy efficiency guidelines	Collection of energy efficiency measures in specific sectors or fields	US Department of Energy – Energy Efficiency & Renewable Energy: Guide to Energy-Efficient Lighting [7]
Energy efficiency principles	Small number of general approaches for energy efficiency	• substitute energy sources • increase efficiency of equipment • energy recovery (selected according to [8])
Energy efficiency methods	Systematic approaches to identify and realize energy efficiency improvement opportunities	Energy metering and assessment of manufacturing processes



Overview on existing types of tools for energy-efficient production

General requirements	Establishing, implementing and improving the energy management system
Management responsibility	- Providing the necessary resources (including energy manager) - Ensure compliance with requirements
Energy policy	- Commitment to continual improvement of energy performance - Obligation to comply with legal requirements - Support the purchase of energy-efficient products and services - Documentation and communication within the organization at all levels
Energy planning	Energetic evaluation by identifying areas with significant energy use with the help of measurements and identification of ways to improve the energy performance - Record and update of energy basis - Determination of energy performance indicators - Definition of strategic and operational energy goals and action plans
Implementation and operation	- Creating awareness and training of employees - Control of documents and processes of critical energy areas - Consideration of the energy performance in purchase and design of systems and devices
Checking	- Regular monitoring, measurements and analysis (energy evaluation, energy performance indicators, action plans, evaluation of current and expected energy consumption) - Internal auditing - Initiation of corrective and preventive actions
Management review	Regular review of energy management system by the management

CASE STUDY

1	<u>STAR GARMENT INNOVATION CENTER KATUNAYAKE, SRI LANKA</u>	
2	<u>PT-UNGARAN SARI GARMENTS (PA6&7) SEMARANG, INDONESIA</u>	
3	<u>FCI(BD)LTD – DEPZ, SAVAR, DHAKA</u>	

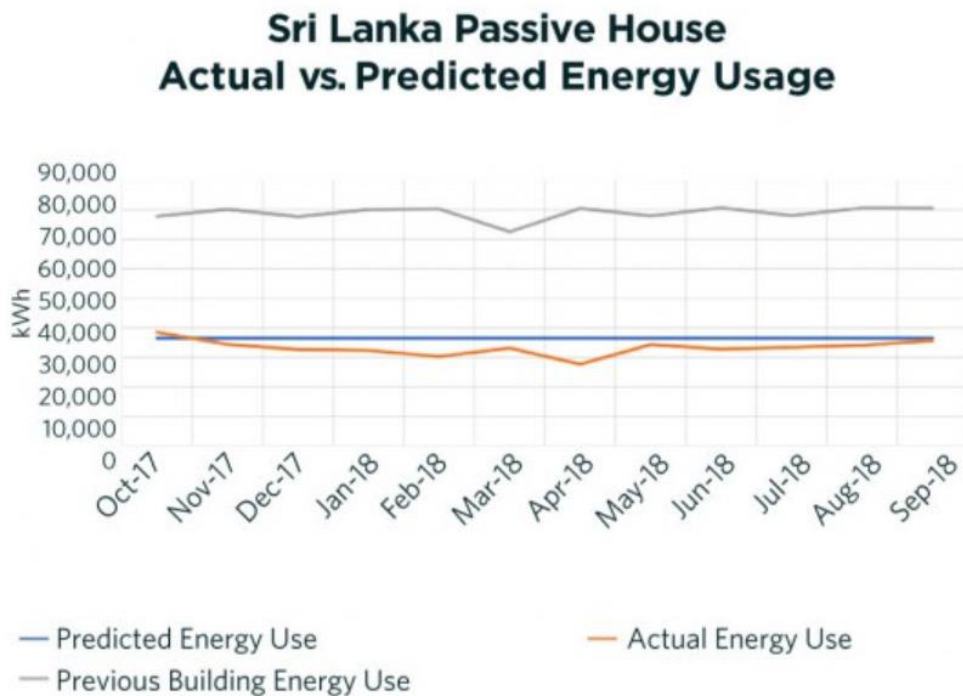
1.STAR GARMENT INNOVATION CENTER KATUNAYAKE, SRI LANKA



Location	Katunayake, Sri Lanka
Coordinates	7° N, 80° E
Occupancy Type	Factory / Industrial
Typology	Existing, Retrofit
Climate Type	Tropical
Project Area	3,675 m ²
Date of Completion	2018
Grid Connectivity	Grid-connected
EPI	164 kWh/m ² /yr
Passive House Design	Jordan Parnass Digital Architecture (JPDA)
Architect & Interior Design	Vinod Jayasinghe Associates (Pvt) Ltd
Energy Consultants	Steven Winter Associates (SWA)

- The Star Innovation Center is an existing garment manufacturing factory building retrofitted through careful design and engineering for sustainability, energy efficiency, and worker comfort.
- The factory building has been upgraded to meet the Passive House standard, thus making it the first certified Passive House (PH) building in Sri Lanka

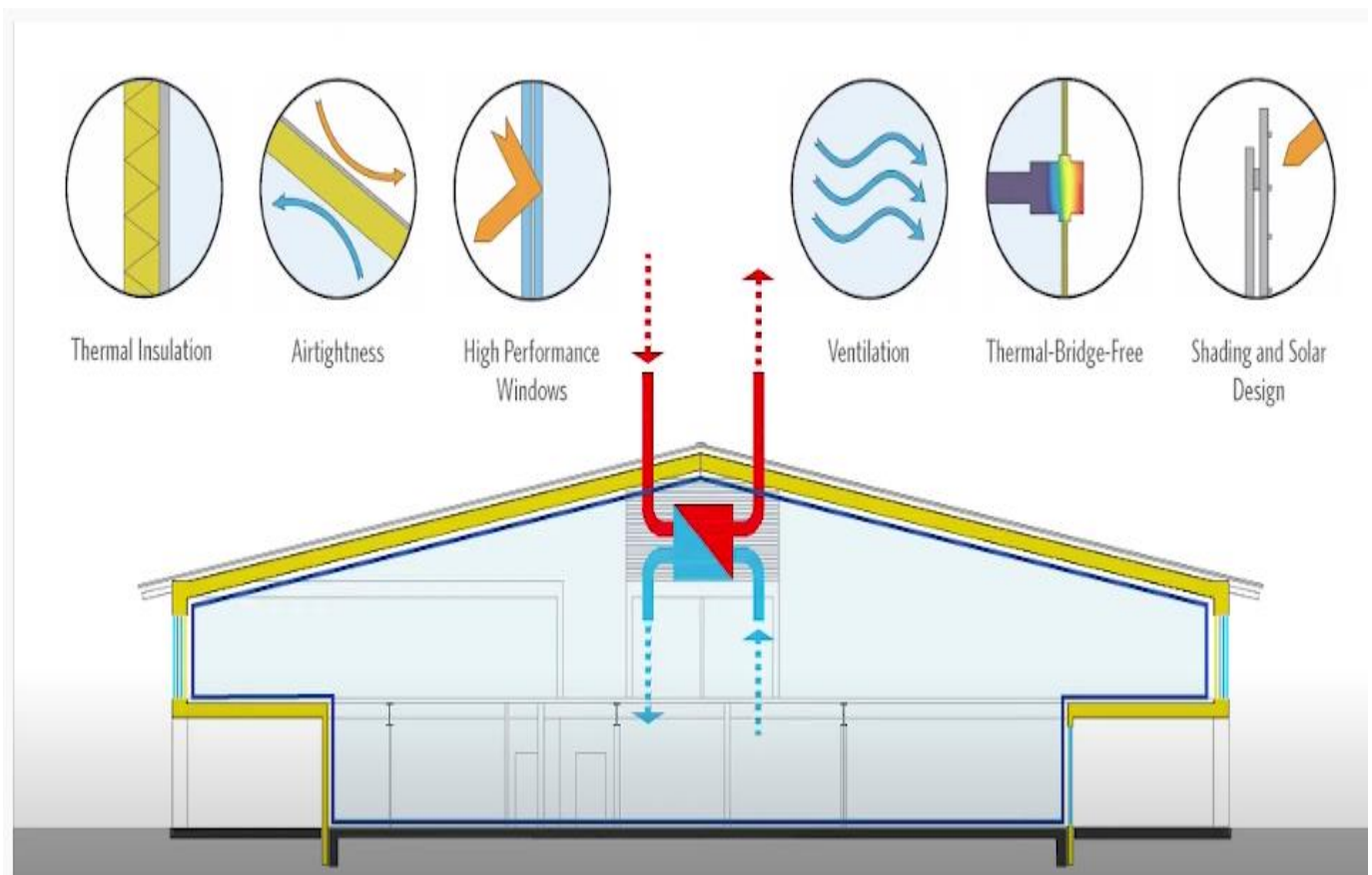
- The building is a milestone as it sets new standards by applying cutting-edge sustainable technologies – providing year-round comfort in **the workspace, abundant natural light, low humidity, filtered fresh air,** and maintaining **temperatures near a constant 24°C.**
- The benefit of these features is reflected in the **reduced annual energy use by around 54%.**



- The Star Innovation Center generates approximately **11% of its energy** through installed solar photovoltaic panels spread over an area of 2,549 m²
- The estimated generation is approximately **4,8340 kWh/yr**, which is **19 kWh /(m²yr)** based on the projected area of 2,549 m².

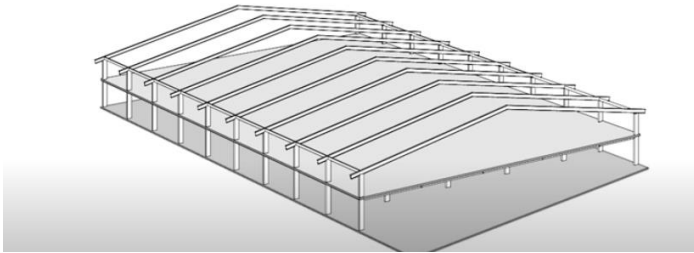


PASSIVE AND ACTIVE SYSTEMS



Re-using the Existing Building

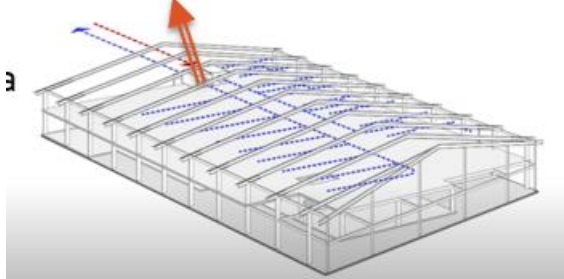
- The existing steel skeleton and the concrete slab have been re-used to reduce carbon footprint of the building.
- This also lowers the use of fossil fuels typically required for demolition and a new build.



High performance heating and ventilating system

- The ventilation system design includes **energy recovery ventilation (ERV)** through heat recovery, wrap-around heat pipes for enhanced dehumidification capacity, and a highly efficient VRF system.
- **5 ventilation units with heat and humidity recovery** have been installed. At an **average electric efficiency 0.7Wh/m³**, this results in **72% heat recovery** and **70% humidity recovery**.
- In the system's heat exchanger, after ERV, **cooling and dehumidification is carried out via fan coil units**. These units first **cool the supply air below the required interior temperature** to dehumidify it. This results in **deposition of the condensate in the ventilation system immediately**, thus avoiding its deposition later in the workspace.
- After dehumidification, **the supply air is slightly warmed up using the heat pipes** which recover **waste heat from the cooling system** and rooms. This **reheated supply air then flows into the building**.
- **The heat pipes work in collaboration with the solar panels** on the roof which **saves costs in comparison with the classic electrical reheat systems**.

VENTILATION SYSTEMS

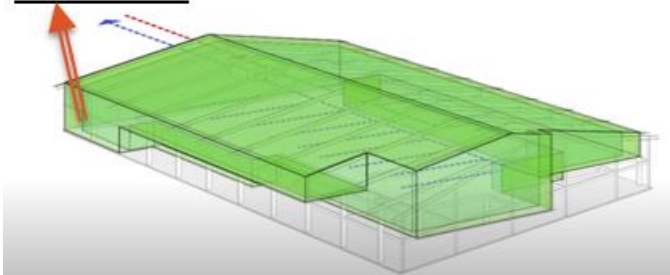


High performance ventilation systems

Air barrier and continuous layer of insulation

- The most important strategy implemented is the **installation of highly efficient airtight insulated envelope.**
- An **Exterior Insulated Finish System (EIFS)** continuously wraps **both existing and new structural components** in insulation with **minimal thermal bridging**. Low absorption or **highly reflective exterior surfaces** helps to **reduce the cooling energy demand** of the building.

Air barrier and continuous layer of insulation



Exterior Infill Walls

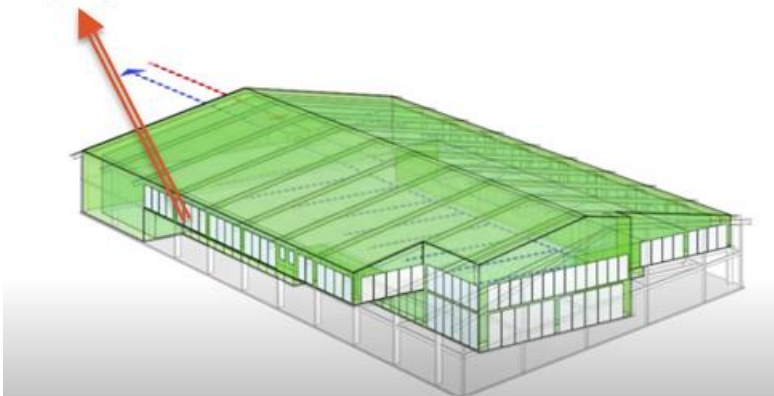
- The exposed steel frame is partly filled with **concrete masonry units (CMU)** which are made efficient by the use of a **thermal insulation composite system made from EPS.**
- The exterior wall is a CMU wall assembly consisting of a **masonry wall**

(203mm), a cement board (12mm), EPS (graphite enhanced, 80mm), and stucco (6mm), resulting in a **U-value of 0.329 W/(m²K)**.

High-Performance Window & Glazing

- The exposed steel frame is filled with extensive floor-to-ceiling insulating glass elements.
- A **high-performing curtain wall with double glazing** and a **solar heat gain coefficient of 0.22** allows only **22% of solar radiation** to enter the building thus significantly **reducing the heat transfer into the interior**, resulting in further **reduction of cooling loads**.

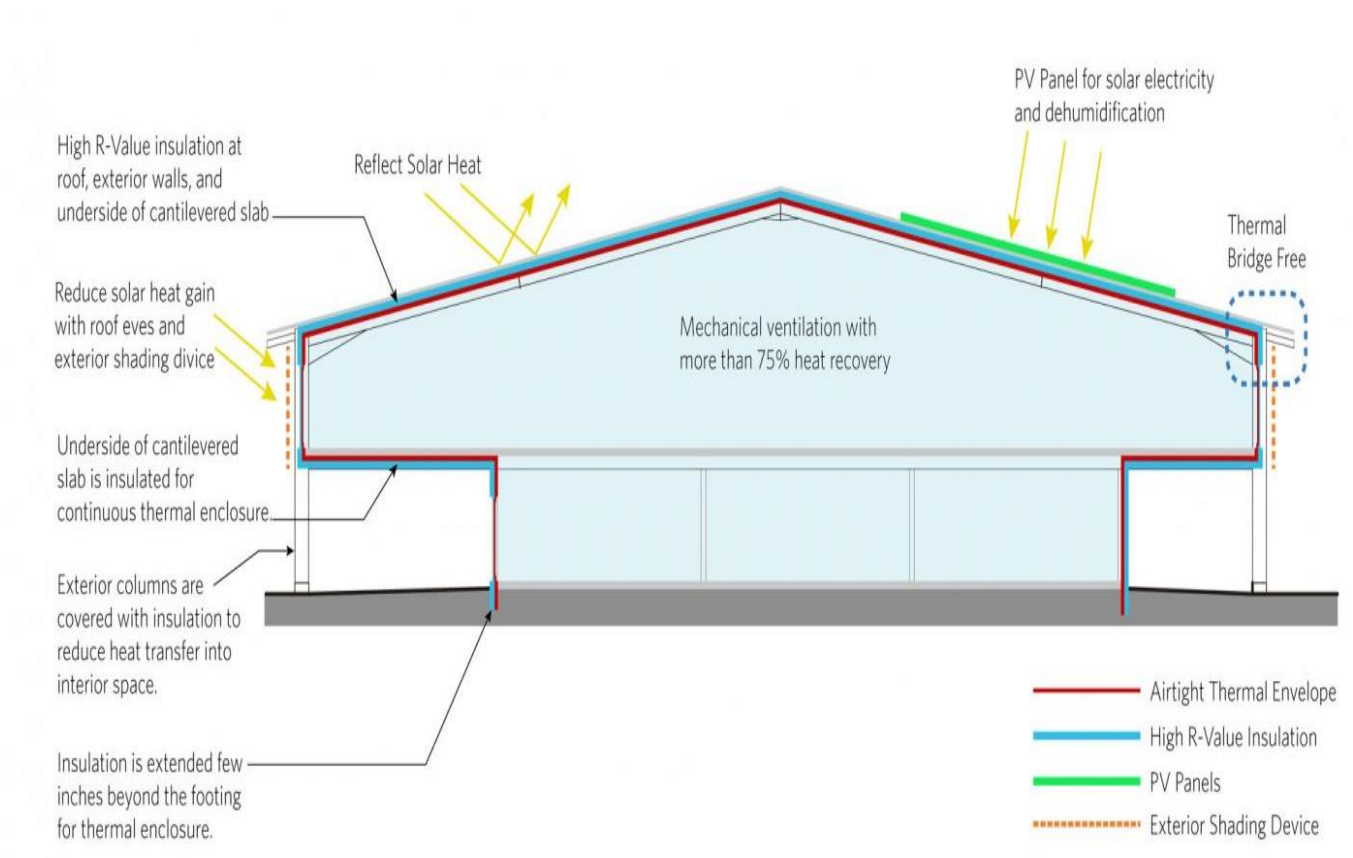
High performance windows and doors



INSULATED ROOF

- A new metal prefabricated roof consists of **120 mm thick** sandwich panels with a **polyurethane rigid (PUR)** foam insulating core and an **outer heat-reflecting coating**.
- This roof assembly results in a thermal transmittance **U-value of 0.182 W/(m²K)**, largely contributing towards keeping the tropical heat away from the interior.
- Installed rooftop **solar photovoltaics generate approximately 11% of the energy requirement of the building**.
- The estimated generation is approximately 4,8340 kWh/yr, which is **19 kWh /(m²yr)** based on the projected area of **2,549 m²**

Insulated roof assembly with solar panels



External Shading & Overhangs:

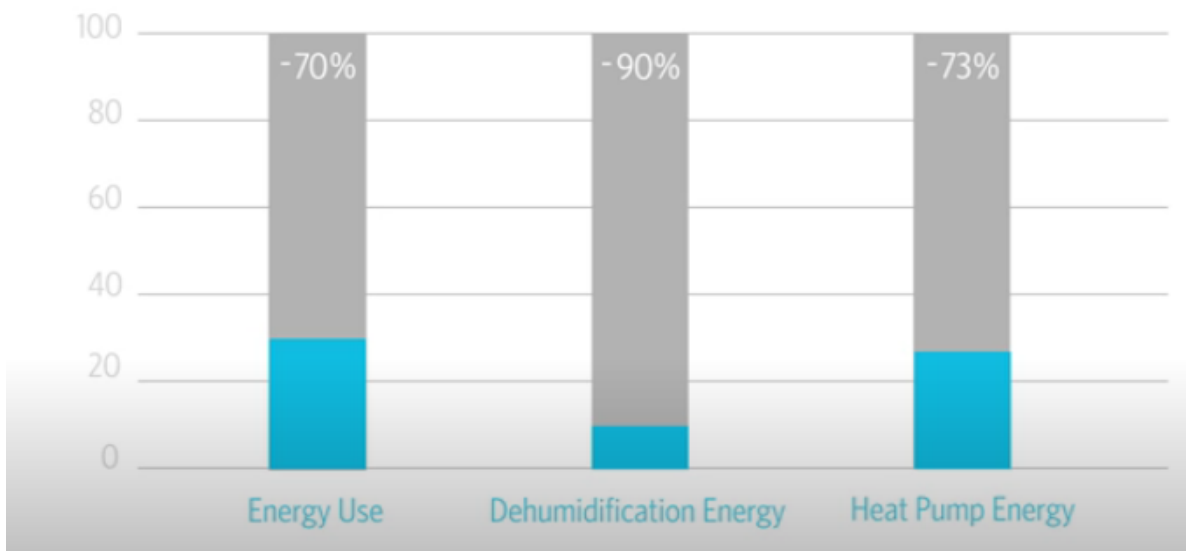
Strategically designed overhangs and decorative external colored glass panels serve as sun protection screens to reduce the overall heat gain into the building

Thermal Bridge:

To minimize the thermal bridging, a fluid-applied thermal break is used at strategic connections to carefully seal the envelope.



ENERGY REDUCTION



THERMAL ENVELOPE

Exterior wall

The exterior wall is a CMU wall consisting of a masonry wall (203mm), a cement board (12mm), EPS (Graphite Enhanced) (80mm) and stucco (6mm).

U-value = $0.329 \text{ W/(m}^2\text{K)}$

Basement floor / floor slab

The floor slab is made of concrete (152mm).

U-value = $5.795 \text{ W/(m}^2\text{K)}$

Roof

The material used for the roof is metal consisting of sandwich panels (120mm).

U-value = $0.182 \text{ W/(m}^2\text{K)}$

2. PT-UNGARAN SARI GARMENTS (PA6&7) ,SEMARANG, INDONESIA

Location	Semarang, Indonesia
Coordinates	7°S, 110°N
Occupancy Type	Manufacturing
Typology	New Construction
Climate Type	Tropical Monsoon
Project Area	17,425 m ²
Date of Completion	2018
Grid Connectivity	Grid-connected
EPI	103 kWh/m ² /yr
Architect	NC Design & Associates, Bali
MEP & Architect of record	PT Cipta Prima Sejahtera, Java Tengah, Indonesia
Energy Consultants	EDS Pvt Ltd



- Pringapus 6&7 (also called PA6&7) is a readymade garment manufacturing facility located near Semarang in Central Java province of Indonesia.
- The facility is part of an existing campus of PT Ungaran Sari Garments with five operational manufacturing facilities (PA1 – PA5), and a canteen
- PA6&7 is spread over two floors with identical functional arrangement for garment manufacturing.
- PTU Sari Garments 6&7 facility is the world's highest-scoring LEED NC v2009 project, under the Industrial Manufacturing space type.



- The facility has achieved an energy cost savings of **51% compared to the ASHRAE 90.1.2007 base case comparison.**
- The building is expected to perform **49%** better than a conventional factory building in the region. The project has **200KWp roof top solar** system which offsets **15% of total energy cost of the project**
-

▼ SUSTAINABLE SITES	25 / 26	
▼ WATER EFFICIENCY	10 / 10	
▼ ENERGY & ATMOSPHERE	35 / 35	
▼ MATERIAL & RESOURCES	7 / 14	
▼ INDOOR ENVIRONMENTAL QUALITY	14 / 15	
▼ INNOVATION	6 / 6	
▼ REGIONAL PRIORITY CREDITS	4 / 4	

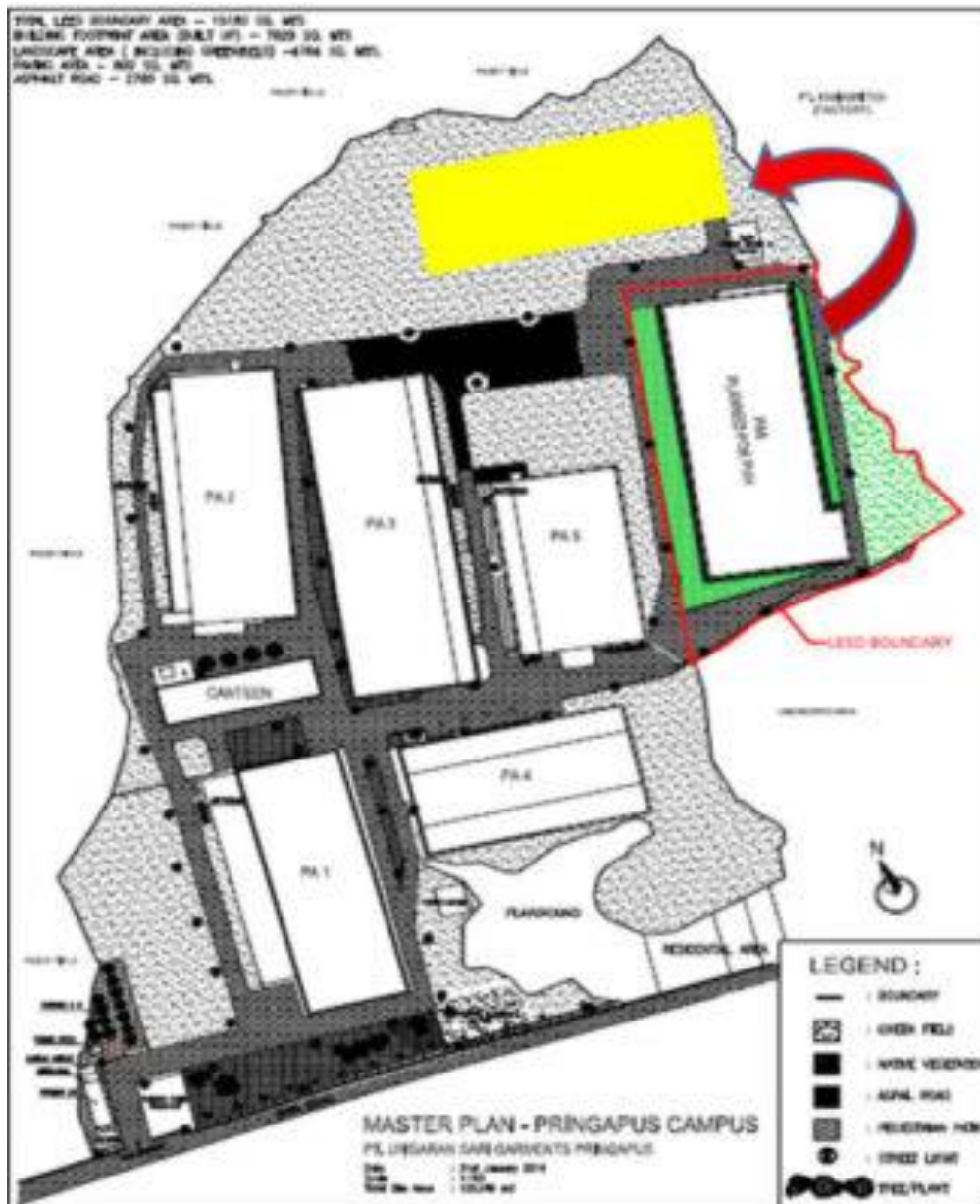


Orientation

- The initial design idea was to have a facility with the longer façade facing east-west.
- However, after several deliberations, the design team decided to orient the **longer facades along the north-south direction**.
- This effectively reduced **direct heat gain from the west facade and allowed more diffused light from north** (the project is located in the southern hemisphere).

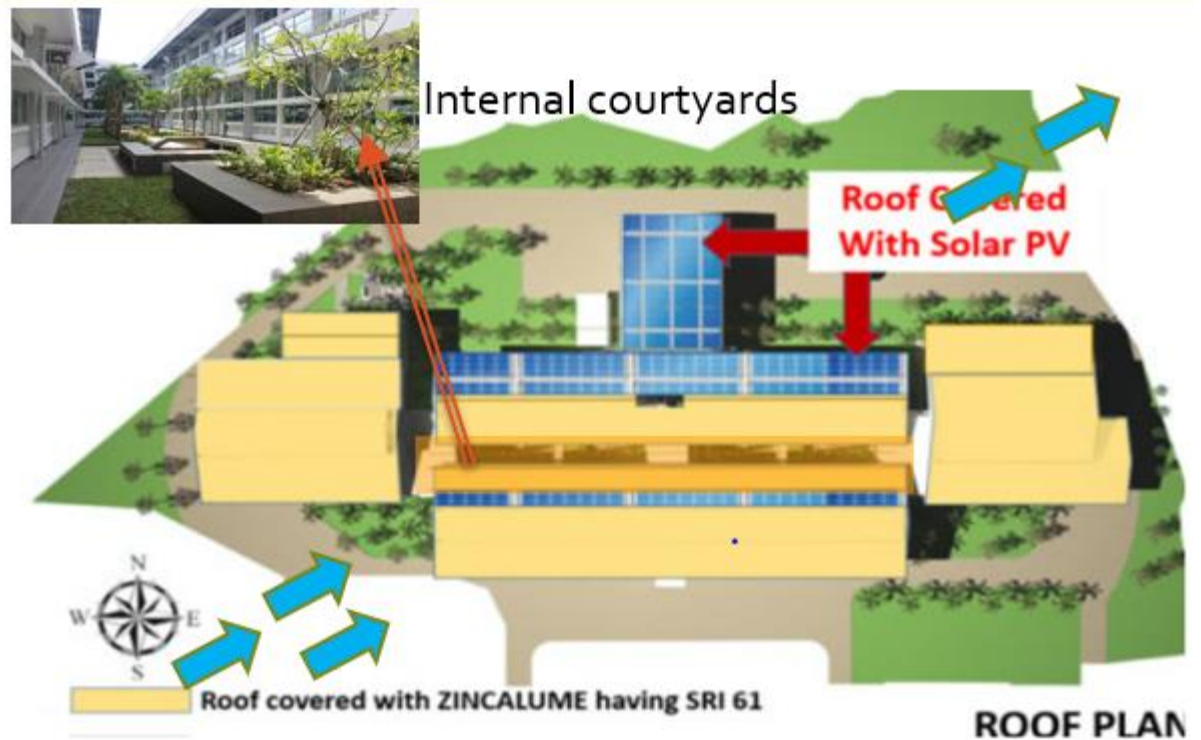
Climate Responsive Design

- As tropical buildings need to limit their exposure on east and west sides, the optimum form is **inevitably rectangular**, with the longer facades facing north south.
- This also helps in achieving shallow floor plans that allow **natural cross ventilation**. For this building, a shallow floor plate was achieved through **incorporating two large courtyards that broke the geometry**.



Form & Massing

- The overall form of the building is rectangular with two intensely landscaped courtyards.
- The courtyard design was effective enough to reduce the building depth to **under 30 m** from an initial depth of 50 m.
- The prevalent wind direction is from **south-west to north-east**.
- The building was designed to be **naturally ventilated having cross ventilation provisions in the north-south façade** that helps achieve the comfort conditions



Façade & Envelope

- The building façade has been **designed to maximize diffused daylight intake**.
- **Light shelves effectively reflect the sunlight off their surfaces** and ensure a **more even and deeper distribution of daylight**.
- A **fixed ventilation louver system provision** – below sill and above lintel level – has helped the facility achieve **comfort conditions indoor**



Ventilation Design

- The building is completely *naturally ventilated*.
- **Operable windows have been provided to ensure occupant comfort.** The areas of operable window meet the requirements of ASHRAE Standard



Artificial Lighting Design

- 100% of the lighting requirement is met by LEDs.
- Interior LPD is 0.34 (W/ft²) as against ASHRAE 90.1 2007 baseline 1.3 (W/ft²).
- Artificial lights have been carefully selected to ensure high color rendering index (CRI) values, low glare, and low flickering. All task lighting is controllable through dimmers having 10 levels of lux setting.
- An efficient combination of ambient and task lighting has helped the project reduce light power density drastically leading to significant energy savings.
- The project deploys state-of-the-art efficient manufacturing equipment which further reduces the internal loads and energy use.



Ambient and task lighting



SUSTAINABLE SITES

AWARDED: 25 / 26

SSp1	Construction activity pollution prevention	REQUIRED
SSc1	Site selection	1 / 1
SSc2	Development density and community connectivity	5 / 5
SSc3	Brownfield redevelopment	0 / 1
SSc4.1	Alternative transportation - public transportation access	6 / 6
SSc4.2	Alternative transportation - bicycle storage and changing rooms	1 / 1
SSc4.3	Alternative transportation - low-emitting and fuel-efficient vehicles	3 / 3
SSc4.4	Alternative transportation - parking capacity	2 / 2
SSc5.1	Site development - protect or restore habitat	1 / 1
SSc5.2	Site development - maximize open space	1 / 1
SSc6.1	Stormwater design - quantity control	1 / 1
SSc6.2	Stormwater design - quality control	1 / 1
SSc7.1	Heat island effect - nonroof	1 / 1
SSc7.2	Heat island effect - roof	1 / 1
SSc8	Light pollution reduction	1 / 1



WATER EFFICIENCY

AWARDED: 10 / 10

WEp1	Water use reduction	REQUIRED
WEc1	Water efficient landscaping	4 / 4
WEc2	Innovative wastewater technologies	2 / 2
WEc3	Water use reduction	4 / 4



ENERGY & ATMOSPHERE

AWARDED: 35 / 35

EAp1	Fundamental commissioning of building energy systems	REQUIRED
EAp2	Minimum energy performance	REQUIRED
EAp3	Fundamental refrigerant Mgmt	REQUIRED
EAc1	Optimize energy performance	19 / 19
EAc2	On-site renewable energy	7 / 7
EAc3	Enhanced commissioning	2 / 2
EAc4	Enhanced refrigerant Mgmt	2 / 2
EAc5	Measurement and verification	3 / 3
EAc6	Green power	2 / 2



MATERIAL & RESOURCES

AWARDED: 7 / 14

MRp1	Storage and collection of recyclables	REQUIRED
MRc1.1	Building reuse - maintain existing walls, floors and roof	0 / 3
MRc1.2	Building reuse - maintain interior nonstructural elements	0 / 1
MRc2	Construction waste Mgmt	2 / 2
MRc3	Materials reuse	0 / 2
MRc4	Recycled content	2 / 2



MATERIAL & RESOURCES

CONTINUED

MRc5	Regional materials	2 / 2
MRc6	Rapidly renewable materials	0 / 1
MRc7	Certified wood	1 / 1



INDOOR ENVIRONMENTAL QUALITY

AWARDED: 14 / 15

EQp1	Minimum IAQ performance	REQUIRED
EQp2	Environmental Tobacco Smoke (ETS) control	REQUIRED
EQc1	Outdoor air delivery monitoring	0 / 1
EQc2	Increased ventilation	1 / 1
EQc3.1	Construction IAQ Mgmt plan - during construction	1 / 1
EQc3.2	Construction IAQ Mgmt plan - before occupancy	1 / 1
EQc4.1	Low-emitting materials - adhesives and sealants	1 / 1
EQc4.2	Low-emitting materials - paints and coatings	1 / 1
EQc4.3	Low-emitting materials - flooring systems	1 / 1
EQc4.4	Low-emitting materials - composite wood and agrifiber products	1 / 1
EQc5	Indoor chemical and pollutant source control	1 / 1
EQc6.1	Controllability of systems - lighting	1 / 1
EQc6.2	Controllability of systems - thermal comfort	1 / 1
EQc7.1	Thermal comfort - design	1 / 1
EQc7.2	Thermal comfort - verification	1 / 1
EQc8.1	Daylight and views - daylight	1 / 1
EQc8.2	Daylight and views - views	1 / 1



INNOVATION

AWARDED: 6 / 6

IDc1	Innovation in design	1 / 1
IDc2	LEED Accredited Professional	1 / 1



REGIONAL PRIORITY CREDITS

AWARDED: 4 / 4

EAc1	Optimize energy performance	1 / 1
EAc3	Enhanced commissioning	0 / 1
EAc5	Measurement and verification	0 / 1
WEc1	Water efficient landscaping	1 / 1
WEc2	Innovative wastewater technologies	1 / 1
WEc3	Water use reduction	1 / 1

TOTAL	101 / 110
--------------	------------------

STAR GARMENT INNOVATION CENTER KATUNAYAKE, SRI LANKA

- First passive house rated building
- Passive and active system
- Thermal insulation
- Airtightness
- High performance windows
- High performance heating and ventilating systems
- Natural ventilation
- Energy usage reduced to 70 percentage
- Solar panels on the roof
- THERMAL ENVELOPE

WALL: Masonry wall, cement board

FLOOR: Floor slab of concrete

ROOF: Prefabricated roof with insulating material PUR

PT-UNGARAN SARI GARMENTS (PA6&7) SEMARANG, INDONESIA

- LEED platinum certified building
- New construction
- Orientation: long walls in north south direction
- Form: rectangle
- A shallow floor plate was achieved through **incorporating two large courtyards that broke the geometry.**
- Naturally ventilated
- Light shelves effectively reflect the sunlight off their surfaces and ensure a more even and deeper distribution of daylight.
- Solar panels used on roof to reduce energy

PASSIVE STRATEGIES FROM MAHONEY TABLE

INFERENCE

LAYOUT

1. ORIENTATION NORTH AND SOUTH [LONG AXIS EAST - WEST]

2. COMPACT COURTYARD PLANNING

SPACING

2. OPENING SPACING FOR BREEZE PENETRATION.

AIR MOVEMENT

3. ROOMS SINGLE BANKED PERMANENT PROVISION FOR THE AIR MOVEMENT.

OPENING

4. LARGE OPENING 40-80%.

OPENING POSITION

5. IN NORTH AND SOUTH WALLS AT BODY HEIGHT OF THE WINDWARD SIDE.

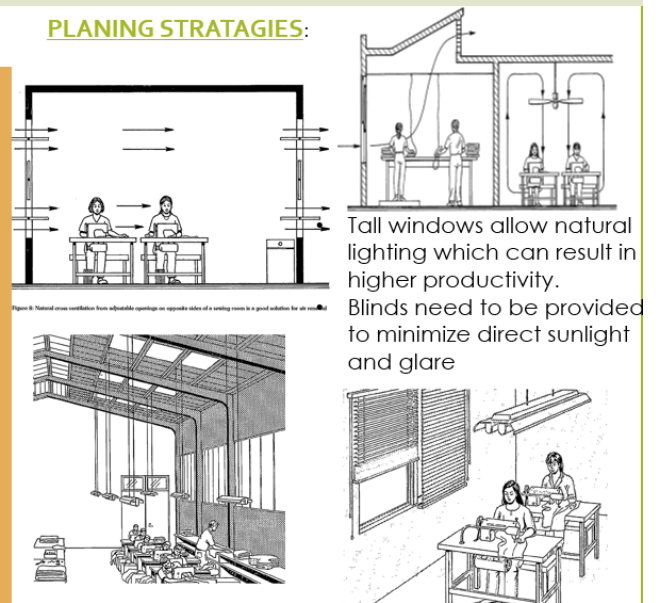
WALLS

6. LIGHT, REFLECTIVE SURFACE, CAVITY

ROOF

7. LIGHT, WELL INSULATED

PLANING STRATEGIES:



Tall windows allow natural lighting which can result in higher productivity.

Blinds need to be provided to minimize direct sunlight and glare

- Clean skylights and high windows contribute to a good general natural lighting and provide good colour rendering

Source:improving working conditions and productivity in the garment industry

PLANING STRATEGIES:

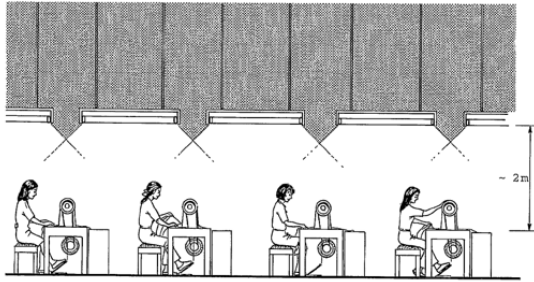


Figure 9: Correct positioning of lights in the sewing area when fluorescent tubes are perpendicular to the heads of machines. Note that tubes are drawn without shades for clarity but shades should not be removed

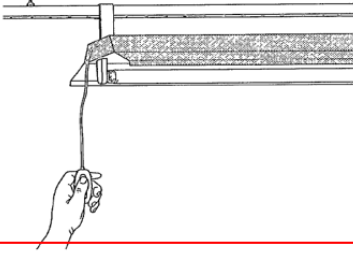


Figure 10: Individual switches for every single workstation could save electricity consumption

- Make full use of daylight.
- Avoid glare.
- Choose an appropriate visual task background.
- Find the right place for light sources.
- Use the right lighting device and fixture.
- Avoid shadows.
- Ensure regular maintenance.

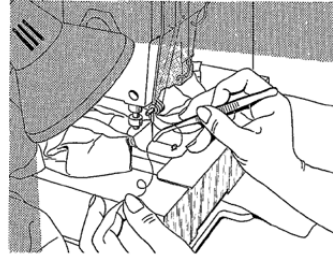


Figure 15: Precision tasks or older workers may need extra local lighting



Figure 16: A bench light fitting for special workstations like quality control or packing tasks

Source:improving working conditions and productivity in the garment industry

Tamil nadu combined development and building rules, 2019 Ecbc- energy conservation building code

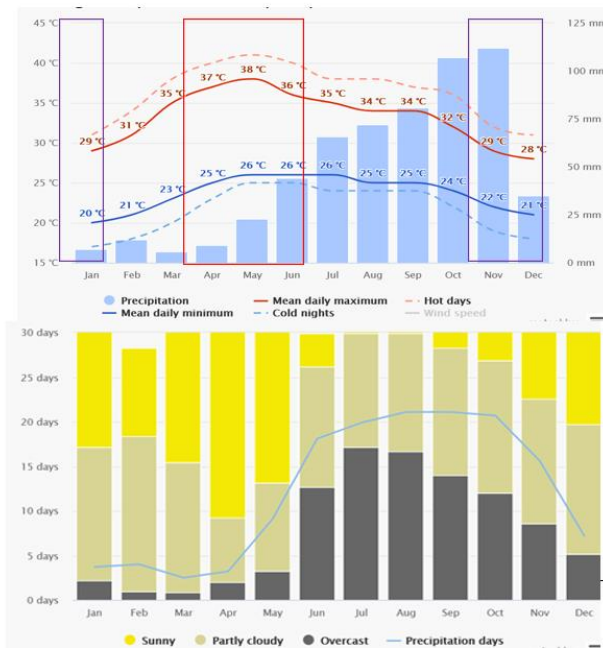
Sl.No.	Description	Category of industries		
		Cottage Industries	Green & Orange industries	Red industries (Special & Hazardous)
A.	Minimum road width	7m.	7m.	7m.
B.	Maximum Height	18.30m.	18.30m	18.30m.
C.	Maximum FSI	1.50	1.50	1.50
D.	Minimum Setback	Where Street Alignment/new road is prescribed, it shall be from that street alignment/new road line. In the case of others, it shall be from the property boundary.		
(i)	Front Setback	Abutting road width less than 9m	Front Setback 1.5m	6.0m
		9m. to 18m.	3.0m.	
		18m. to 30.50m.	4.5m	
		More than 30.5m.	6.0m.	
(ii)	Side Setback	1.50m.	3.0m.	6.0m.
(iii)	Rear Setback	Nil	2.0m.	6.0m.
E.	Structures permissible in the minimum prescribed Front set back, Side setback and Rear set back are given in the rule 28. In addition, incidental structures such as Gate pillars, servant room, watch man booth, cycle stand and toilets with height not exceeding 4m are permissible in these minimum prescribed setback spaces.			
F.	Parking spaces shall be provided within the site conforming to standards prescribed in the Annexure - IV.			
G.	Rainwater harvesting provisions as prescribed in the Annexure - XXII.			

Table:11 Sanitation Requirements for Factories

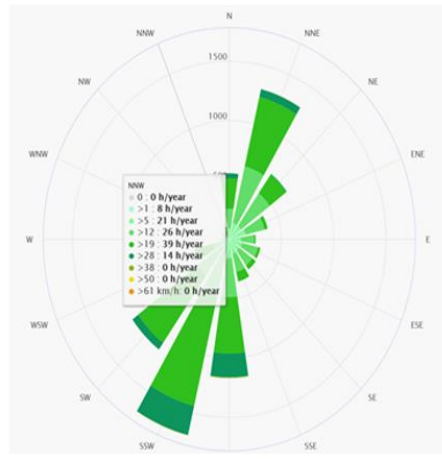
Sl. No.	Sanitary Unit	For Male Personnel	For female Personnel
1.	Water Closet	1 for 15 persons 2 for 16-35 persons 3 for 36-65 persons. 4 for 66-100 persons. For 101 to 200 persons add at rate of 3%. From over 200 persons, add at the rate of 2.5%.	1 for 1-12 persons 1 for 13-25 persons. 2 for 26-40 persons. 3 for 41-57 persons. 4 for 58-77 persons. 5 for 78-100 persons. For 101 to 200 persons, add at the rate of 5%. From over 200 persons add at the rate of 4%.
2.	Ablution Taps	One in each W.C	One in each W.C.
3.	Urinals	Nil upto 6 persons 1 for 7-20 persons 2 for 21-45 persons 3 for 46-70 persons 4 for 71-100 persons From 101 to 200 persons add at the rate of 3%; for over 200 persons add at the rate of 2.5%.	--
4.	Washing Taps with draining arrangement	One for every 25 persons or part thereof	
5.	Drinking Water Fountains	One for every 100 persons with a minimum of one on each floor	
6.	Baths Preferably Showers	As required for particular trade or occupation	
7.	Emergency shower and eye wash fountain	1 per every shop floor per 500 persons	

CLIMATE STUDY

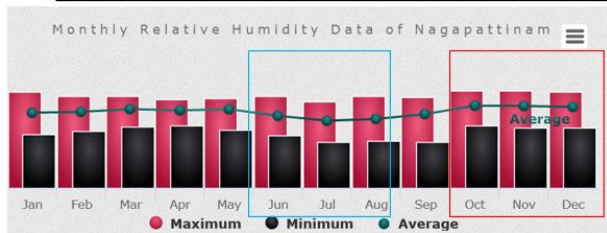
SUSTAINABLE READY MADE GARMNET FACTORY FOR WARM AND HUMID CLIMATE



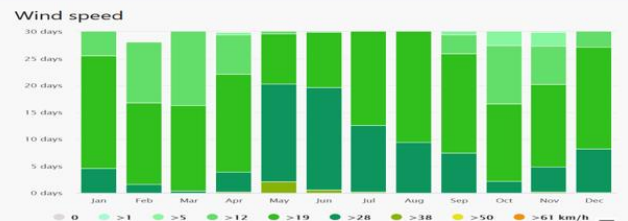
- Average maximum temperature of the district is **32°C**
- The average minimum temperature is **24.6°C**.
- **Dust storms, whirl winds and dusty winds** Blow from various quarters towards the **end of may**.



- Major wind direction is from the **south west and north east**
- The district receives rainfall under the influence of both **southwest and northeast monsoon**. The district receives **rainfall almost throughout the year**.



Parameter	Relative Humidity, %			Standard Deviation
	Minimum	Maximum	Average	
January	52.4	94.5	73.5	± 9.1
February	55.7	90.2	74.5	± 8.1
March	60.5	90.2	77.1	± 7.6
April	61.2	86.4	75.9	± 6.5
May	57.3	88.0	77.0	± 6.6
June	51.5	89.9	70.5	± 8.9
July	44.9	84.4	65.7	± 9.1
August	45.7	89.5	67.5	± 9.6
September	44.6	89.2	72.3	± 9.5
October	61.1	95.8	80.5	± 7.3



- The relative humidity ranges from **80 - 79% [high -October to December]**
- The southwest monsoon rains occur from **June to September**. the air is calm and undisturbed.
- The Northeast monsoon which starts in **October and ends in December** contributes about 60% of the total annual rainfall.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Air temperature												
Radiation												
Relative humidity												
Airflow												

Environmental matrix Table

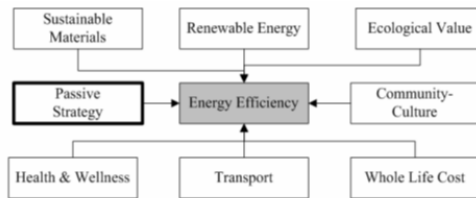
Table 5.66 Design recommendations for the industrial building

Parameter	Jodhpur (Hot & Dry Climate)	Mumbai (Warm & Humid Climate)	Pune (Moderate Climate)	New Delhi (Composite Climate)	Srinagar (Cold & Cloudy Climate)	Leh (Cold & Sunny Climate)
Building Orientation	NE-SW	NE-SW	NW-SE	E-W	E-W	E-W
Glazing Type	Reflective coated glass (single pane)	Reflective coated glass (single pane)	Reflective coated glass (single pane)	Reflective coated glass (double pane)	Reflective coated glass (single pane)	Clear glass (double pane)
Shading	20	20	20	10	20	0
Wall Type	Concrete block	Concrete block	Concrete block	Brick	Concrete block	Brick wall with thermocol insulation
Roof Type	RCC with bitumen felt waterproofing	RCC with bitumen felt waterproofing	RCC with bitumen felt waterproofing	RCC with brick-bat-coba waterproofing	RCC with PUF insulation	RCC with PUF insulation
Surface Colour (External)	White	White	White	Cream	White	Grey
Air exchanges (ach)	12	12	12	12	12	3

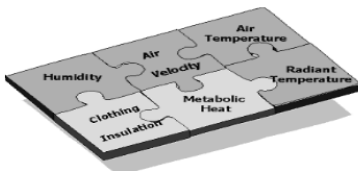
NE-SW: Northeast-southwest; NW-SE: Northwest-southeast; E-W: east-west

Thermal condition in RMG factories has to be considered carefully mainly because of the **high occupant density** in production spaces and the negative influences that an **unsatisfactory thermal environment has on performance** and well being of the workers.

Components of energy efficiency

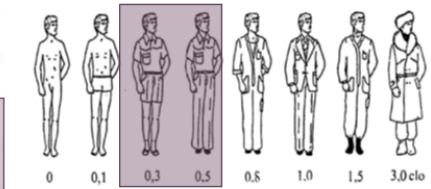
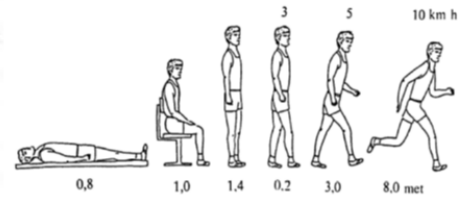


Passive design features are discussed to achieve thermal comfort level
Factors determining thermal comfort include:



Metabolic rate Metabolic Rate of Different Activities (Fanger, 1986)

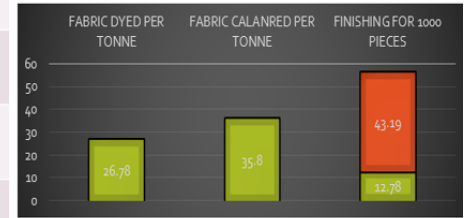
Activity	Heat Generation W/m ²	met
Miscellaneous occupational activities		
Cooking	90-115	1.5-1.9
House cleaning	115-200	1.9-3.3
Heavy limb movement	130	2.2
Handling 49 kg bags	235	3.9
Pick and shovel work	235-280	3.9-4.7
Machine Work		
Sawing (table saw)	105	1.8
Light (electrical industry)	115-200	1.9-3.3
Heavy	235	3.9
RMG Factory works		
Fabric cutting	105	1.8
Bias cutting	85	1.4
Sewing	85	1.4
Packing	85	1.4
Stamping	100	1.7
Button sewing	85	1.4



Light summer cloth is common in warm and humid environments have a clo value of 0.35 to 0.5 (Mallik, 1994).

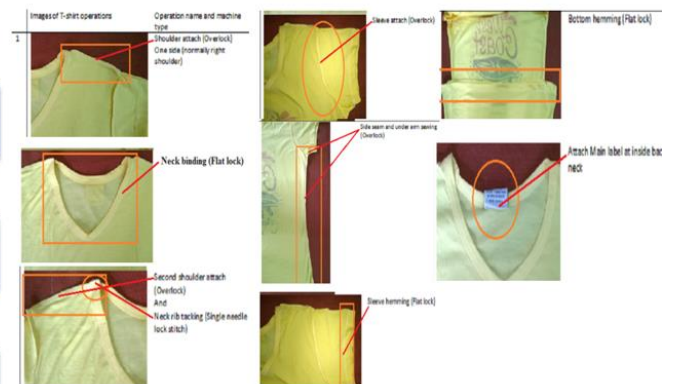
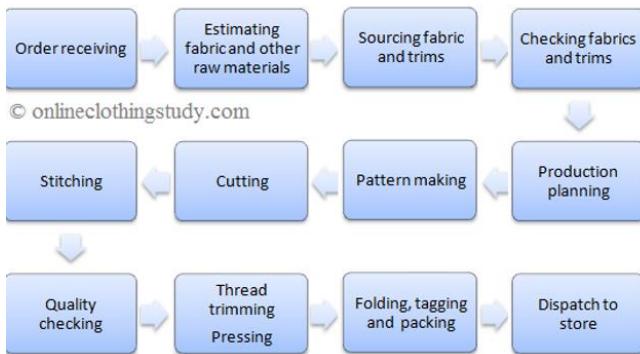
SOURCE: Some Typical Values of Metabolic Rate (Butera, 1988; Gouvêa et al, 2006)

ENTRY/EXIT	PRODUCTION UNITS	
Parking Space	Loading and unloading bay	Stitching section
Office	Receiving and issuing area	Printing section
Kitchen & dining	Office	Pressing & ironing section
Production unit	Fabric storage & checking	Packing section
Waste storage & scrap	Rejection store	Display section
	Toilets and changing rooms	Storage unit
	Cutting section	



PROCESS FLOW

T-Shirt Manufacturing Process Flow



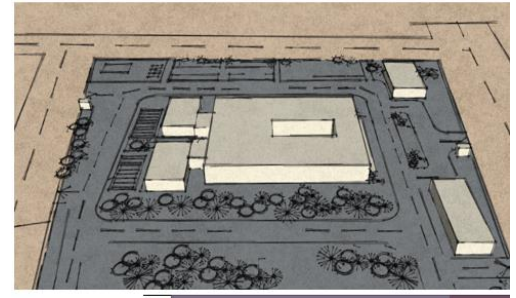
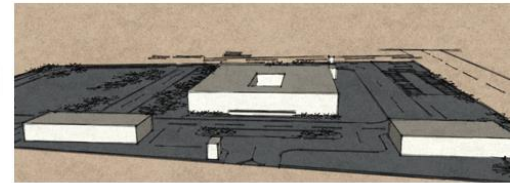
SITE PLAN



SUSTAINABLE READY MADE GARMNET FACTORY FOR WARM AND HUMID CLIMATE

Site area- 12acres

Build up area- 6293 Sq.m

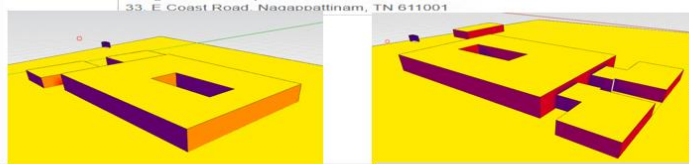


FORMIT ANALYSIS

BTU/sq ft 0 151 302
Range: Month - Apr Method: Peak
33 E Coast Road, Nagaopattinam, TN 611001

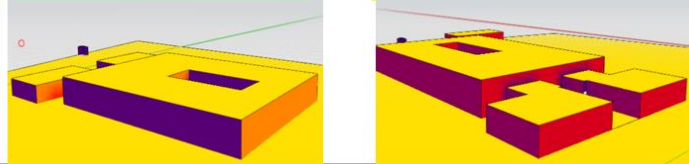
INFERENCE

MAY



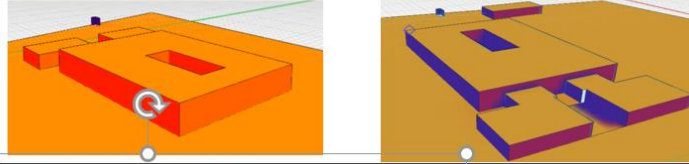
E -233.7 W-119 ROOF-289.5
N-60.51 S-31.39
• North and south façade has less radiation
• East and west has high radiation

AUGUST



E -230.3 W-120.4
N-58.97 S-24.13 ROOF-284.2
• North and south façade has less radiation
• East and west has high radiation

DECEMBER



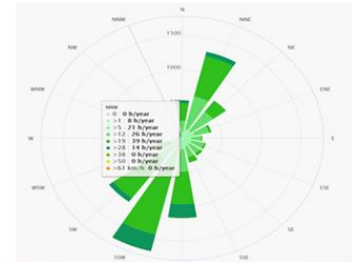
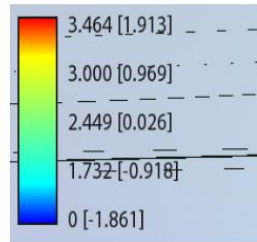
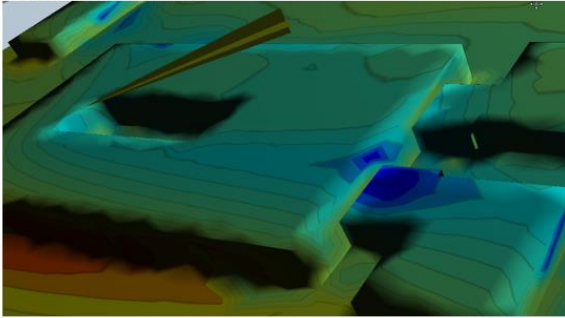
E -208.9 W-93.73
N-19.57 S-168.5 ROOF-235.3
• North and west façade has less radiation
• East and South has high radiation

ANALYSIS - SOLAR RADIATION

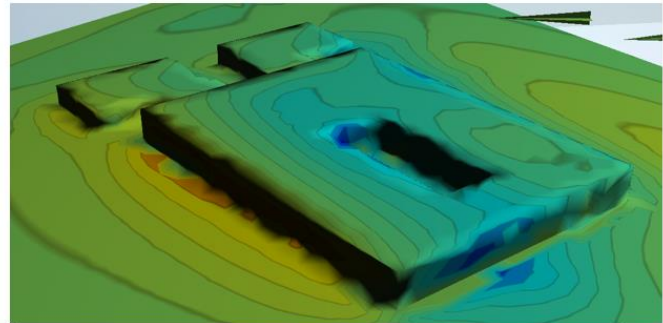
ANALYSIS - WIND ANALYSIS

SUSTAINABLE READY MADE GARMNET FACTORY FOR WARM AND HUMID CLIMATE

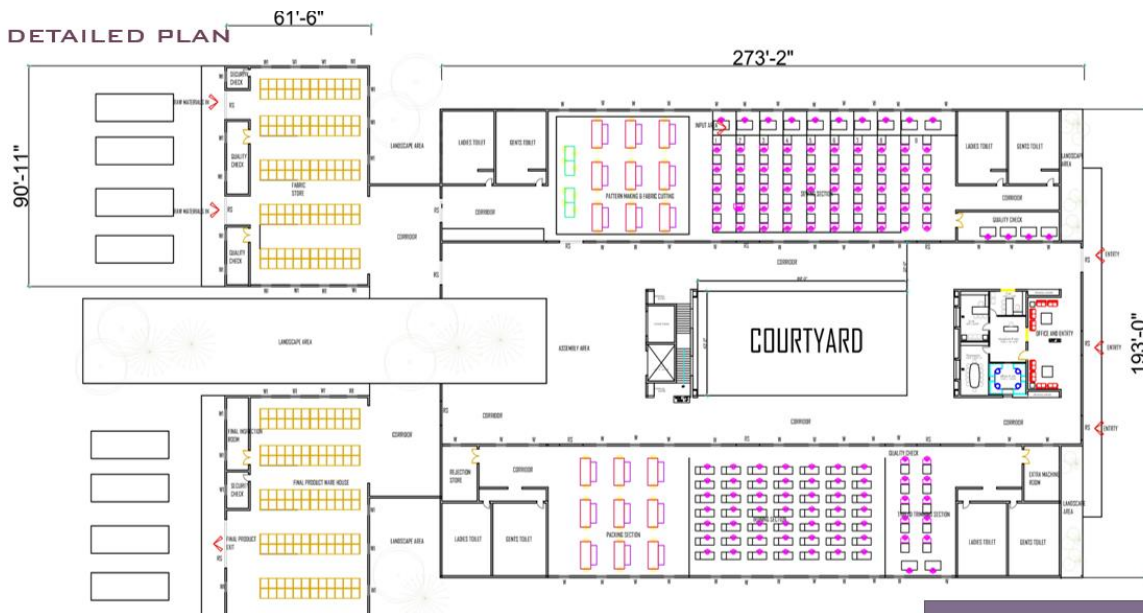
NORTH EAST WIND



- Wind speed is to 2 m/s
- Wind flow is obtained in the building envelope
- north West side on the corridor area wind flow is very less
- Wind flow is achieved through out the year
- Wind flow is higher [3m/s] in north side while north east winds
- Wind flow is higher [3m/s] in the south side while in the south west wind

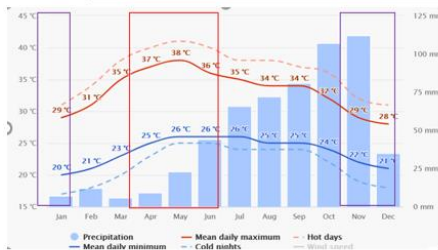


SOUTH WEST WIND

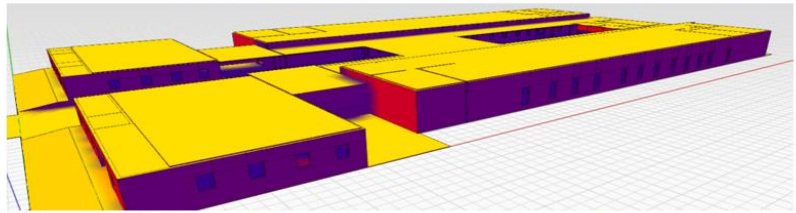


ANALYSIS - SOLAR RADIATION

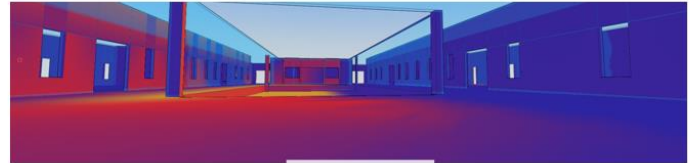
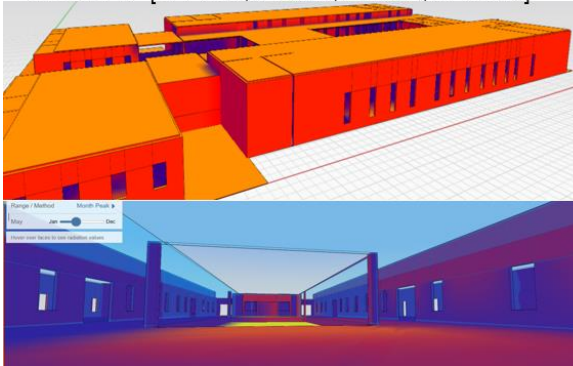
SUSTAINABLE READY MADE GARMNET FACTORY FOR WARM AND HUMID CLIMATE



MAY [N-66.67,S-27.81,E-225.4W-111]



DECEMBER [N-19.47,S-168.5,E-208.9,W-93.73]



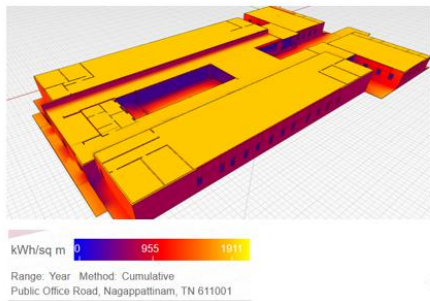
- Critical area is south and east façade in hot and cold month
- Areas near the corridor, landscape area and courtyard has much less radiation in both months

BTU/sq ft 0 151 302
Range: Month - Dec Method: Peak
Public Office Road, Nagappattinam, TN 611001

ANALYSIS - SOLAR, WIND & LIGHTING

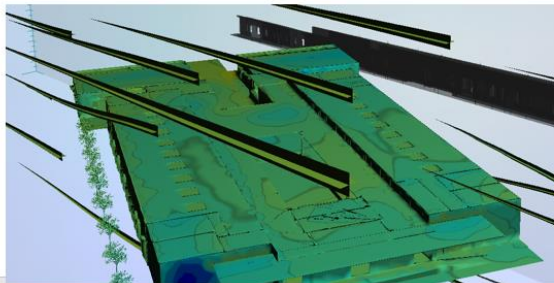
SUSTAINABLE READY MADE GARMNET FACTORY FOR WARM AND HUMID CLIMATE

YEARLY CUMULATIVE

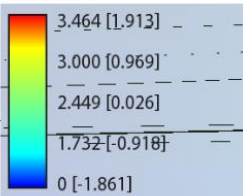


N- 458.1 S-701.3
E-1149 W-527.5

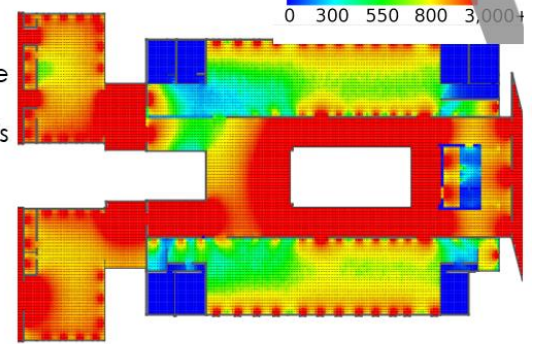
- fabric and store and ware house area in the west side is natural ventilation is high [1000 lux]
- Production unit near the windows lux is higher and center core lux is lower
- Near the courtyard area lux is higher



In south block, north west lux is lower



MAY



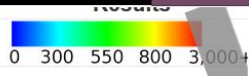
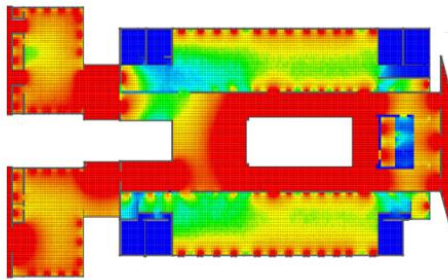
Avg: 7,576.3 lux
Max: 106,455.8 lux
Min: 0.0 lux

- Wind flow is achieved through out the year

ANALYSIS - SOLAR, WIND & LIGHTING

SUSTAINABLE READY MADE GARMNET FACTORY FOR WARM AND HUMID CLIMATE

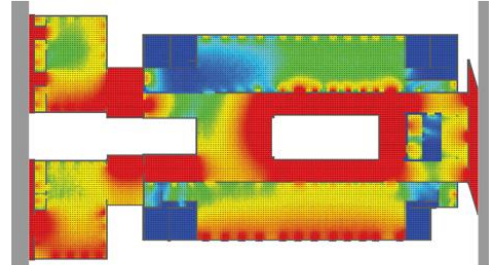
AUGUST



Avg: 7,486.9 lux
Avg/Min: ∞
Max: 105,581.6 lux
Min: 0.0 lux

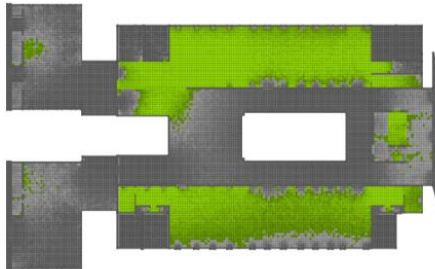
DECEMBER

- North block receives less lighting and south block receives a maximum lighting
- In store area, centre core has less lighting level



Avg: 6,246.2 lux
Avg/Min: ∞
Max: 80,487.3 lux
Min: 0.0 lux

UDI



Below Above

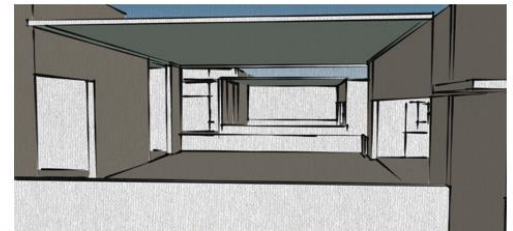
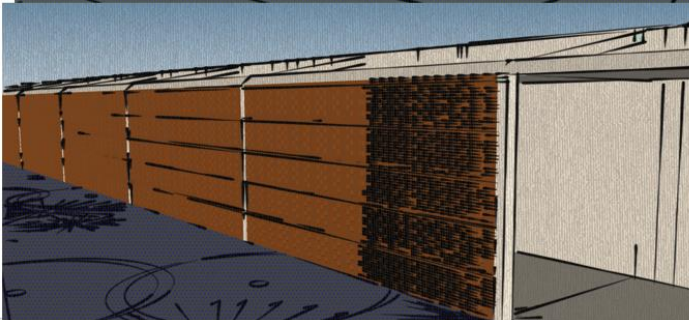
UDI-a (100 - 2000 lux): 36.87%
UDI-s (<100 lux): 8.52%
UDI-e (>2000 lux): 50.56%

- UDI- threshold- 100 to 2000 lux
- According to ecbc standards, udli average should be 50% and it does not comply with ecbc

ITERATION-1

SUSTAINABLE READY MADE GARMNET FACTORY FOR WARM AND HUMID CLIMATE

BUFFER SPACE WITH JALI WALL

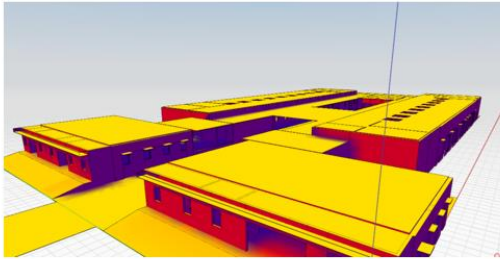


CANOPY IN THE EAST WALL

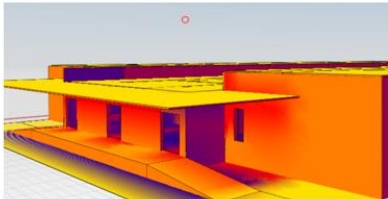
ITERATION - 1

SUSTAINABLE READY MADE GARMNET FACTORY FOR WARM AND HUMID CLIMATE

MAY [N-66.67,S-20.1,E-15.2,W-81.16]



- Front canopy in the east side
- Buffer space in the south side

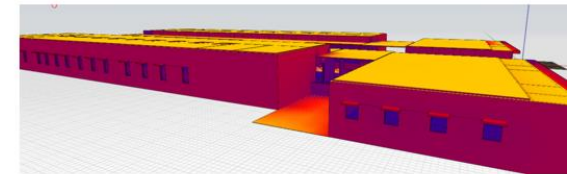
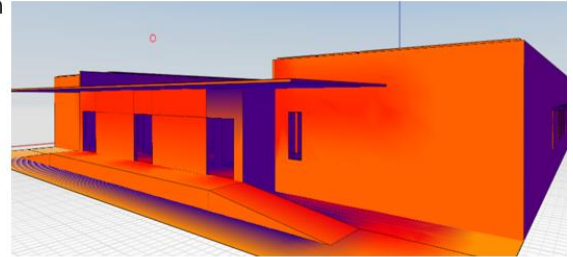


- Canopy in the east side reduces the radiation in the east façade
- Buffer space is south with jalli wall reduces the radiation in the december



0 151 302 kWh/sq m
nth - Dec Method: Peak
e Road, Nagappattinam, TN 611001

DECEMBER [N-66.67,S-20.1,E-15.2,W-81.16]



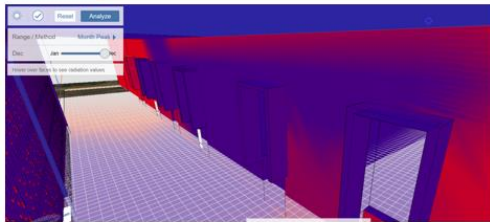
Yearly cumulative

0 955 1191 kWh/sq m
Range: Year Method: Cumulative
Public Office Road, Nagappattinam, TN 611001

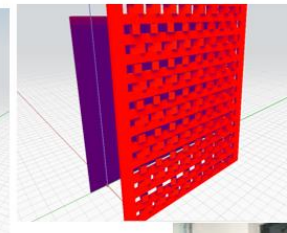
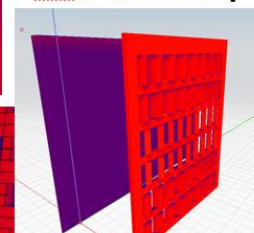
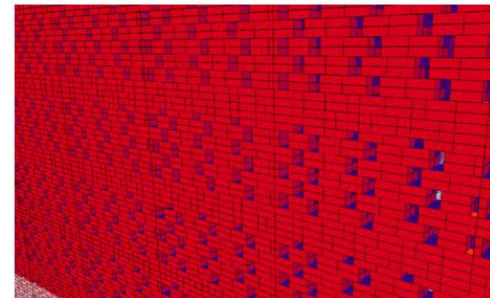
ITERATION - 1

SUSTAINABLE READY MADE GARMNET FACTORY FOR WARM AND HUMID CLIMATE

Critical area is south and east facade



- Buffer space with landscape area is given in the south side for reduced radiation [yearly cumulative s-288.1]
- South wall is radiation is much reduced due to jalli wall buffer space [normal s- 701 Jali wall s-288.14]



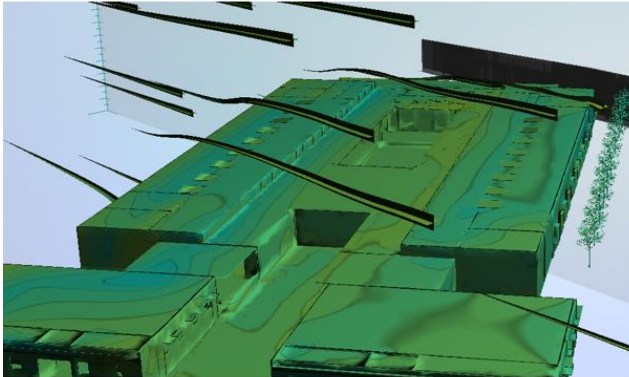
Different type of Jali patterns
Tried for reduced radiation

Jali walls which allow controlled passed of air and light into the interior space. The jalis also ensure a constant flow of breeze into the interior, allowing the occupant comfort in the hot humid climate.

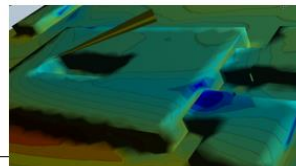
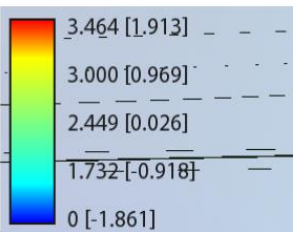
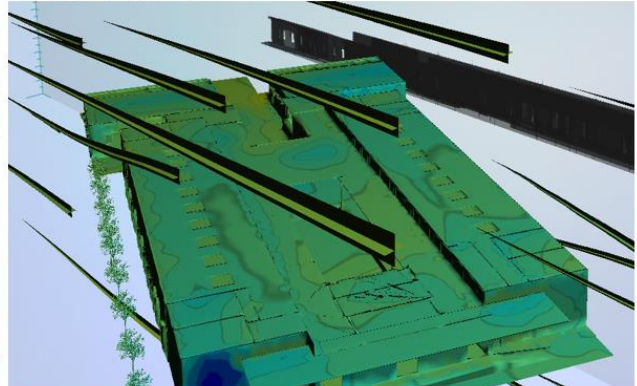


0 955 1191 kWh/sq m
Range: Year Method: Cumulative
Public Office Road, Nagappattinam, TN 611001

NORTH EAST WIND



SOUTH WEST WIND



BASE CASE

- Required wind flow is achieved through out the year [cross ventilation is provided in each area]
- Courtyard in the Centre ventilated through out the building

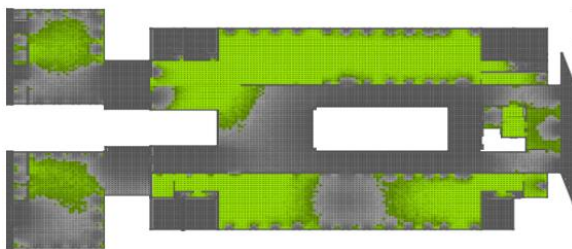
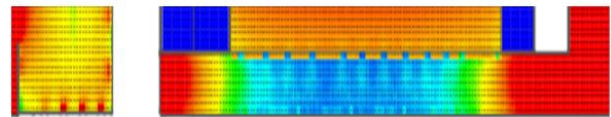
Table 4-1 Daylight Requirement

Building Category	Percentage of above grade floor area meeting the UDI requirement		
	ECBC	ECBC	SuperECBC
Business, Educational	40%	50%	60%
No Star Hotel	30%	40%	50%
Star Hotel			
Healthcare			
Resort	45%	55%	65%
Shopping Complex	10%	15%	20%
Assembly*	Exempted		

*and other buildings where daylighting will interfere with the functions or processes of 50% (or more) of the building floor area

4.2.3.1 Daylighting Simulation Method

Only BEE approved software shall be used to demonstrate compliance through the daylighting simulation method. Buildings shall achieve illuminance level between 100 lux and 2,000 lux for the minimum percentage of floor area prescribed in Table 4-1 for at least 90% of the potential daylight time. Illuminance levels for all spaces enclosed by permanent internal partitions (opaque, translucent, or transparent) with height greater or equal to 2 from the finished floor, shall be measured as follows:



UDI

LIGHTING LEVEL IS REDUCED IN THE BUFFER SPACE



UDI-s (<100 lux):

7.99%

UDI-e (>2000 lux):

49.45%

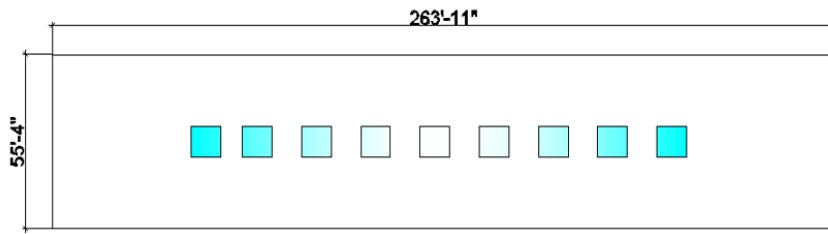
Lux level is reduced in the south façade by jalli wall

Window wall ratio 40 % is achieved and it compliance with ecbc standard for warm and humid climate

ROOF VENTILATION

SUSTAINABLE READY MADE GARMNET FACTORY FOR WARM AND HUMID CLIMATE

TYPICAL NORTH AND SOUTH BLOCK



4.3.4 Skylights

Skylights shall comply with the maximum U-factor and maximum SHGC requirements of Table 4-15. Skylight roof ratio (SRR), defined as the ratio of the total skylight area of the roof, measured to the outside of the frame, to the gross exterior roof area, is limited to maximum of 5% for ECBC Building, ECBC+ Building, and SuperECBC Building, when using the Prescriptive Method for compliance.

Table 4-15 Skylight U-factor and SHGC Requirements (U-factor in $W/m^2 \cdot K$)

Climate	Maximum U-factor	Maximum SHGC
All climatic zones	4.25	0.35

$SRR = \frac{\text{total skylight area}}{\text{gross exterior roof area}}$

$SRR = 73.3/1348.9$

$SRR = 5.3\%$

11,066 kWh/Year*

SOLAR PV PANELS

Month	Solar Radiation (kWh / m ² / day)	AC Energy (kWh)
January	6.41	1,130
February	6.64	1,047
March	6.85	1,176
April	6.14	1,011
May	5.23	910
June	5.05	865
July	4.91	865
August	4.82	848
September	5.56	938
October	4.65	813
November	4.08	706
December	4.18	756
Annual	5.38	11,065

Location and Station Identification

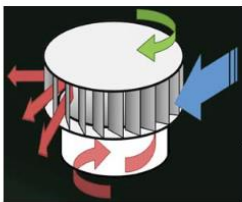
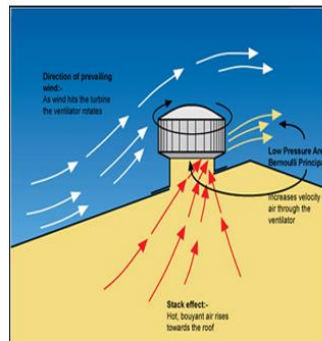
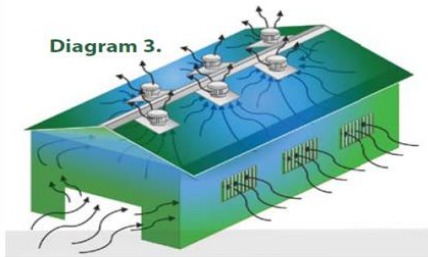
Requested Location	NAGAPATTINAM		
Weather Data Source	Lat, Lng: 10.65, 79.9	8.7 mi	
Latitude	10.65° N		
Longitude	79.90° E		

ROOF VENTILATION

SUSTAINABLE READY MADE GARMNET FACTORY FOR WARM AND HUMID CLIMATE

TURBO VENTILATORS

A properly ventilated building utilizing Green-vent Wind with adequate inlets, allowing fresh and cooler air to enter and hot & stale enter to exit.



CALCULATION FOR TURBO VENTILATORS

To Determine Number Of Ventilators Required:

$$\left\{ \frac{\text{Volume of shed} \times \text{No. Of Changes}}{60} \right\} / \text{Exhaust Capacity of Ventilator}$$

$$\text{Volume of Shed} = \text{Length} \times \text{Width} \times \text{Height}$$

- Green-vent Wind utilizes the renewable energy of the Wind to create a positive flow through the ventilator.
- Even the slightest wind speeds will cause the head to spin.
- This process allows for a continuous air flow through the Green-vent Wind.

VENTILATOR PERFORMANCE DATA

Wind Velocity		8 Km/Hr	
Model	Ventilator Size	Height	Exhaust Capacity
UKVENT 24	24 inches	20 Ft	1972 CFM
		30 Ft	2076 CFM
		40 Ft	2164 CFM

$$\begin{aligned} \text{No of turbo vents} &= (190300/60)/1972 \\ &= 31716/1972 \\ &= 16 \end{aligned}$$

16 no of mechanical turbo vents is needed for north and south blocks

POLISHED CONCRETE FLOORING

Table 4-4 Roof Assembly U-factor ($W/m^2.K$) Requirements for ECBC Compliant Building

	Composite	Hot and dry	Warm and humid	Temperate	Cold
All building types, except below	0.33	0.33	0.33	0.33	0.28
School <10,000 m ² AGA	0.47	0.47	0.47	0.47	0.33
Hospitality > 10,000 m ² AGA	0.20	0.20	0.20	0.20	0.20



U value-0.42

Table 4-7 Opaque Assembly Maximum U-factor ($W/m^2.K$) Requirements for a ECBC compliant Building

	Composite	Hot and dry	Warm and humid	Temperate	Cold
All building types, except below	0.40	0.40	0.40	0.55	0.34
No Star Hotel < 10,000 m ² AGA	0.63	0.63	0.63	0.63	0.40
Business < 10,000 m ² AGA	0.63	0.63	0.63	0.63	0.40
School <10,000 m ² AGA	0.85	0.85	0.85	1.00	0.40

Resistant to moisture transmission issues: polished concrete allows the floor to breathe and eliminates issues that arise with other flooring materials that seal off the concrete, such as tile, etc.

High light reflectivity: important for FACTORY building floors, hotels, restaurants, and other public facilities that want to project a bright, clean, professional image. Also saves energy by reducing artificial lighting requirements

is a sustainable flooring alternative: polished concrete does not require hazardous coatings, cleaners or adhesives

MATERIAL STUDY

Table 2 Alternative window specifications

Window type (glazing, infill gas, coating)	Specification ^a	Glazing unit ^b U-value (W/m ² K)	Additional embodied energy per window unit
Double, air, no coating	4 – 20Air – 4	2.76	standard specification
Double, air, low-e	4e – 20Air – 4	1.58	8.42
Double, argon, low-e	4e – 16Ar – 4	1.31	8.43
Double, krypton, low-e	4e – 12Kr – e4	0.94	525.04
Triple, argon, low-e	4e – 16Ar – 4 – 16Ar – e4	0.65	161.56
Triple, krypton, low-e	4e – 12Kr – 4 – 12Kr – e4	0.52	1167.14

- Upvc windows with thermal upgrade and triple glazing with the u value of 1.1 W/m²k
- Upvc doors has u value of 1.1. With triple glazing

Frame material	Embodied energy (MJ) ^a	Survey results (years) ^a	Literature review range (years)
Aluminium	5978	43.6	35 to 60
uPVC	2657	24.1	25 to 30
Timber	738	39.6	35 to over 60
Aluminium-clad timber	899	46.7	45

^aEmbodied energy and survey results from Asif.¹⁷

Embodied energy figures are for window units measuring 1.2 m by 1.2 m, with argon gas infill.



Toilets: install modern **DUAL flush toilets**. They only dispense 3 L per half flush and either 4.5 or 6 L for a Complete flush, compared to up to 12 L for the older Single-flush toilet.

– **Drinking fountains and taps:** place containers under School water fountains and utilize excess water in the Garden.

– **Hand basins and sinks:** equip the taps with aerators. They diminish the quantities of water fluxing from The tap by up to 50%, while maintaining the pressure.

– **Hot water systems:** set up the thermostat or temperature Of your hot water so that you are not overheating The water unnecessarily and wasting energy.

– **Irrigation system:** install moisture sensors that activate The irrigation system only when the garden needs It.

– **Canteens and classrooms:** diminish waste and save Money by encouraging refillable water bottles instead Of having bottled water in your canteen and at School events.

– **Swimming pools, gardens and ovals:** utilize a pool Blanket when it's not in use. Plant local drought tolerant Plants that are more suitable for your local Climate. Understand the water efficiency of your oval Irrigation system.

– **Gutters and rain water tanks:** set up rainwater tanks To collect water in order to be used for gardening/ Or flushing toilets. Make sure you maintain gutters by Keeping them clear, so rainwater doesn't overflow And does not make it to the collection system.

RAIN WATER HARVESTING

