International Institute for Energy Conservation

Provision of Services Related to Enabling Readiness for Up Scaling Investments in Building Energy Efficiency for Achieving NDC Goals in Thailand

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TASK 2: REPORT ON TECHNOLOGY ASSESSMENT OF FIVE BUILDING TYPES WITHIN BEC FRAMEWORK

(Activity 2.2)

Prepared for

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Leading the Transition to Clean Energy

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Acronyms

BEC	-	Building Energy Code
BESM	-	Building Energy Simulation Model
CBEEC	-	Commercial Building Energy Efficiency Information Center
CC	-	Cooling Capacity
COP	-	Coefficient of Performance
CTCN	-	Climate Technology Centre and Network
DEDE	-	Department of Alternative Energy Development and Efficiency
DPT	-	Department of Public Works and Town and Country Planning
ECON	-	Economic Building
EEP	-	Energy Efficiency Plan
EER	-	Energy Efficiency Ratio
EIA	-	Environment Impact Assessment
ENCON Act	-	Energy Conservation and Promotion Act
EnPI	-	Energy Performance Indicator
EPPO	-	Energy Policy and Planning Office (EPPO)
EUI	-	Energy Use Indicator
GGGI	-	Global Green Growth Institute
HEPS	-	High Energy Performance Standard
IIEC	-	International Institute for Energy Conservation
INDC	-	Intended Nationally Determined Contributions
KMUTT	-	King Mongkut University of Technology Thonburi
LAOs	-	Local Administration Organizations
LED	-	Lighting Emitting Diode
LPD	-	Lighting Power Density
MOE	-	Ministry of Energy
MOI	-	Ministry of Interior
MRV	-	Measurement, Report and Verification
NAMA	-	Nationally Appropriate Mitigation Actions
NCCC	-	National Committee on Climate Change Policy
NDC	-	Nationally Determined Contributions
NXPO	-	Office of National Higher Education Science Research and Innovation Policy Council
ONEP	-	Office of Natural Resources and Environmental Policy and Planning
OTTV	-	Overall Thermal Transfer Value
PEECB	-	Promoting Energy Efficiency in Commercial Buildings

RTTV	-	Roof Thermal Transfer Value
SEER	-	Seasonal Energy Efficiency Ratio
TBEED	-	Thailand Building Energy Efficiency Disclosures
TGO	-	Thailand Greenhouse Gas Management Organization
UNFCC	-	UN Framework Convention on Climate Change
UNEP	-	United Nations Environment Programme
ZEB	-	Zero Energy Building

1 Progress by Activities 2.2: Prioritizing Relevant Technologies with BEC Compliance

This report provides the complete result of activities 2.2 – Prioritizing of relevant technologies with the BEC compliance. This report continues from the previous progress report on activities 2.1 which has initially identified the list of technologies for improving energy performance and BEC compliance. In this report technologies for each of the six BEC components are technically assessed for their applicability, impacts to building energy performance, impacts to BEC compliance and their growth potential. Assessment scoring is given to prioritize the technologies, which should be focused for enhance market acceptance and BEC effectiveness. The listed technologies from the task 2 will be further analyzed for their potential savings and investment return in the subsequent task 3: Financial Assessment for New Buildings within the BEC Framework.

1.1 Assessment Methodology and Criteria for prioritizing

This section performs technical assessment of technologies for six BEC components. The assessment aspects and scoring criteria are defined. Each technologies are evaluated individually on the same criteria. For each BEC components, current status of the technologies being implemented and list of potential technologies are given with the provision of technology details in the Annex-2 of the progress report on activities 2.1. The results of all technology assessment are subsequently consolidated for overall score comparison. The assessment scores classify technologies into priority groups of top, medium and low priority.

1.1.1 Assessment Methodology and Criteria

BEC relevant technologies are assessed on seven aspects as follows.

(1) Applicability to BEC buildings – how the technology is applicable to BEC buildings.

(2) Complexity in implementation – The difficulty of technology implementation and its impact to the building design and functions.

(3) Technology availability – availability of technology suppliers for implementation.

(4) Impact on energy savings – how much the technology can save building energy consumption.

(5) Return on investment – how quickly the technology can achieve the saving and give the return on the investment premium.

(6) Impact on BEC compliance – how the technology can improve the number of buildings to comply with BEC.

(7) Potential growth from the existing status – implementation maturity and potential growth from the current status.

Three levels scoring on the scale of 1 to 3 will be given for each technology on every aspects. The lowest score of 1 indicates least favor and the highest score of 3 indicates the most favor of the technology on the aspect. All technologies will be ranked by the total score from all aspects with scoring criteria defined below.

Applicability to BEC buildings

1: Technology is limited to specific BEC building types or sizes.
2: Technology is applicable to some BEC building types or sizes with large building population.

3: Technology is applicable to most BEC building types, and sizes from low-rise to high-rise and small to large building areas.

Complexity in implementation

1: Technology can be implemented but requiring major changes of building design, functional area or building systems.
2: Technology is implementable but requires some adjustment of building design, functional area or building systems.
3: Technology can be implemented to most buildings with low impact on building design, functional area or building systems.

Technology availability

1: Technology is still considerably new with no supplier locally.
2: Technology is commonly known and proven but has a few suppliers locally.
3: Technology is commonly available from many suppliers locally.

Impact on energy savings

1: Technology can save less than 1% of total building energy consumption.
2: Technology can save from 1% to 5% of total building energy consumption.
3: Technology can save over 5% of total building energy consumption.

Return on investment

1: Technology has potential investment return over its life cycle but depends a lots on other design or operation factors.
2: Technology has payback period more than 5 years but generates good investment return over its life cycle.
3: Technology has high return on investment with payback period less than 5 years in most circumstances.

Impact on BEC compliance

1: Technology is for BEC component 5 renewable energy or component 6 whole building energy performance, which most buildings can comply with.
2: Technology is for BEC component 2 lighting, component 3 air conditioning or component 4 hot water generation, which majority of buildings can comply with.
3: Technology is for BEC component 1 building envelope, which are difficult to comply with.

Potential growth from existing status

1: Technology has been commonly implemented by over 50% of BEC building population.
2: Technology has been implemented by 10% to 50% of BEC building population.
3: Technology has been implemented by less than 10% of BEC building population.

Information from local and international sources including technology suppliers, and related publications are used for assessment on technology applicability, implementation complexity, technology availability, energy saving and return on investment. Assessment on BEC compliance impact and potential growth are based on the results of BEC database analysis in task 1 for the BEC population profile, technology implementation status and impacts on BEC compliance.

1.2 TECHNOLOGY ASSESSMENT BY BEC COMPONENTS

1.2.1 Component 1: Building Envelope

Assessment of technologies relevant to BEC are shown by components in these subsequent pages. The scoring for each technology are depicted on the radar chart and assessment notes on the aspects are summarized at the end of each component.

1.2.1.1 Opaque wall

Current technologies being implemented

The analysis of 10-year BEC database reveals the most common materials for opaque walls for the BEC buildings, which are brick, concrete, concrete block and low mass concrete block. Majority of the buildings use concrete (49%) or concrete block (8%) or brick (16%) while 25% of the buildings apply low mass concrete. Very few buildings of only 0.7% implement wall insulation. With these common materials 75% of the buildings fail to comply with the OTTV requirement.

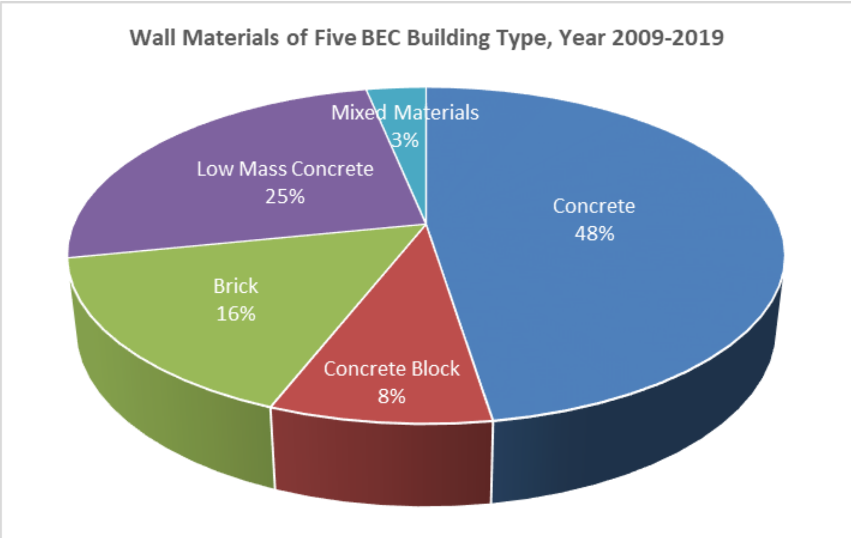

Figure 1: Common wall materials used by five BEC building types

List of potential technologies

1-1 Low mass wall materials

Using low mass materials with better heat insulation to reduce heat absorption and accumulation of walls, which will transfer inward to the building. Low mass concrete blocks can replace conventional concrete or concrete block. The most common low mass materials which can replace the conventional concrete or brick are Autoclaved Aerated Concrete (AAC), Cellular Light Weight Concrete (CLC) and Glass Fiber Reinforced Concrete (GFRC).

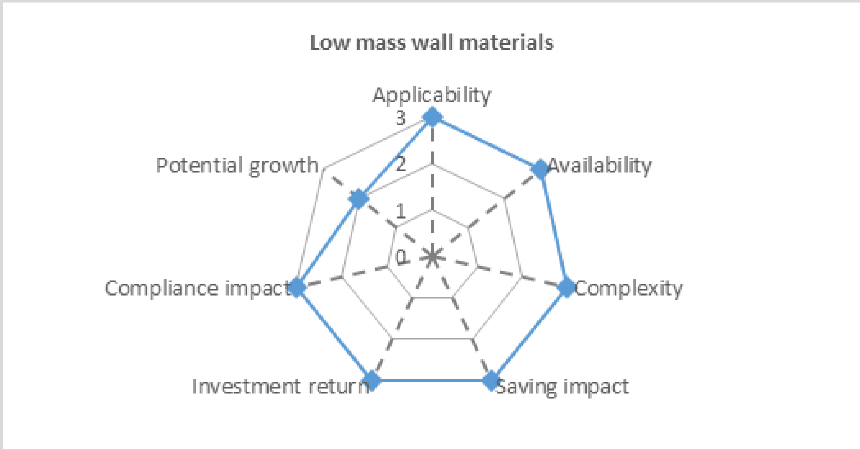

Figure 2: Technology assessment of low mass wall materials

1-2 Wall insulation

Adding insulation to building walls lowers heat transfer caused by the temperature difference between indoors and outdoors. Insulation reduces unwanted heat gain and energy consumption of the air conditioning systems. Insulation materials range from fiber materials such as fiberglass, rock and slag wool, to rigid foams.

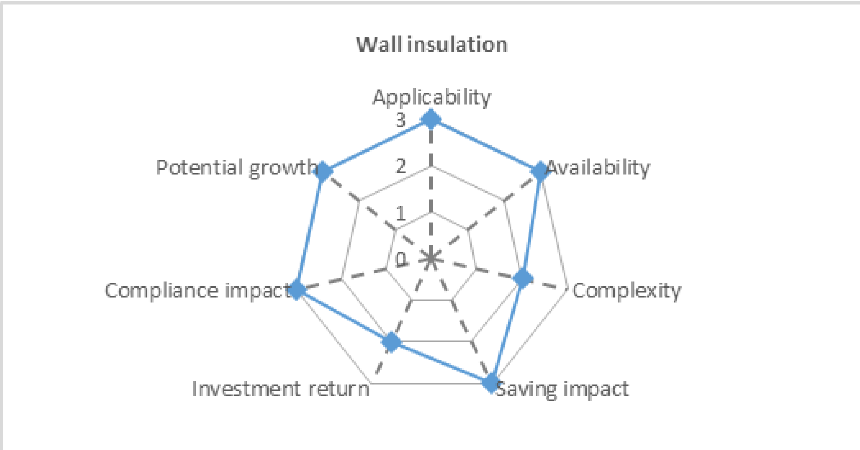

Figure 3: Technology assessment of wall insulation

1-3 Composite insulated panels

Composite insulated panels consist of insulation core covering by external sheets. Composite insulated panels are factory-manufactured by order and can be used as wall, ceiling and roof. They can be attached to a support structure and are simultaneously stable walls or roofs with excellent insulation properties.

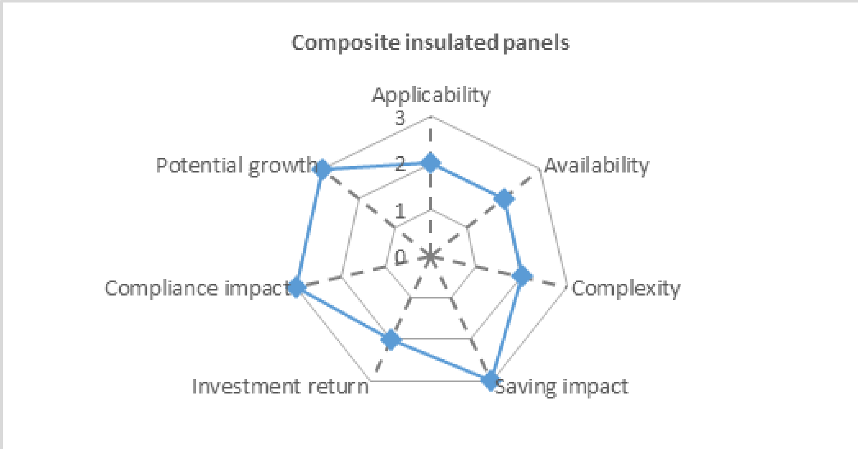

Figure 4: Technology assessment of composite insulated panels

1.2.1.2 Transparent Wall and Window

Current technologies being implemented

The BEC database shows the most common materials for transparent walls and windows for BEC buildings. Single glazing are by far the most common windows with 95% of total buildings. Majority of them are single clear (41%) and tinted glass (43%). Low numbers of buildings implement heat preventing glass, only 1.8% for reflective glass, 1.5% for low-emissivity glass, 5% for double glazing and less than 1% for triple glazing.

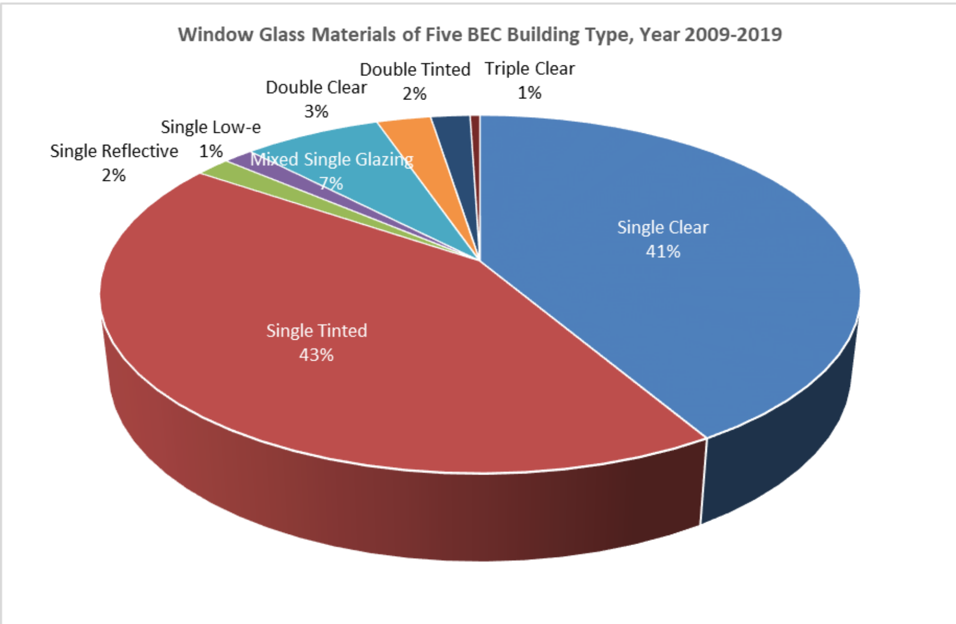

Figure 5: Common window glass materials used by five BEC building types

List of potential technologies

1-4 Energy efficient coated glass

Energy efficient coated glass minimizes heat gain through solar radiation and heat conduction while admitting more visible light to the building spaces. These properties are expressed by Solar Heat Gain Coefficient (SHGC), U-Value and Visible Light Transmittance (VT). As the guideline BEC recommends glass with low SHGC below 0.4 and high VT over 0.7. Two common types of energy efficient coated glass are reflective and low emissivity (low-e) glass.

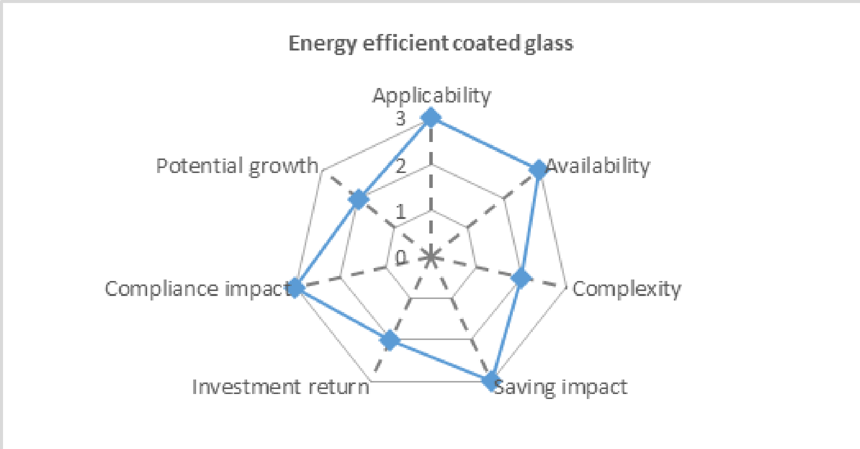

Figure 6: Technology assessment of energy efficient coated glass

1-5 Insulating glass

Insulating glass consists of two or more glass window panes separated by a vacuum or gas-filled space to reduce heat transfer across a part of the building envelope. A window with insulating glass is commonly known as double glazing triple glazing or quadruple glazing depending upon how many panes of glass are used in its construction.

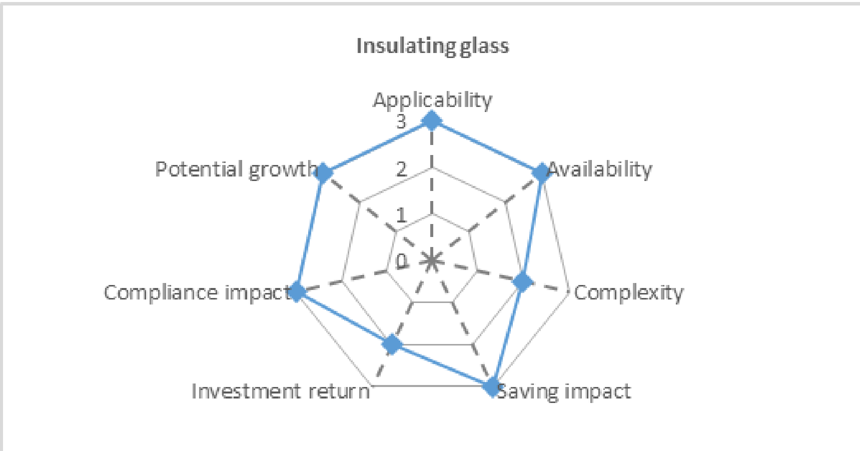

Figure 7: Technology assessment of insulating glass

1-6 Window Shading

Exterior shading can block the sunlight before it hits the glass and can block up to 95% of the sun's heat. The variety of shading strategies can be effective at accomplishing the goal. Windows facing south can be shaded from above with roof overhangs or awnings. For windows facing west or east, louvered shutters or other types of shades that cover the entire glass area are most effective. Shading effectiveness is rated by a number called a Shading Coefficient which represents the percent of the sun's heat that passes through the shading devices. The lower the number, the more heat will be blocked.

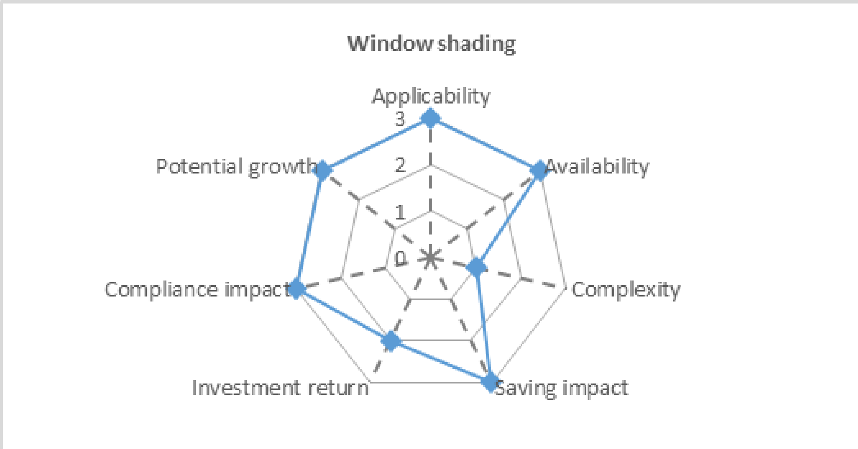

Figure 8: Technology assessment of window shading

1.2.1.3 Roof

Current technologies being implemented

From the database the most common roof materials used by BEC buildings are concrete (75%), concrete tile (4%) and metal sheet (8%). 61% of these building roofs apply some kinds of heat insulation materials and air gap to reduce the roof heat gain. Applying BEC 2020 criteria, the RTTV compliance percentage are 32% for the building roofs with no insulation and increases to 71% for the roofs with insulation.

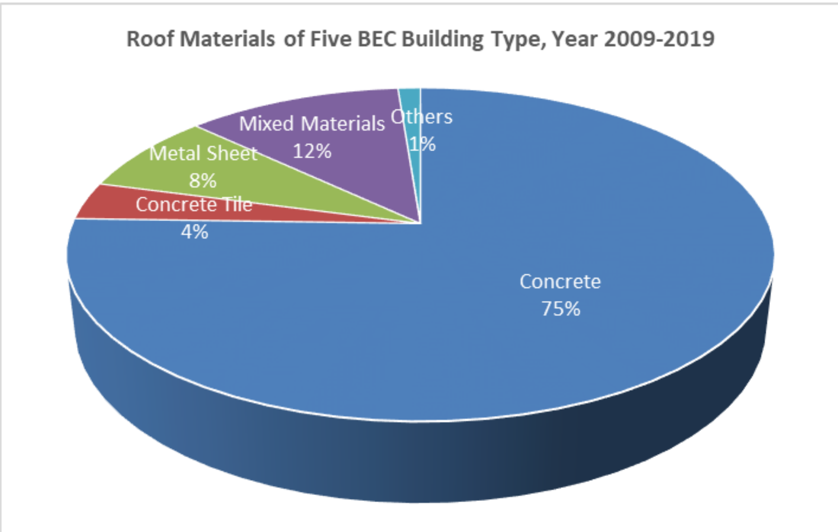

Figure 9: Common roof materials used by five BEC building types

List of potential technologies

1-7 Roof insulation

Adding insulation or air gap to lower U-value and minimize heat transfer through roofs. This is the most common and cost effective practice for roof improvement. Insulation are highly recommended for conventional concrete, concrete tile or metal sheet roofs.

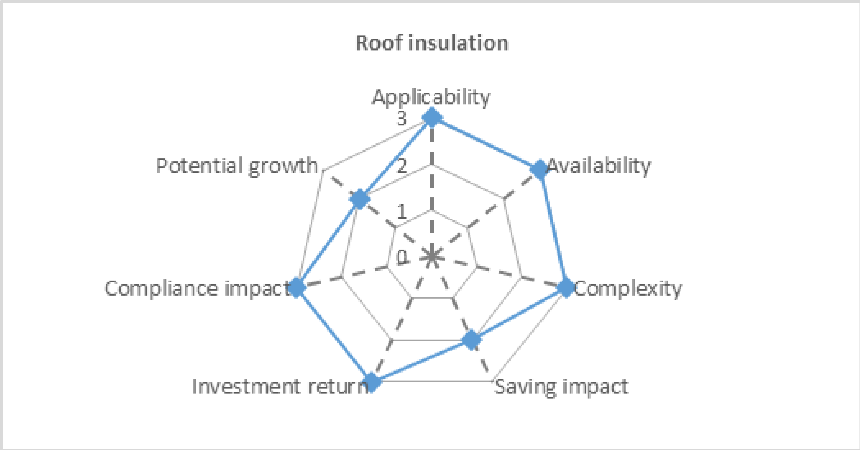

Figure 10: Technology assessment of roof insulation

1-8 High solar reflective roof coating

The high solar reflective paint incorporates a composition of reflectivity and refractivity pigment such as: Titanium dioxide, IR reflective and microsphere ceramic. These materials increase reflection of sunlight, ultraviolet and infrared rays of the external surface of the building envelope.

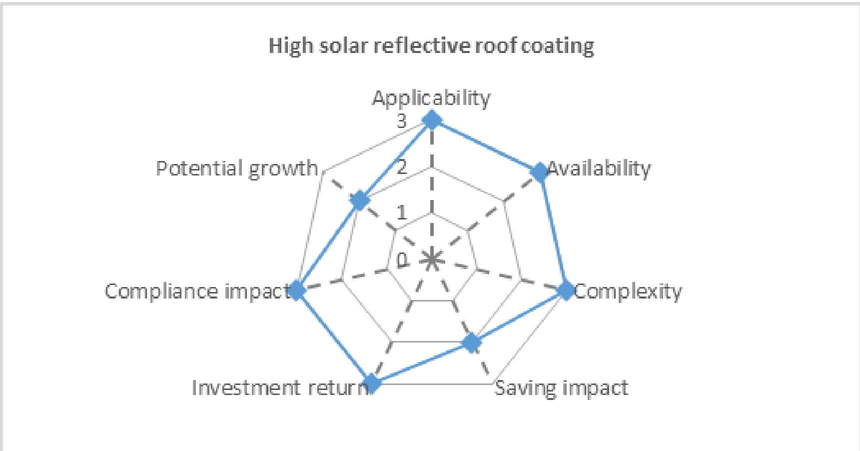

Figure 11: Technology assessment of high solar reflective roof coating

Table 1: Assessment of component 1 technologies

Item	Technology	Baseline Technology	Applicability to BEC buildings	Technology availability	Complexity in implementation	Impact on energy savings	Return on investment	Impact on BEC compliance	Potential growth
Component 1: Building Envelope									
	Opaque Wall								
1-1	Low mass wall materials	Concrete, concrete block or brick.	Technology is applicable to all building types and sizes.	Technology is available and can be supplied by many suppliers in Thailand.	Technology can replace conventional concrete materials in most cases.	Energy savings from reduced heat gain through building walls can greatly reduce air conditioning energy consumption.	With the comparable prices to conventional concrete materials, technology has good payback on investment, normally less than 5 years.	Technology has high impact in helping more BEC buildings comply with OTTV criteria.	Technology is well proven and has been used by designers with energy efficiency awareness.
1-2	Wall insulation	No insulation wall.	Technology is applicable to all building types and sizes.	Technology is available and can be supplied by many suppliers in Thailand.	Technology cannot be implemented directly without preparation of wall structure and appearance design.	Energy savings from reduced heat gain through building walls can greatly reduce air conditioning energy consumption.	Technology provides good life cycle savings. But investment payback could be over 5 years due to extra investment on insulation, wall structure and installation.	Technology has high impact in helping more BEC buildings comply with OTTV criteria.	Technology is well proven but still very limited used by BEC buildings.
1-3	Composite insulated panels	No insulation wall.	Technology is applicable to most building types but difficult for high rise building installation.	Technology is available but can be supplied by a few suppliers in Thailand.	Technology cannot be implemented directly without preparation of wall structure and appearance design.	Energy savings from reduced heat gain through building walls can greatly reduce air conditioning energy consumption.	Technology provides good life cycle savings. But investment payback could be over 5 years due to extra investment on insulation, wall	Technology has high impact in helping more BEC buildings comply with OTTV criteria.	Technology is well proven but still very limited used by BEC buildings.

Item	Technology	Baseline Technology	Applicability to BEC buildings	Technology availability	Complexity in implementation	Impact on energy savings	Return on investment	Impact on BEC compliance	Potential growth
							structure and installation.		
	Transparent Wall and Window								
1-4	Energy efficient coated glass	Clear or tinted float or laminated glass.	Technology is applicable to all building types and sizes.	Technology is available and can be supplied by many suppliers in Thailand.	Technology can replace clear float or laminated glass. Caution must be made on reflectance of sunlight to the surrounding area.	Energy savings from reduced heat gain through building with high WWR which is the main portion of air conditioning heat load.	Technology provides good life cycle savings. But payback on the investment could be over 5 years due to extra investment on glass material.	Technology has high impact in helping more BEC buildings comply with OTTV criteria.	Technology is well proven and has been used by designers with energy efficiency awareness.
1-5	Insulating glass	Clear or tinted float or laminated glass.	Technology is applicable to all building types and sizes.	Technology is available and can be supplied by many suppliers in Thailand.	Technology requires preparation of the window structure to support installation.	Energy savings from reduced heat gain through building with high WWR which is the main portion of air conditioning heat load.	Technology provides good life cycle savings. But investment payback could be over 5 years due to extra investment on glass material.	Technology has high impact in helping more BEC buildings comply with OTTV criteria.	Technology is well proven but still very limited used by BEC buildings.
1-6	Window shading	Windows with no shading devices	Technology is applicable to all building types and sizes.	Technology is available and can be supplied by many suppliers in Thailand.	Technology must be integrated to the building envelope appearance design.	Energy savings from reduced heat gain through building with high WWR which is the main portion of air conditioning heat load.	Technology provides good life cycle savings. But investment payback could be over 5 years due to extra installation.	Technology has high impact in helping more BEC buildings comply with OTTV criteria.	Technology is well proven but still very limited used by BEC buildings.
	Roof								
1-7	Roof insulation	Concrete or metal sheet	Technology is applicable to all	Technology is available and can be supplied	Technology can be installed directly as new	Energy savings from reduced heat gain	Technology has good payback on investment,	Technology has high impact in helping more	Technology is well proven and has been used

Item	Technology	Baseline Technology	Applicability to BEC buildings	Technology availability	Complexity in implementation	Impact on energy savings	Return on investment	Impact on BEC compliance	Potential growth
		roof without insulation.	building types and sizes.	by many suppliers in Thailand.	or retrofit to existing roof with minor modification.	through building roof.	normally less than 5 years.	BEC buildings comply with RTTV criteria.	by designers with energy efficiency awareness.
1-8	High solar reflective roof coating	Normal roof material.	Technology is applicable to all building types and sizes.	Technology is available and can be supplied by many suppliers in Thailand.	Technology can be installed directly as new or retrofit to existing roof with minor modification.	Energy savings from reduced heat absorption and temperature of the roof surface and thus heat gain through building roof.	Technology has good payback on investment, normally less than 5 years.	Technology has high impact in helping more BEC buildings comply with RTTV criteria.	Technology is well proven and has been used by designers with energy efficiency awareness.

1.2.2 Component 2: Lighting System

Current technologies being implemented

The BEC database does not collect the details of lighting system used in BEC buildings. However the database shows very high compliance percentage on lighting LPD criteria of more than 99% over 10 years and 100% in the last 7 years. From the market perspective the LED lightings have become dominant technology with continual improvement in energy efficiency at the reasonable prices. With the choices of available LED lighting, BEC buildings can comply with the BEC requirement without extra design effort and investment.

List of potential technologies

2-1 High efficiency LED lamps

LEDs become one of the most energy-efficient and rapidly-developing lighting technologies. They come in different forms, brightness levels and color temperatures replacing conventional incandescent, fluorescent and HID lamps. The highest luminous efficacy of commercially available LED lights has raised to the level of 200 lumen per watt in the last few years.

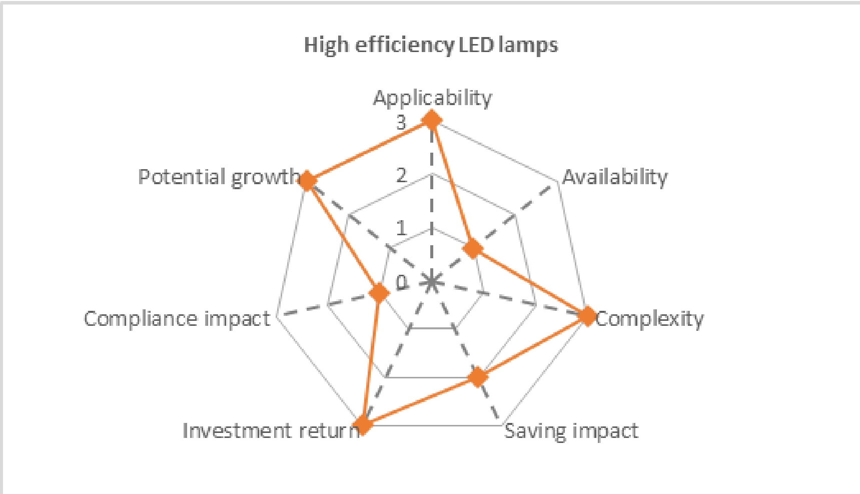

Figure 12: Technology assessment of high efficiency LED lamps

2-2 Energy efficient luminaires

Energy efficient luminaires deliver high percentage of the light output from the lamps. High reflective material and reflector design minimizes the light loss and maximizes the lamp coverage to the building space.

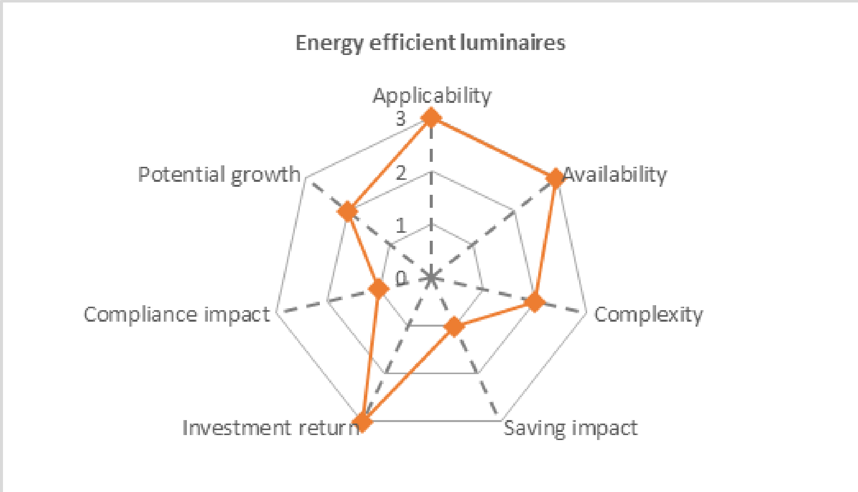

Figure 13: Technology assessment of energy efficient luminaires

2-3 Lighting controls

Energy consumption for lighting can be saved with a lighting controls system. They vary from basic wall switch to a sophisticated computerized control by building management system. A combination of a lighting controls, energy-efficient lamps and luminaires maximizes the lighting performance of the building. In most cases lighting controls systems can furtherly save 20 to 40 percent of lighting consumption.

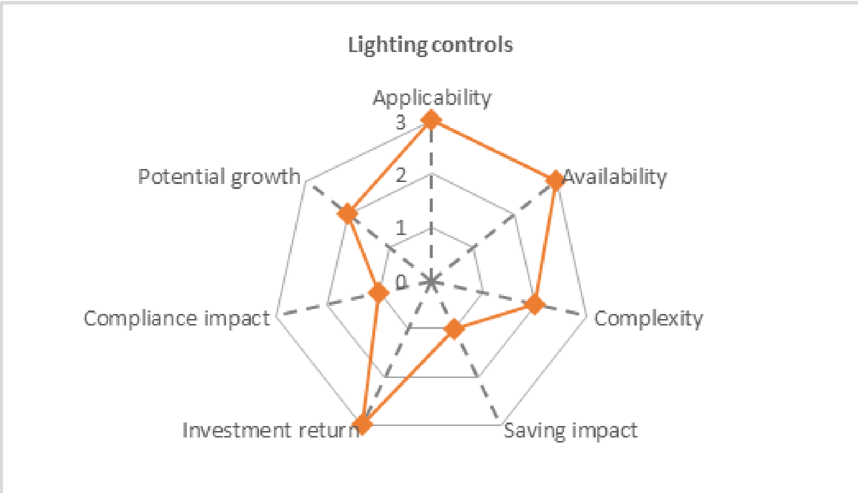

Figure 14: Technology assessment of lighting controls

2-4 Daylighting

Daylighting is the controlled admission of natural light, direct sunlight, and diffused-skylight into a building to reduce electric lighting and saving energy. Some common daylighting devices include skylight, tubular daylighting devices (light tubes) and daylight redirection devices (light shelves).

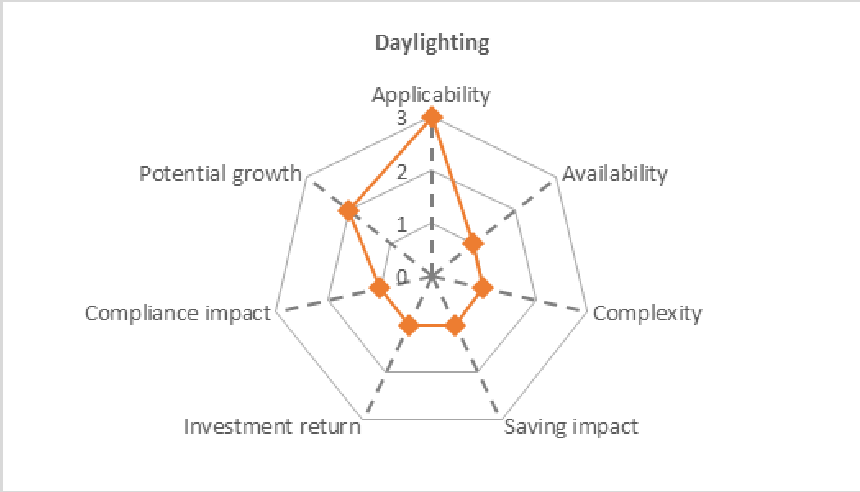

Figure 15: Technology assessment of daylighting

Table 2: Assessment of component 2 technologies

Item	Technology	Baseline Technology	Applicability to BEC buildings	Technology availability	Complexity in implementation	Impact on energy savings	Return on investment	Impact on BEC compliance	Potential growth
Component 2: Lighting System									
2-1	High efficiency LED lamps	Fluorescent lamps, normal LED lamps with efficiency less than 150 lumen/Watt.	Technology is applicable to all building types and sizes.	High efficiency LED at 200 lumen/Watt are still limited to a few brand name suppliers.	Technology can be installed directly as new or retrofit to existing lighting with minor modification.	Technology can save 30%-40% of energy use compared with common LED lighting.	Technology has good payback on investment, normally less than 5 years.	Technology has low impact on BEC compliance as most BEC buildings can already comply using common LED lightings.	Technology is expected to become common in the next few years.
2-2	Energy efficient luminaires	Normal luminaires with low efficiency reflector.	Technology is applicable to all building types and sizes.	Technology is available and can be supplied by many suppliers in Thailand.	Technology needs to be incorporated with lighting interior design and area functions.	Energy saving from the reduced lamps and number of installed luminaires.	Return on investment depends on lighting design but at worst investment paybacks are normally within 5 years.	Technology has low impact on BEC compliance as most BEC buildings can already comply using common LED lightings.	Technology is well proven and has been used by designers with energy efficiency awareness.
2-3	Lighting controls	Basic light on-off switches.	Technology is applicable to all building types and sizes.	Technology is available and can be supplied by many suppliers in Thailand.	Technology can be implemented to new or retrofitted lighting system.	Energy saving from optimizing lighting use and avoiding lighting waste.	Return on investment depends on lighting design but at worst investment paybacks are normally within 5 years.	Technology has low impact on BEC compliance as most BEC buildings can already comply using common LED lightings.	Technology is well proven and has been used by designers with lighting efficiency awareness.
2-4	Daylighting	Artificial lighting and natural lighting from windows and openings.	Technology is applicable to all building types and sizes.	Technology is available but very limited suppliers.	Technology requires consideration in the design of building envelope.	Energy saving from the avoided electric lamps in the areas of daylighting.	Technology provides good life cycle return on investment. But payback on the investment could be over 5 years due to extra	Technology has low impact on BEC compliance as most BEC buildings can already comply using common LED lightings.	Technology is well proven and has been used by designers with lighting efficiency awareness.

Item	Technology	Baseline Technology	Applicability to BEC buildings	Technology availability	Complexity in implementation	Impact on energy savings	Return on investment	Impact on BEC compliance	Potential growth
							investment and installation.		

1.2.3 Component 3: Air Conditioning System

Current technologies being implemented

All types of air conditioning systems from split-type units to central chiller systems are used in BEC buildings. Similar to lighting system the BEC database shows more than 99% of buildings complied with the air conditioning criteria. Common energy efficiency of air conditioning in the market are well above the set criteria. The energy efficiency label no. 5 sets the mandatory requirement for energy efficiency of split-type air conditioners. For the larger air conditioner system, DEDE has specified the minimum energy efficiency requirements for chillers in the designated buildings under ENCON act and these requirements are also adopted as the benchmark for all buildings. Chiller market are competitive and most of new chillers are more efficient than the minimum DEDE and BEC requirements.

List of potential technologies

3-1 High efficiency inverter split-type air conditioners

The inverter split-type air conditioners with energy-efficient label 5 and three-star rating could offer very high efficiency more than 21.5 SEER. These savings are over 40% of energy consumption of the normal fixed speed label 5 split-type air conditioners

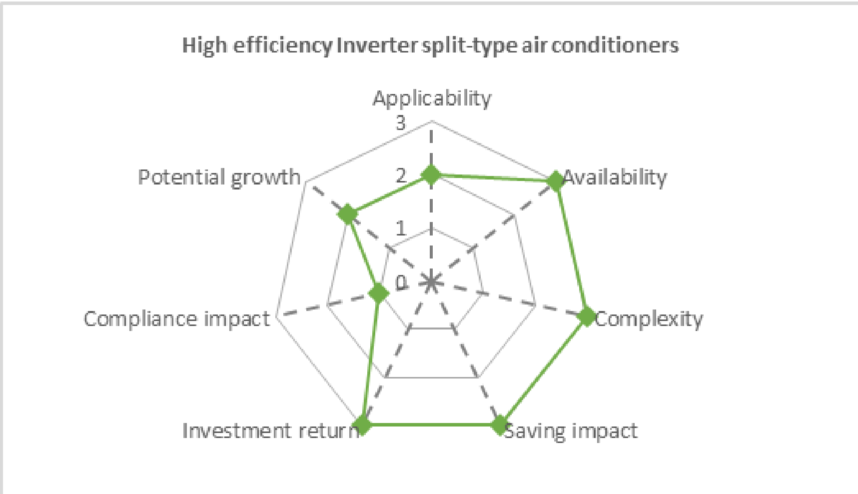

Figure 16: Technology assessment of high efficiency inverter split-type air conditioners

3-2 VRF/VRV air conditioning system

Variable refrigerant flow (VRF), also known as variable refrigerant volume (VRV) is an air conditioning technology using refrigerant as the cooling medium. This refrigerant is conditioned by a single or multiple condensing units which may be outdoors or indoors and is circulated within the building to multiple indoor units. VRF systems allow for varying degrees of cooling in more specific areas. Unlike the chiller system, VRFs use only smaller indoor units with no air handing units and large air ducts.

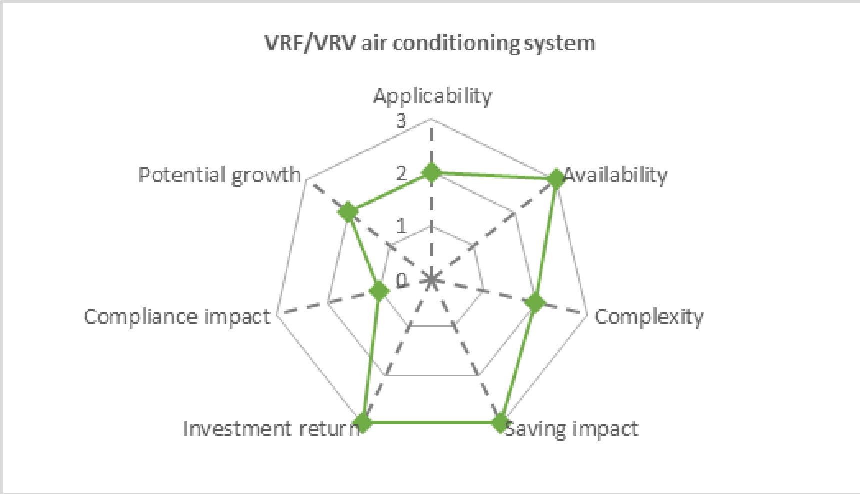

Figure 17: Technology assessment of VRF/VRV air conditioning system

3-3 Oil-free magnetic bearing chiller

Magnetic bearing chillers apply the magnetic field with internally controlled sensors to support the rotating shaft without physical contact, reducing friction and eliminating the need for oil lubrication. The compressors are soft started and speed controlled by the inverter to the required cooling loads. The magnetic bearing centrifugal chillers can operate at low level of 20 to 40% of load and having electricity consumption lower than 0.55 kW/TR.

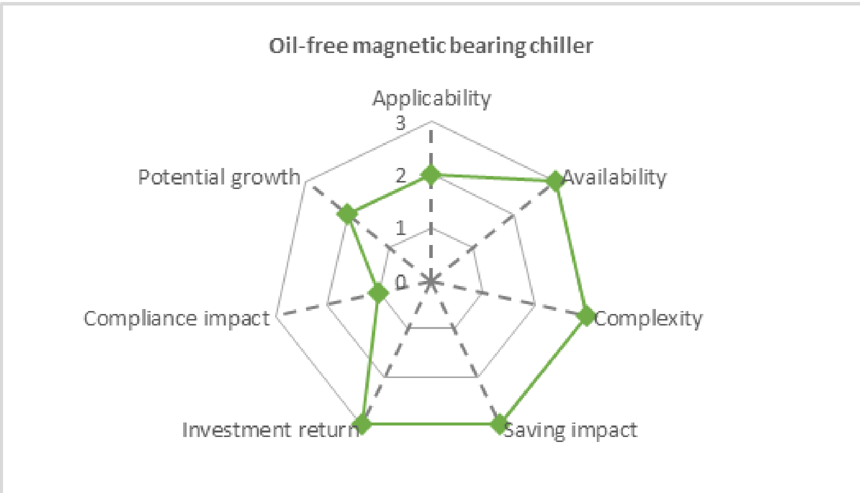

Figure 18: Technology assessment of oil-free magnetic bearing chiller

3-4 Absorption chiller

Absorption chillers use heat instead of electricity to produce cooling. The electric-driven compressor is replaced by a thermal compressor that consists of an absorber, a generator, a pump, and a throttling device. Absorption chillers can substantially reduce chiller operating costs because they utilize low-grade waste heat, while normal electric chillers use electricity.

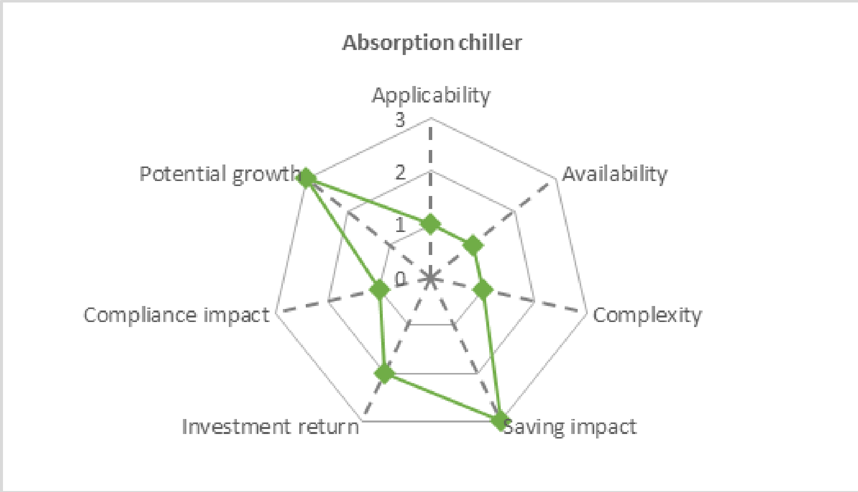

Figure 19: Technology assessment of absorption chiller

3-5 Energy Recovery Ventilation (ERV)

Building air conditioning system requires air change by the new fresh air to remove CO_2 from the air conditioned space. The Energy Recovery Ventilator (ERV) can control and clean fresh air supply to the space. The unit is equipped with energy recovery feature to exchange the cool from the exhaust air to pre cool fresh air intake. The technology can save 10%-30% of air conditioning consumption.

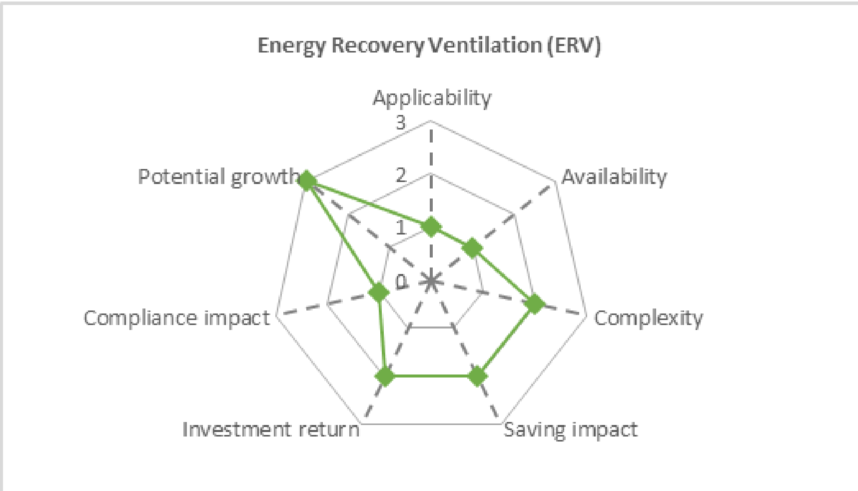

Figure 20: Technology assessment of Energy Recovery Ventilator (ERV)

Table 3: Assessment of component 3 technologies

Item	Technology	Baseline Technology	Applicability to BEC buildings	Technology availability	Complexity in implementation	Impact on energy savings	Return on investment	Impact on BEC compliance	Potential growth
Component 3: Air Conditioning System									
3-1	High efficiency Inverter split-type air conditioners	Normal or standard inverter split-type air conditioners.	Technology is applicable to small to medium sized buildings.	Technology is available and can be supplied by many suppliers in Thailand.	Technology can replace lower efficiency split-type air conditioners at similar capacities.	30% or more energy savings from normal split-type air conditioners.	Technology has good payback on investment, normally less than 5 years.	Technology has low impact on BEC compliance as most BEC buildings can comply with standard split-type air conditioners.	Technology is well proven and has been used by designers with energy efficiency awareness.
3-2	VRF/VRV air conditioning system	Split-type or packaged unit air conditioner.	Technology is applicable to small to medium sized buildings.	Technology is available and can be supplied by many suppliers in Thailand.	Technology requires design of the central compressor and refrigeration piping.	30% or more energy savings from normal split-type air conditioners.	Technology has good payback on investment, normally less than 5 years.	Technology has low impact on BEC compliance as most BEC buildings can comply with standard split-type or packaged-unit air conditioners.	Technology is well proven and has been used by designers with energy efficiency awareness.
3-3	Oil-free magnetic bearing chiller	Standard electric chillers.	Technology is applicable to medium to large sized buildings with central chilled water air conditioning system.	Technology is available and can be supplied by many suppliers in Thailand.	Technology can directly replace conventional chillers with similar capacities.	30% or more energy savings from conventional chillers.	Technology has good payback on investment, normally less than 5 years.	Technology has low impact on BEC compliance as most BEC buildings can comply with available chillers.	Technology is well proven and has been used by designers with energy efficiency awareness.

Item	Technology	Baseline Technology	Applicability to BEC buildings	Technology availability	Complexity in implementation	Impact on energy savings	Return on investment	Impact on BEC compliance	Potential growth
3-4	Absorption chiller	Electric chillers.	Technology is applicable to medium to large sized buildings with central chilled water air conditioning system and available waste heat.	Technology is available but very limited suppliers.	Technology requires design of waste heat utilization and integration to the electric chiller system.	Energy savings from using of waste heat to replace electricity use by electric chiller.	Technology provides good life cycle savings. But investment payback could be over 5 years due to extra investment per cooling capacity.	Technology has low impact on BEC compliance as most BEC buildings can comply with commonly available chillers in the market. And most absorption chillers in the market are BEC compliant.	Technology is well proven but still very limited used by BEC buildings.
3-5	Energy Recovery Ventilation (ERV)	Central air conditioning system or packaged unit.	Technology is applicable to medium to large sized buildings with AHU and fresh air duct.	Technology is available but very limited suppliers.	Technology requires design of air ventilation and integration to ventilation system.	Energy savings from reduced heat gain from fresh air intake to air conditioning area.	Technology provides good life cycle savings. But investment payback could be over 5 years due to extra investment and system integration costs.	Technology has low impact on BEC compliance as most BEC buildings can comply with available air conditioning system.	Technology is well proven but still very limited used by BEC buildings.

1.2.4 Component 4: Hot Water Generation

Current technologies being implemented

BEC database has no information on the types of hot water generation used in BEC buildings. There is no record of noncompliance on the hot water generation criteria over 10-year database. Based on the project team energy audit experiences, the most common hot water generation system for hotels and hospitals are central oil-fired and LPG boiler to produce hot water for central laundry, kitchen and room services. Small electric hot water heater are also prevalent in small to medium sized hotels and condominiums as they are convenient and cost effective. Heat pump systems have also been implemented for more than 10 years in many hotels and hospitals, especially large chain and international-owned business with energy efficiency awareness. However they are still not common in most local buildings although the technologies are proven on their high efficiency and cost effectiveness.

List of potential technologies

4-1 Heat pump hot water generation

Heat pump hot water systems use refrigerant as the medium to concentrate low-grade heat from the air and transfer it to the water instead of generating heat directly. They are two to three times more efficient than conventional hot water boilers using electricity or fuels such as fuel oil or LPG as the energy source. Heat pump water heater can be installed as a stand-alone or as an integrated unit to the conventional hot water system.

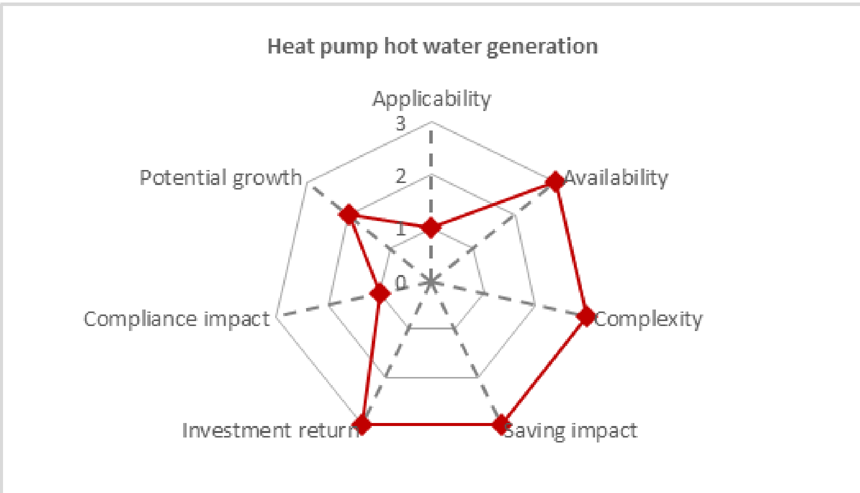

Figure 21: Technology assessment of hot water generation

Table 4: Assessment of component 4 technologies

Item	Technology	Baseline Technology	Applicability to BEC buildings	Technology availability	Complexity in implementation	Impact on energy savings	Return on investment	Impact on BEC compliance	Potential growth
Component 4: Hot Water Generation									
4-1	Heat pump hot water generation	Electric or fuel hot water boiler.	Technology is applicable to buildings with hot water or steam system. Main target are hotels and hospitals.	Technology is available and can be supplied by many suppliers in Thailand.	Technology can replace or supplement to existing boiler.	Energy savings from three times more energy efficient than conventional boiler.	Technology has good payback on investment, normally less than 5 years.	Technology has low impact on BEC compliance as most BEC buildings can comply with hot water boiler commonly available in the market.	Technology is well proven and has been used by designers with energy efficiency awareness.

1.2.5 Component 5: Renewable Energy Utilization

Current technologies being implemented

Although BEC database shows no evidence on the inclusion of renewable energy in the BEC building design, the downtrend of price per performance of energy production from renewable energy sources especially solar photovoltaic (PV) system have increased the implementation in the commercial buildings over the last few years. The potential for inclusion of the PV system in new building design or retrofitting are high especially buildings with large roof areas. Nevertheless renewable energy for thermal applications in the potential BEC buildings such as hotels and hospitals is still underutilized.

List of potential technologies

5-1 Solar power generation

Rooftop solar power generation system produces electricity for use in conjunction with the electricity from the grid and helps reduce monthly electricity bill effectively. With participation to the government program, the surplus electricity generated can be sold to the electricity authority.

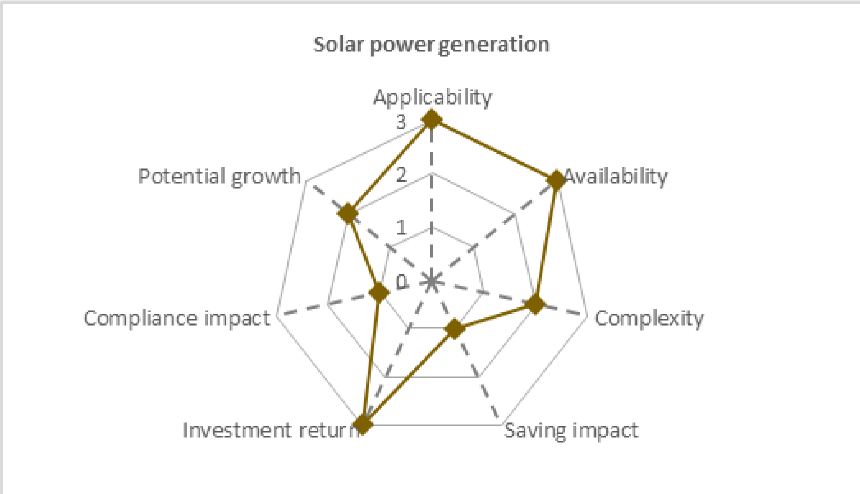

Figure 22: Technology assessment of solar power generation

5-2 Solar Hot Water Generation

Solar water heater convert energy from sunlight to heat water. They can be used to generate hot water for building. Solar water heating system can be incorporated with the economizer and the heat recovery system. This combination is called the solar hybrid system; it combines the sunlight with the excess heat from air conditioners and boilers. The solar water heater becomes the alternative in the energy saving installed in households, schools, industries, hotels, resorts & spas, restaurants, and beauty shops.

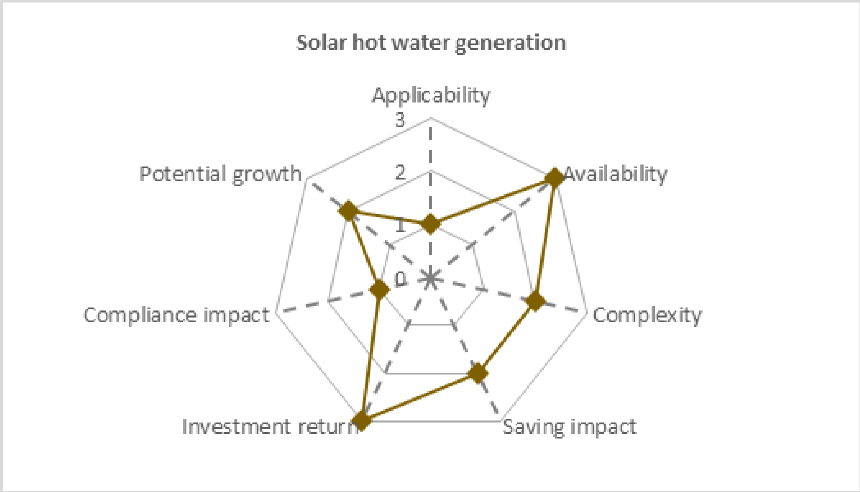

Figure 23: Technology assessment of solar hot water generation

Table 5: Assessment of component 5 technologies

Item	Technology	Baseline Technology	Applicability to BEC buildings	Technology availability	Complexity in implementation	Impact on energy savings	Return on investment	Impact on BEC compliance	Potential growth
Component 5: Renewable Energy Utilization									
5-1	Solar power generation	100% use of on-grid electricity.	Technology is applicable to all building types and sizes.	Technology is available and can be supplied by many suppliers in Thailand.	Technology can be installed on most available roof space of all types.	Energy and cost savings depending on the system size but normally fractional of the consumption of the large buildings.	Technology has good payback on investment, normally less than 5 years.	Technology has low impact on BEC compliance as it contributes to the compliance of option 2: overall energy performance, which most BEC buildings can comply.	Technology is well proven internationally but low percentage of implementation in Thailand.
5-2	Solar hot water generation	Electric or fuel hot water boiler.	Technology is applicable to buildings with hot water or steam system. Main target are hotels and hospitals.	Technology is available and can be supplied by many suppliers in Thailand.	Technology can replace or supplement to existing boiler but need installation area for solar collector.	Energy savings from free energy source.	Technology has good payback on investment, normally less than 5 years.	Technology has low impact on BEC compliance as it contributes to the compliance of option 2: overall energy performance, which most BEC buildings can comply.	Technology is well proven internationally but low percentage of implementation in Thailand.

1.2.6 Component 6: Whole Building Energy Performance

Current technologies being implemented

BEC has no data record on the implementation of technologies in this component. As the majority (>xx%) of BEC buildings can comply with the BEC overall building energy performance criteria, the technologies for improving energy performance through building system integration seem to have lower priority than the technology for the individual building systems. Some implementation however can be seen on the large building complex with long operating hours and high energy costs. Other driving factors for implementing the technology in this component are the needs for achieving high energy performance to meet the corporate sustainability targets, or the requirements on building automation or modernization for enhancing operation comfort and business functions.

List of potential technologies

6-1 Building Energy Management Systems (BEMS)

BEMS provide real-time monitoring and integrated control of connected systems from lighting and HVAC to security systems and elevators. They allow modes of operation, energy use and environmental conditions to be monitored and allowing hours of operation, set points and so on to be adjusted to optimize building's performance and comfort.

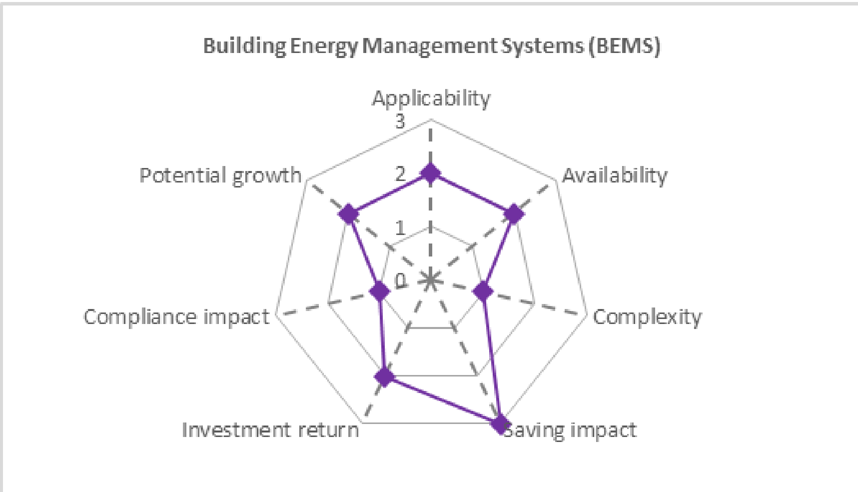

Figure 24: Technology assessment of Building Energy Management System (BEMS)

6-2 Combined Heat and Power (CHP)

Combined heating and power (CHP) or cogeneration uses single energy source to produce electricity and thermal energy for heating and/or cooling at the same time. By capturing and using heat that would otherwise be wasted, CHP can achieve over 80% energy efficiencies compared to 50% for conventional electricity generation and independent heating generation. CHP are suitable for facilities or buildings that need both electricity and thermal energy and operate at long operating hours such as hotels, hospitals and mixed-use building compound.

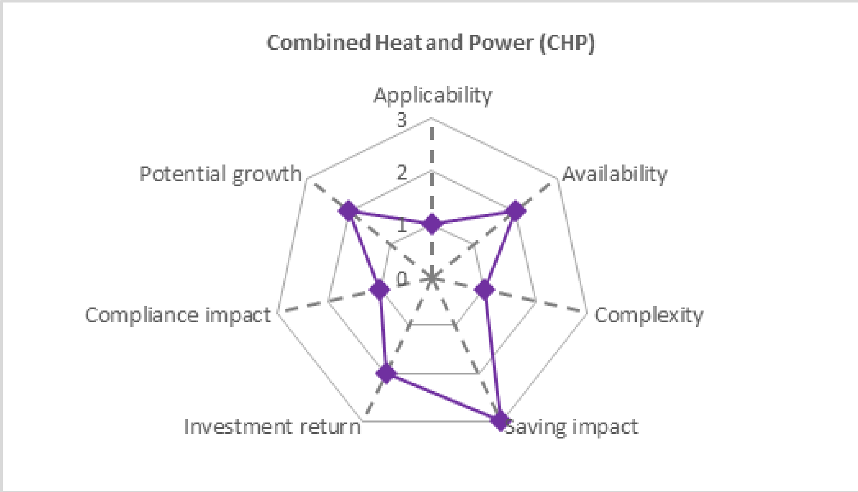

Figure 25: Technology assessment of Combined Heat and Power (CHP)

Table 6: Assessment of component 6 technologies

Item	Technology	Baseline Technology	Applicability to BEC buildings	Technology availability	Complexity in implementation	Impact on energy savings	Return on investment	Impact on BEC compliance	Potential growth
Component 6: Whole Building Energy Performance									
6-1	Building Energy Management Systems (BEMS)	No BEMS.	Technology is applicable to all building types but practical for medium to large sizes.	Technology is available and can be supplied by medium-to-large engineering companies and suppliers.	Technology requires implementation of data communication and connectivity of the building systems.	Energy and cost savings from the operational integration and performance benchmarking.	Technology provides good life cycle savings. But investment payback is over 5 years due to high investment, installation and system integration costs.	Technology has low impact on BEC compliance as it contributes to the compliance of option 2: overall energy performance, which most BEC buildings can comply.	Technology is well proven internationally but low percentage of implementation in Thailand.
6-2	Combined Heat and Power (CHP)	Separated supply of electricity from on-grid system and generation of heat from boiler.	The target application are large hotels, hospitals, and multiuse complex with access to natural gas or LNG supply.	Technology is available and can be supplied by medium-to-large engineering companies and suppliers.	Technology requires balancing of electricity and thermal energy profile and integration design of the building systems.	Significant energy and cost savings from high efficiency energy production.	Technology provides good life cycle savings. But investment payback is over 5 years due to high investment, installation and system integration costs.	Technology has low impact on BEC compliance as it contributes to the compliance of option 2: overall energy performance, which most BEC buildings can comply.	The technology is well proven internationally and but only a few implementation in Thailand.

2 SUMMARY OF PRIORITIZING RELEVANT TECHNOLOGIES WITH BEC COMPLIANCE

Continuing from the assessment of technologies relevant to BEC shown in Chapter 1 in these report. The results of all technology assessment are subsequently consolidated for overall score comparison. The summarized of prioritizing of relevant technologies with BEC compliance are concluded in this chapter.

The assessment scores classify technologies into priority groups of top, medium and low priority. Table 7 at the end of this section shows the list of technology for BEC and their overall score from the technology assessment. The score result helps prioritize the technologies into three groups.

Group A: High priority technologies with assessment score 80% or more

Group B: Medium priority technologies with assessment score from 70% to 80%

Group C: Low priority technologies with assessment score 70% or less

Group A: High priority technologies

Technologies in this group receive high scores on most assessment aspects. These technologies are considered as top priority for BEC implementation. All identified technologies for component 1 building envelope are in this group as they help the BEC buildings comply with the stringent OTTV and RTTV criteria. The energy efficient air conditioning systems in component 3 are also in this group. All technologies in this group can greatly improve building energy performance with high return on investment or long-term life cycle savings.

Component 1: Building Envelope

Opaque Wall

1-1 Low mass wall materials
1-2 Wall insulation
1-3 Composite insulated panels

Transparent Wall and Window

1-4 Energy efficient coated glass
1-5 Insulating glass
1-6 Window shading

Roof

1-7 Roof insulation
1-8 High solar reflective roof coating

Component 3: Air Conditioning System

3-1 High efficiency Inverter split-type air conditioners
3.3 Oil-free magnetic bearing chiller

Group B: Medium priority technologies

Technologies in Group B are also potentially good for BEC buildings. Despite lower impact on improving BEC compliance, they are still worth considering as most technologies in this group have high energy savings and good return on investment.

Component 2: Lighting System

2-1 High efficiency LED lamps
2-2 Energy efficient luminaires
2-3 Lighting controls

Component 3: Air Conditioning System

3-2 VRF/VRV air conditioning system

Component 4: Hot Water Generation

4-1 Heat pump hot water generation

Component 5: Renewable Energy Utilization

5-1 Solar power generation

Group C: Low priority technologies

Technologies in this group have the lowest overall potential compared to the ones in group A and B. Nevertheless they could still help improve energy performance of some specific BEC building types and applications.

Component 2: Lighting System

2-4 Daylighting

Component 3: Air Conditioning System

3-4 Absorption chiller
3-5 Energy Recovery Ventilation (ERV)

Component 5: Renewable Energy Utilization

5.2 Solar Hot Water Generation

Component 6: Whole Building Energy Performance

6-1 Building Energy Management Systems (BEMS)
6-2 Combined Heat and Power (CHP)

Continually progress from this task 2 technical assessment result, the financial assessment of task 3 will simulate the energy performance and analyze their return on investment of the above identified technologies on five types of BEC buildings under this project scope.

Table 7: Technology assessment scores on potential technologies for six BEC components

Item	Technology	Baseline Technology	Applicability	Availability	Complexity	Saving impact	Investment return	Compliance impact	Potential growth	Total Score	% Total Score	Group
Component 1: Building Envelope												
	Opaque Wall											
1-1	Low mass wall materials	Concrete, concrete block or brick.	3	3	3	3	3	3	2	20	**95%**	**A**
1-2	Wall insulation	No insulation wall.	3	3	2	3	2	3	3	19	**90%**	**A**
1-3	Composite insulated panels	No insulation wall.	2	2	2	3	2	3	3	17	**81%**	**A**
	Transparent Wall and Window											
1-4	Energy efficient coated glass	Clear float or laminated glass.	3	3	2	3	2	3	2	18	**86%**	**A**
1-5	Insulating glass	Clear float or laminated glass.	3	3	2	3	2	3	3	19	**90%**	**A**
1-6	Window shading	Clear float or laminated glass.	3	3	1	3	2	3	3	18	**86%**	**A**
	Roof											
1-7	Roof insulation	Concrete or metal sheet roof without insulation.	3	3	3	2	3	3	2	19	**90%**	**A**
1-8	High solar reflective roof coating	Normal roof material.	3	3	3	2	3	3	2	19	**90%**	**A**
Component 2: Lighting System												
2-1	High efficiency LED lamps	Fluorescent lamps, normal LED lamps with efficiency < 150 lumen/Watt.	3	1	3	2	3	1	3	16	**76%**	**B**
2-2	Energy efficient luminaires	Normal luminaire with low efficiency reflector.	3	3	2	1	3	1	2	15	**71%**	**B**
2-3	Lighting controls	Basic light on-off switches.	3	3	2	1	3	1	2	15	**71%**	**B**
2-4	Daylighting	Artificial lighting and natural lighting from windows and openings.	3	1	1	1	1	1	2	10	**48%**	**C**

Item	Technology	Baseline Technology	Applicability	Availability	Complexity	Saving impact	Investment return	Compliance impact	Potential growth	Total Score	% Total Score	Group
Component 3: Air Conditioning System												
3-1	High efficiency Inverter split-type air conditioners	Normal or standard inverter split-type air conditioners.	2	3	3	3	3	1	2	17	**81%**	**A**
3-2	VRF/VRV air conditioning system	Split-type or packaged unit air conditioner.	2	3	2	3	3	1	2	16	**76%**	**B**
3-3	Oil-free magnetic bearing chiller	Standard electric chillers.	2	3	3	3	3	1	2	17	**81%**	**A**
3-4	Absorption chiller	Electric chillers.	1	1	1	3	2	1	3	12	**57%**	**C**
3-5	Energy Recovery Ventilation (ERV)	Central air conditioning system or packaged unit.	1	1	2	2	2	1	3	12	**57%**	**C**
Component 4: Hot Water Generation												
4-1	Heat pump hot water generation	Electric or fuel hot water boiler.	1	3	3	3	3	1	2	16	**76%**	**B**
Component 5: Renewable Energy Utilization												
5-1	Solar power generation	100% use of on-grid electricity.	3	3	2	1	3	1	2	15	**71%**	**B**
5-2	Solar hot water generation	Electric or fuel hot water boiler.	1	3	2	2	3	1	2	14	**67%**	**C**
Component 6: Whole Building Energy Performance												
6-1	Building Energy Management Systems (BEMS)	No BEMS.	2	2	1	3	2	1	2	13	**62%**	**C**
6-2	Combined Heat and Power (CHP)	Separate supply of electricity from on-grid system and generation of heat from boiler.	1	2	1	3	2	1	2	12	**57%**	**C**

3 NEXT STEP

Following the detailed assessment of prioritizing of relevant technologies with BEC compliance in activities 2.2, the list of prioritized technologies will be further analyzed for their potential savings and investment return in the task 3: Financial Assessment for New Buildings within the BEC Framework. The finalize of short-list priority of feasible technologies and criteria of applicable technologies for the key energy components of the five selected building types will be served as the input for continue of parametric run simulation work under activities 1.3.

Following the completion of technology and financial assessment of task 2 and task 3, the consultation with relevant stakeholders will be organized. A workshop will be organized to disseminate the result of technology and financial assessment (Outcome 2 and 3) to relevant stakeholders for gathering further recommendation.