# Appendix 5.4

# SOLAR GLARE ASSESSMENT

# Appendix 5.4

*Solar Glare Assessment*

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# 1 INTRODUCTION

GIA have assessed the proposed scheme in order to ascertain whether solar reflections given off the proposed building's facade will be visible from sensitive viewpoints which may affect road users and train drivers.

## 1.1 GLARE

Glare is a phenomenon occurring in the eye that is caused by the presence of bright light sources within the visual field. It can lead to visual discomfort and, if the glare source is very bright compared to its surrounding, even be disabling in the sense that objects become hard or impossible to see. This is because they are cloaked by the high intensity glare source, whose light gets scattered within the eye.

The CIE 146:2002 Collection on Glare expresses the latter type of glare more formally as:

*"Disability glare is glare that impairs vision (CIE, 1987). It is caused by scattering of light inside the eye [...]. The veiling luminance of scattered light will have a significant effect on visibility when intense light sources are present in the peripheral visual field and the contrast of objects to be seen is low. "*

*"Disability glare is most often of importance at night when contrast sensitivity is low and there may well be one or more bright light sources near to the line of sight, such as car headlights, streetlights or floodlights. But even in daylight conditions disability glare may be of practical significance: think of traffic lights when the sun is close to them, or the difficulty viewing paintings hanging next to windows."*

Glare is of particular concern if it affects drivers of motor vehicles or trains, since it might impair the visibility of signals and traffic signs, potentially putting the driver, passengers or other parties at risk.

## 1.2 GLARE FROM REFLECTED SUNLIGHT

Whether or not a sun reflection will cause an instance of glare depends upon a number of factors, these are summarised below:

- The location of the observer and his view direction;
- The sun's position in the sky, which changes not only with the hour of the day, but with the seasons too;
- The location and orientation of the reflective surface, e.g. a glazed facade, in relation to the observer's view direction;
- The specific quality of the reflective surface, e.g. sheen, specularity, etc.;
- The observer's physiology, e.g. age and eye pigmentation; and
- The background brightness defining the state of adaptation in the observer's eye;

This final point is an important one as the same brightness which could cause glare against a dark background may be perfectly acceptable when looked against a light one. A typical example of adaptation is illustrated in Fig. 01 and Fig. 02 where the same headlights cause glare at night whereas they do not during daytime hours.

Understanding whether solar glare is likely to occur is based on the observer's position and view direction. Given the transitory nature of the phenomenon, due to the sun's constant movement, any glare assessment should be carried out for a number of representative locations and view directions.

Such studies are often carried out with the help of sun path protractors, as depicted in Fig. 03 opposite, or with the aid of a full 3 dimensional computer simulation.

When a large number of locations need to be looked at, studies involving solar protractors become rather impractical. Computer software allows multiple view points to be assessed with greater ease so that it has even become feasible to render video sequences showing when and where reflections may become an issue.

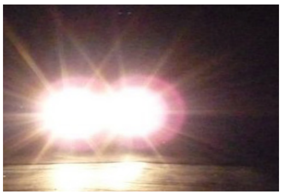


Fig. 01: Headlights at night

Fig. 02: Headlights during day

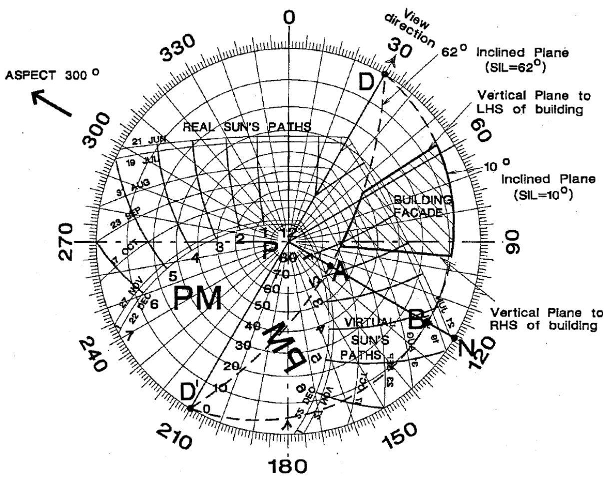



Fig. 03: Hassall's Protractor

## 1.3 EXISTING GUIDANCE

In the UK, guidance that is relevant to glare assessments is limited to a short section in Littlefair's Site Layout Planning for Daylight and Sunlight published by the BRE in 2011. This document is commonly referred to as BR 209. It suggests that:

*"If it is likely that a building may cause solar dazzle the exact scale of the problem should be evaluated. This is done by identifying key locations such as road junctions and windows of nearby buildings, and working out the number of hours of the year that sunlight can be reflected to these points. BRE Information Paper IP 3/87 gives details."*

BR IP3/87 provides more detailed instructions on why and how solar dazzle can be calculated:

*"Glare or dazzle can occur when sunlight is reflected from a glazed facade. For vertical facades this problem usually occurs only when the sun is low in the sky; but some types of modern design incorporate sloping glazed facades which can, under certain circumstances, reflect unwanted high altitude sunlight into the eyes of motorists, pedestrians and people in nearby buildings."*

Both BR 209 and BR IP3/87 only deal with geometrical considerations of glare by identifying when and where reflections occur. However, neither pieces of guidance suggest any threshold values above which reflected sunlight may give rise to an instance of glare. That such a threshold exists in theory becomes clear from the guidance in BR 209:

*"... Substituting clear or absorbing glass for reflective glass can also help although sometimes even clear glass may cause reflected glare if, eg, a motorist has the reflected sun close to the centre of their line of sight."*

Recommendations on acceptable limits for solar glare is equally sparse in other countries. The only document dealing with the subject is Hassall's Dealing with Rogue Solar Reflections from 1996. Although published in Australia, the theory, methodology and recommendations it introduced are equally applicable in other countries such as the UK.

The severity of glare can be calculated as the equivalent veiling luminance which is caused by the excess light being scattered in the eye thereby creating a 'veil' through which objects are seen. If the brightness of the veil is sufficiently high compared to that of the actual object, the latter becomes less visible. In very severe cases of disability glare, the object cannot be seen at all.

The veiling luminance can be calculated with a simple empirical formula first proposed by Holladay:

$$L_{seq}\,[cd/m^2] = K{*}E_{gl}\,/Q^n < \text{threshold}$$

The Holladay glare formula depends on four variables, namely:

- **K**, which is a factor accounting for the observer's sensitivity to glare (eg. age);
- **Egl**, which is the illuminance from the glare source, measured at the eye of the observer;
- **Q**, the angle between the line of sight and the glare source;
- **n**, indicating the power with which Q affects the outcome;

An individual's sensitivity to glare is affected primarily by age. We used a K factor of 17.5 in our calculations, which represents a 65-year old driver.

According to CIE 146:2002, the n power in Holladay's equation has three angular domains:

- Q3 for angles between 0.1° and 1°;
- Q2 for angles between 1° and 30°; and
- Q for angles beyond 30°;

This angular dependency means that a glare source close to the object being looked at has a much more severe impact upon the visibility of that object than a glare source at the periphery of the observer's visual field.

As stated in CIE 146:2002, occurrences at angles beyond 30° would be of little significance in most situations, but may be relevant in exceptional circumstances. When seated in a driving seat of a typical car, for example, the limits of the windscreen would generally obstruct the driver's view at angles beyond 30° from the line of sight. We have therefore adopted the 1° to 30° domain as a reference for our calculations.

Hassall in his paper proposes a threshold value of 500 cd/m², which we have adopted as a threshold in our assessments.

# 2 GIA'S APPROACH

Following the guidance documents referenced above, GIA have developed specialised computer software in order to undertake reflected glare assessments.

The preparation of reflected solar glare assessments is based upon the approach described below, which entails:

- The construction of a three-dimensional computer model that includes the proposed building and its relevant setting;
- The physically accurate description of the reflective surface properties;
- Rendering of stills or video animations of the solar reflections;
- Masking the images to represent the human field of view; and
- Image analysis;

The individual steps of our work flow are further explained below.

## 1.1 3D COMPUTER MODELLING

Detailed geometry of the proposed building, specifically of its facade and glazing configuration is provided by the project architects either in 2d format i.e. plans, sections and elevation drawings, or 3d format as a computer model. The received information is processed by GIA and prepared for assessment with our proprietary software.

A computer model of the proposed building's context is built from high resolution stereoscopic aerial photographs, examples of which are shown in Fig. 04 and Fig. 05.

This includes rail tracks, sleepers, gantries and signals as well as relevant neighbouring buildings. An example is provided in Fig. 06.

Fig. 04: High-resolution aerial photograph

Fig. 05: High-resolution aerial photograph (close-up)

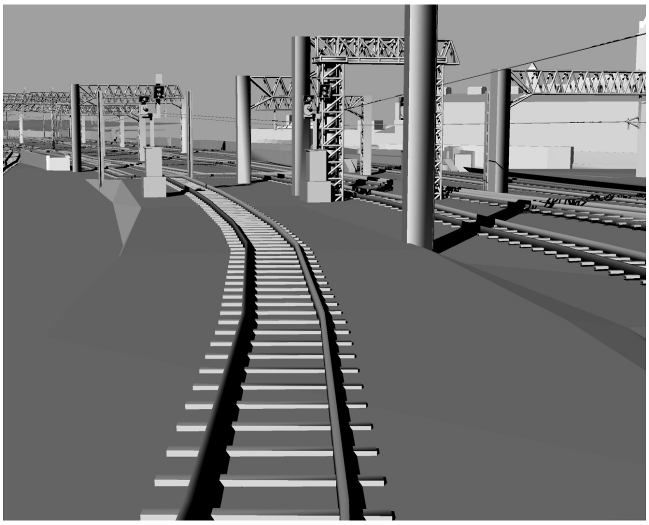


Fig. 06: Computer model of train tracks & signals from photogrammetry

## 2.1 REFLECTIVE SURFACE PROPERTIES

In order to undertake the glare studies it is necessary to acquire physically accurate computer representations of all materials that have the potential of specularly reflecting sunlight, thereby becoming sources of glare. Such materials would include all vertical or sloped glazing, but also certain facade materials such as metal cladding or glazed building tiles.

Diffuse surface reflectance values and object colours can be measured relatively easily however, the same cannot be said of their specular characteristics. These parameters are very hard to estimate yet critical for the study of glare. It is therefore best practice to have samples of the glazing or cladding materials studied in specialised optical laboratories. An example of such a data set is given in Fig. 07. It shows the angular dependency of the reflective properties of a glazed cladding tile.

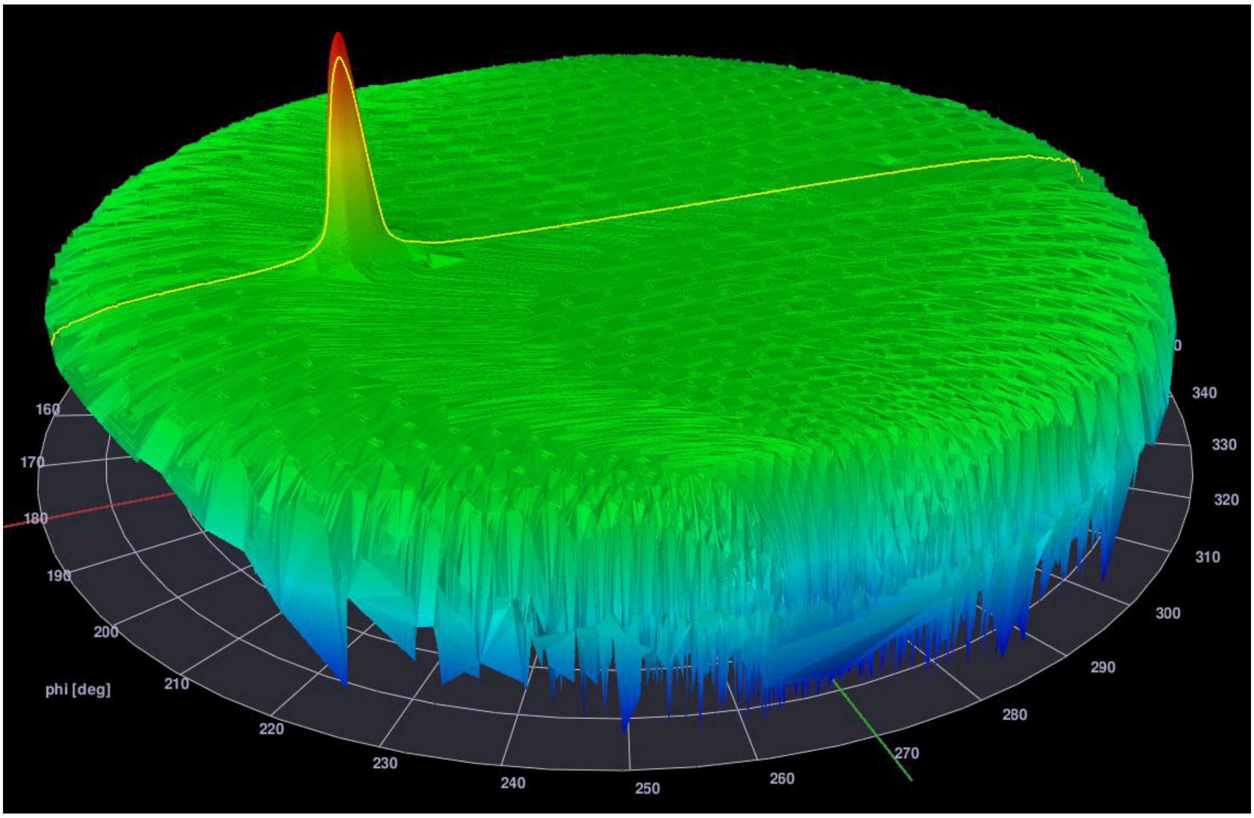


Fig. 07: Reflective properties measurement of a glazed tile

# 3 METHODOLOGY

The methodology described below is not aimed at addressing the intensity of an instance of reflected solar glare, but its occurrence and duration throughout the year and the location of this occurrence in respect of a driver's line of sight.

This will inform the necessity of implementing mitigations at either early or detailed design stage.

For this purpose the glazed facade of the proposed development is assumed to have the same properties of a mirror i.e. it is fully reflective and all of its reflected component is specular. This therefore portrays a worst-case scenario.

The potential for reflected solar glare or dazzle from the glazed or reflective façades of the development are assessed using specialist lighting software.

Potentially sensitive viewpoints around the site are selected. These viewpoints representing locations where reflected solar glare may cause adverse impacts to those travelling towards the development, such as road users or train drivers. The viewpoints are generally located at the minimum stopping distance and at the driver's eye height. The focal point is a relevant traffic element, such as signals or incoming traffic.

The stopping distance is calculated as the combination of thinking and breaking distances $D_{total} = D_{thinking} + D_{breaking} = V*T + V^2/(2\mu*g)$, where each component is:

V = Relevant vehicle speed, typically the road speed limit.

T = Thinking time (0.67 sec)

μ = Breaking effort (considered 0.65 for cars, 0.5 for buses and 0.031 for trains)

g = Gravity acceleration.

The height of the viewpoint is considered to be 1.5 m for cars, 2.0 m for busses and 2.5 m for trains.

I.e. A viewpoint for car driving at 30 mph would be placed at 23 m (see Figure 4) from a traffic light and at 1.5 m above the ground.

## 2.2 FIELD OF VIEW

"The field of view (also field of vision) is the angular extent of the observable world that is seen at any given moment."

"Different animals have different fields of view, depending on the placement of the eyes. Humans have an almost 180-degree forward-facing field of view[...]."

(http://en.wikipedia.org/wiki/Field_of_view)

"The normal human visual field extends to approximately 60° nasally (toward the nose, or inward) in each eye, to 100° temporally (away from the nose, or outwards), and approximately 60° above and 75° below the horizontal meridian. In the United Kingdom, the minimum field requirement for driving is 60° either side of the vertical meridian, and 20° above and below horizontal. The macula corresponds to the central 13° of the visual field; the fovea to the central 3°."

(http://en.wikipedia.org/wiki/Visual_field)

"The fovea centralis, also generally known as the fovea, is a part of the eye, located in the center of the macula region of the retina. The fovea is responsible for sharp central vision (also called foveal vision), which is necessary in humans for reading, watching

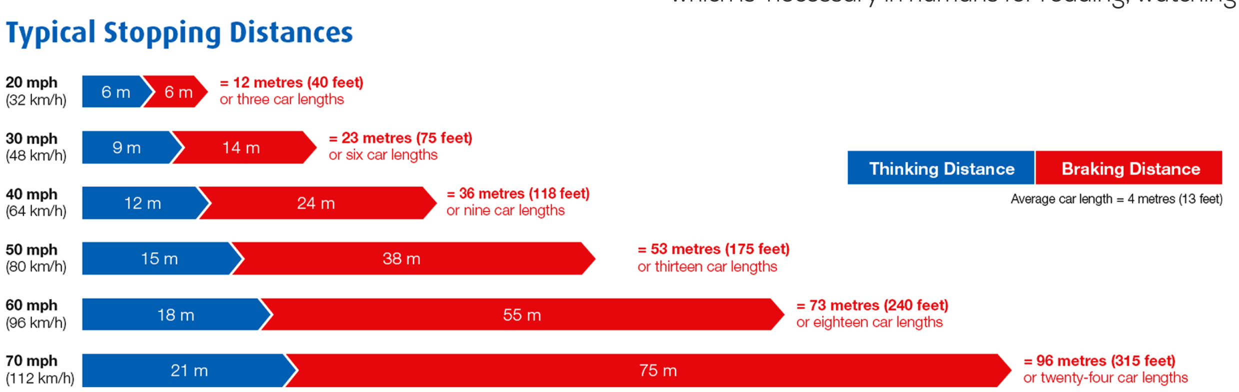


Fig. 08: Typical car stopping distances for various speed limits

television or movies, driving, and any activity where visual detail is of primary importance."

(http://en.wikipedia.org/wiki/Fovea_centralis_in_macula)

## 2.3 RENDERING OF STILLS AND VIDEO ANIMATIONS

As mentioned above, glare is a phenomenon that depends on the observer's location, but also on his view direction. In the case of a train driver the view direction is defined by the rail tracks. UK recommendations set the eye level of the driver at 2.75 m above the rails. The view point is centred between the tracks for ease of reference. Although train drivers sit slightly to the left within the cabin, this bears no material effect on the analysis of the images as the signals are visible at a distance of hundreds of metres at which point the slight shift in the cabin equates to a very small angular change. Fig. 09 shows the typical set up of our viewpoints. Actual trains and driver's cabin are not included in our 3d computer model.

Individual virtual cameras located accordingly in our 3d computer model are spaced between 1 and 3m apart in the direction of travel. Before the stills are compiled into video clips, a human field of view mask is overlayed onto them in order to define the angular distance between the instance of reflection and the observer's line of sight.

This procedure allows for the assessment of entire stretches of railway tracks providing a complete overview of potential risks as well as information about signal sighting.

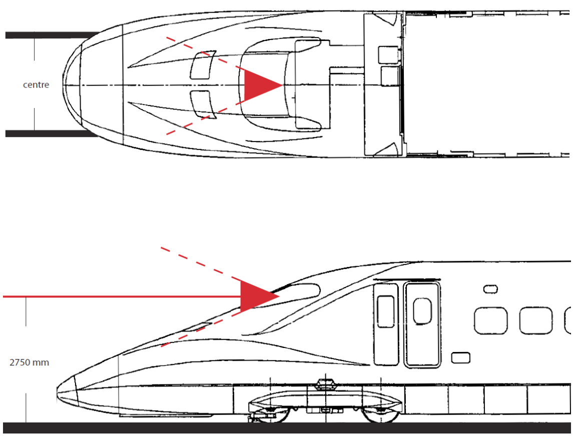



Fig. 09: Driver Viewpoint

## 2.4 IMAGE ANALYSIS

The assessment shows the path of the sun for the entire year around the development. Two computer generated angular images are produced for each selected viewpoint, indicating the area which sees the reflection of the sunpath at any point during the year. A modified diagram portraying a standardised extent of human vision (Fig. 10) is then overlaid onto the image.

As stated in the CIE 146:2002 occurrences at angles beyond 30° would be of little significance in most situations, but may be relevant in exceptional circumstances. When seated in a driving seat of a typical car, for example, the limits of the windscreen would generally obstruct the driver's view at angles beyond 30° from the line of sight.

## 3.1 LIMITATIONS

The methodology described above is not suitable to quantify the intensity of reflected solar glare. Wherever the potential for reflected solar glare is identified it should be assumed that its intensity is sufficient to cause nuisance and thus mitigating measures ought to be investigated.

Although great care is taken in identifying typical viewpoints around a new development this does not guarantee that there are no further sensitive locations where reflected solar glare could present a particular risk. This assessment is based on the assumption that in an urban environment moving traffic represents the biggest risk factor and so viewpoints and focus points are selected accordingly.

For practical reasons the area of the assessment is limited to the vicinity of a new development. The occurrence of reflected solar glare at greater distances is not subject of this assessment.

IMPORTANT: The hours shown in the diagrams and described in the text reflect solar time and therefore do not take Daylight Saving Hours into account.

# 4 SCENARIO OVERVIEW

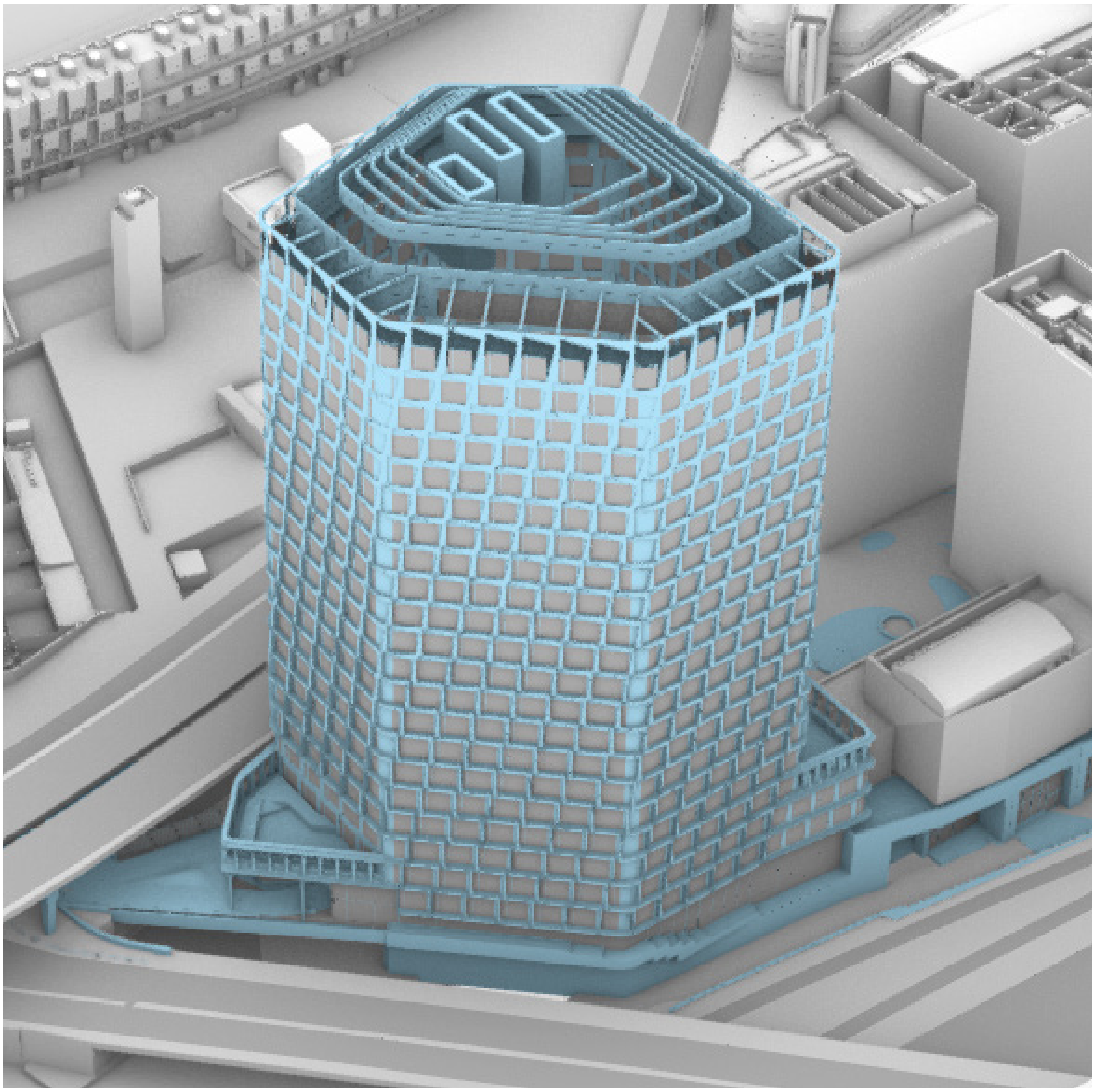


Fig. 10: Site Overview Perspective

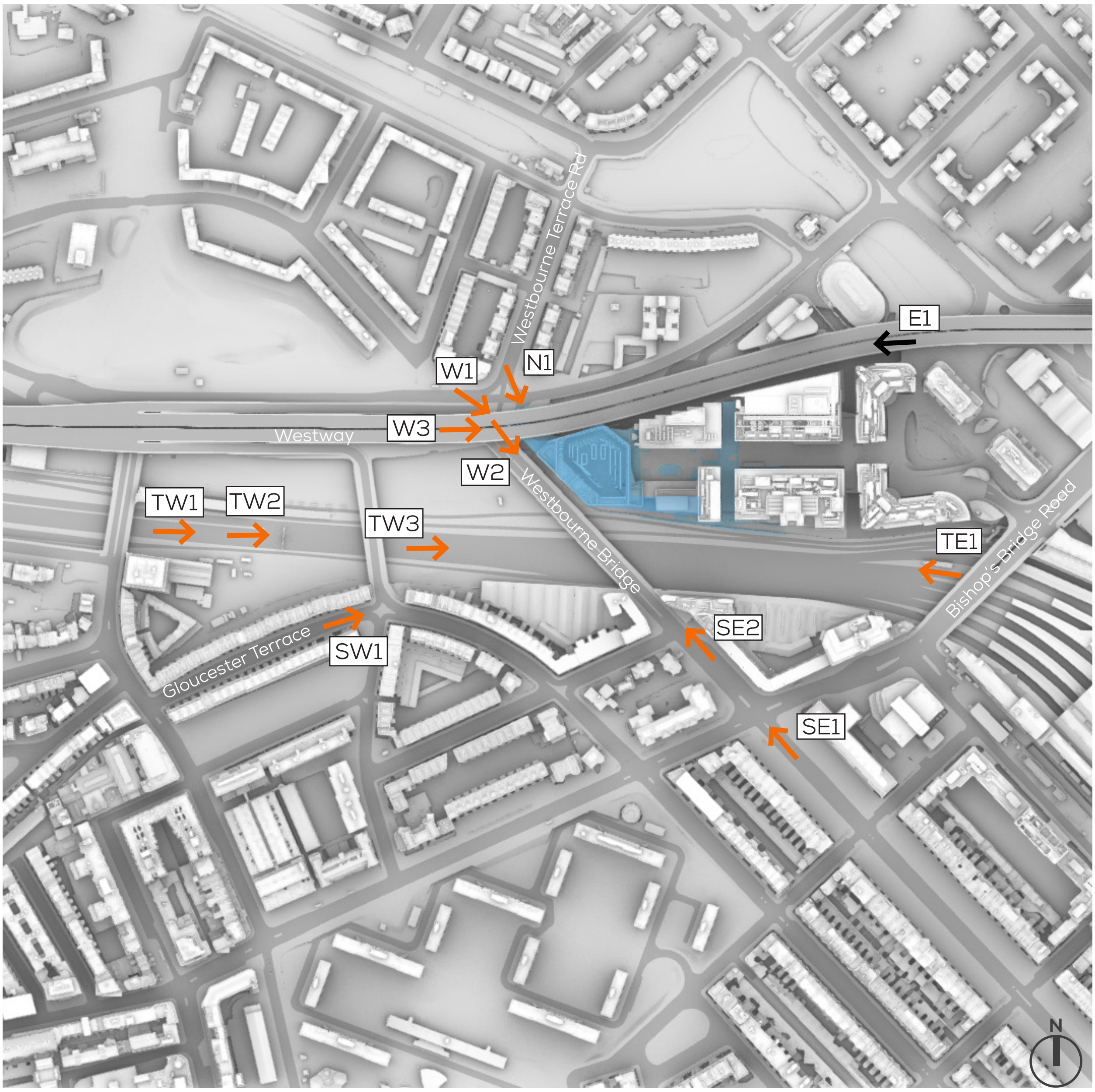



Fig. 11: Site Plan - Viewpoints

- Building visible from the viewpoint
- Building NOT visible from the viewpoint
- Proposed development

# 5 SOLAR GLARE ASSESSMENT

The following pages present our Stage 1 Assessment results

**60° FIELD OF VIEW: TIME OF DAY**
**VIEWPOINT E1**

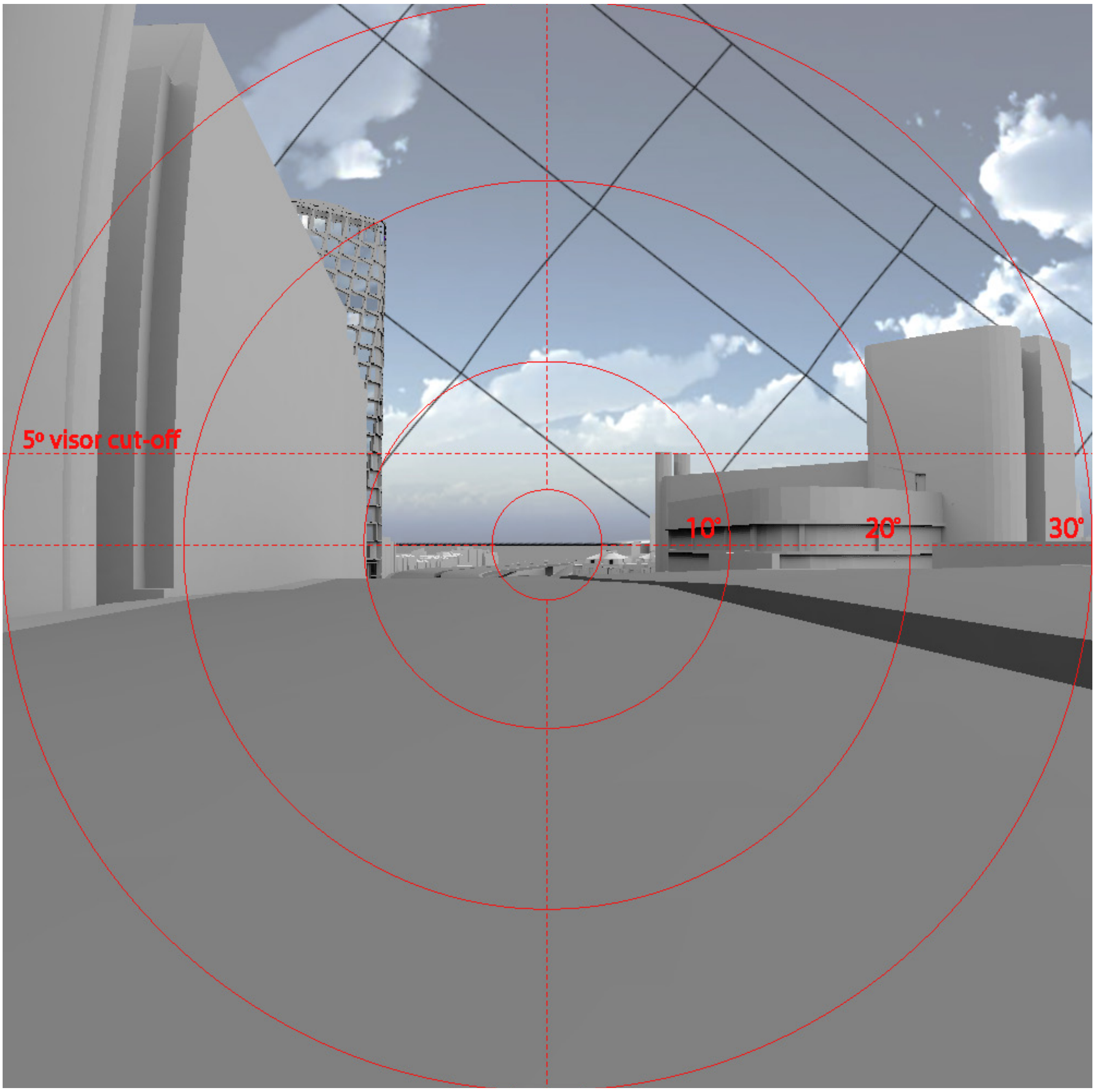
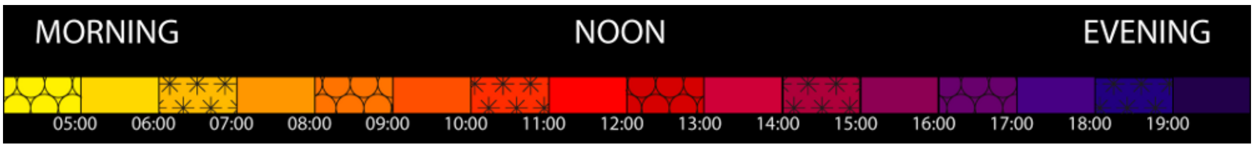



Fig. 12: Solar reflections



## 60° FIELD OF VIEW: SEASON
### VIEWPOINT E1

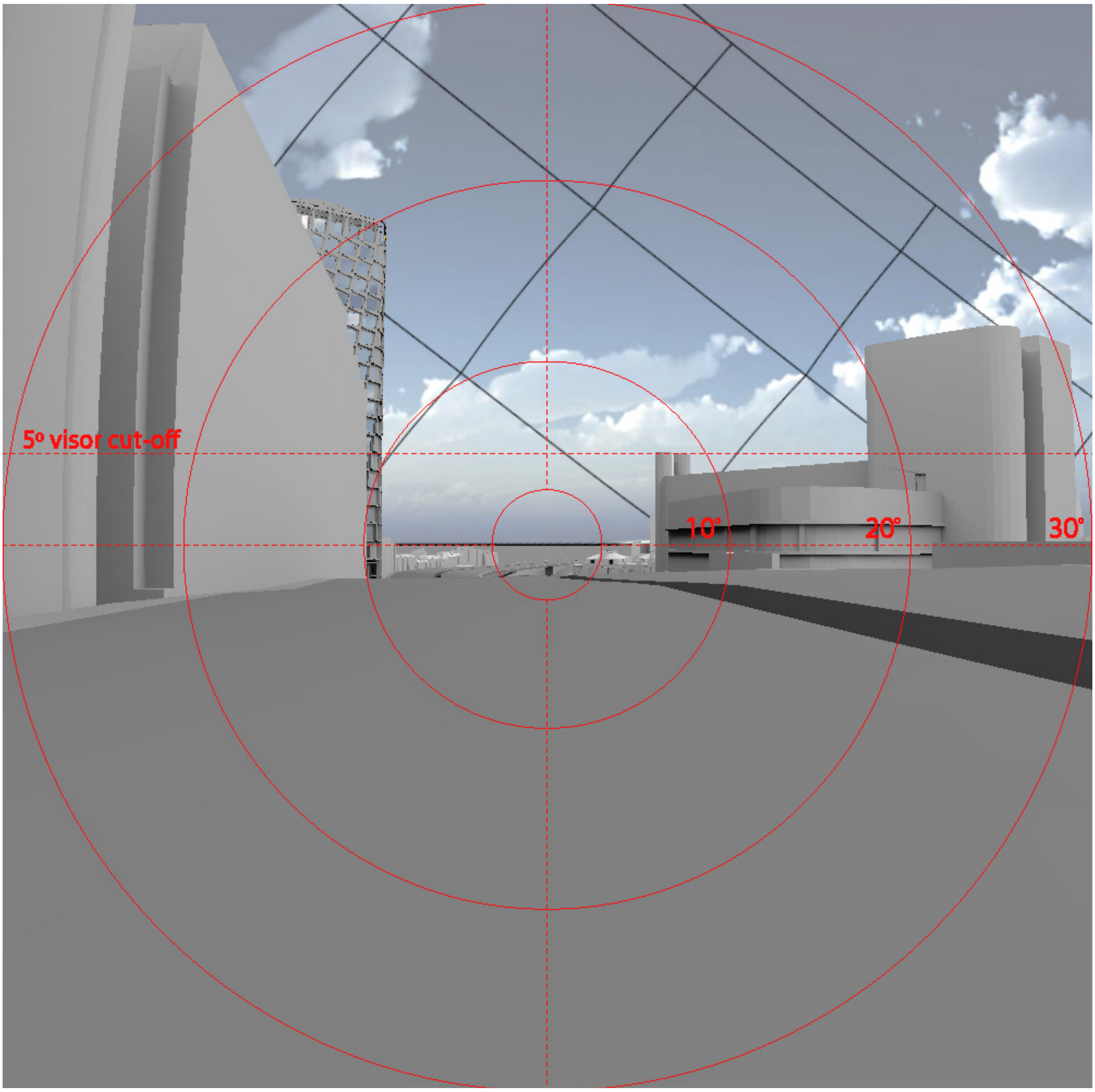



Fig. 13: Solar reflections

## 60° FIELD OF VIEW: TIME OF DAY
### VIEWPOINT N1A

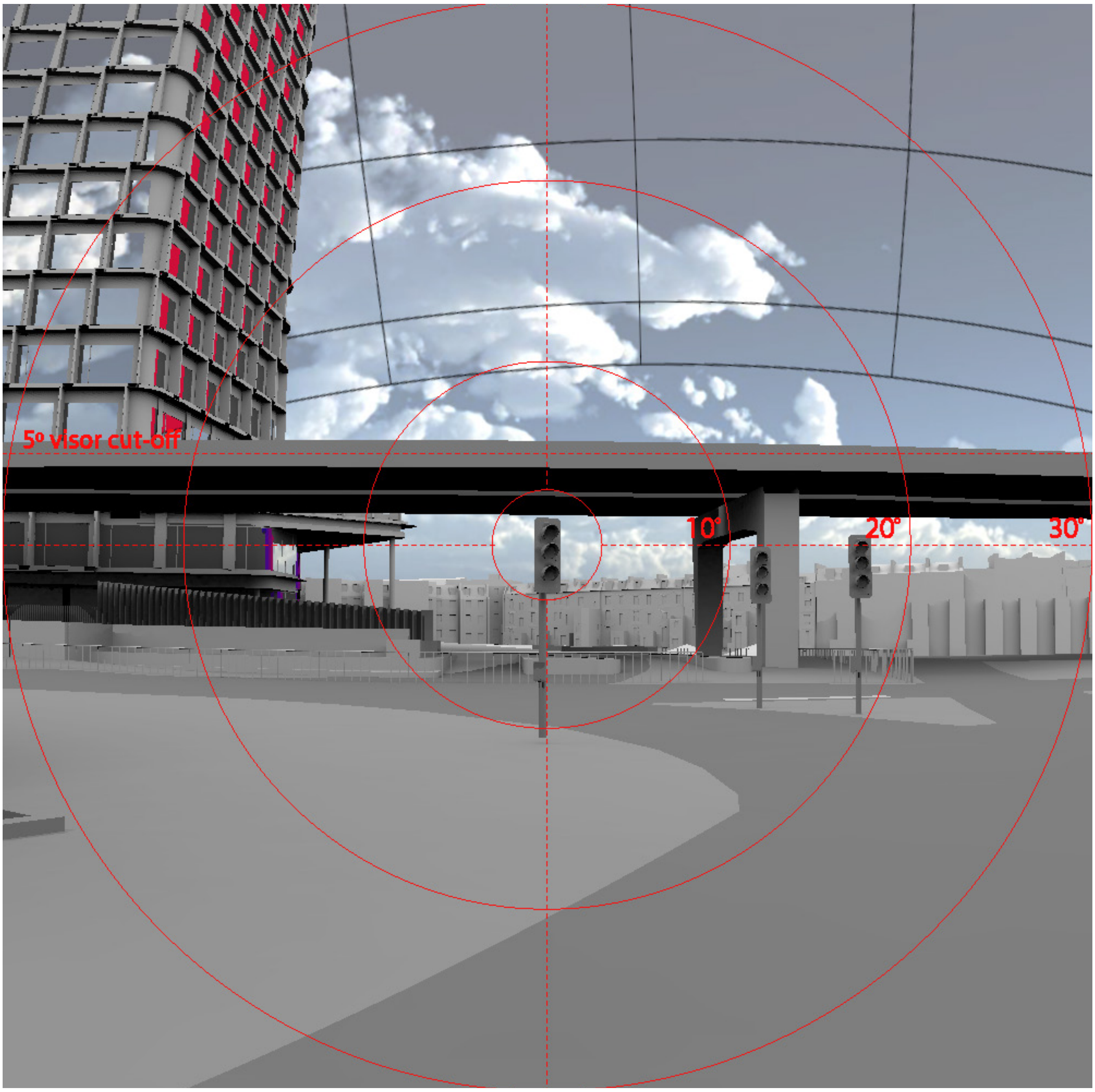
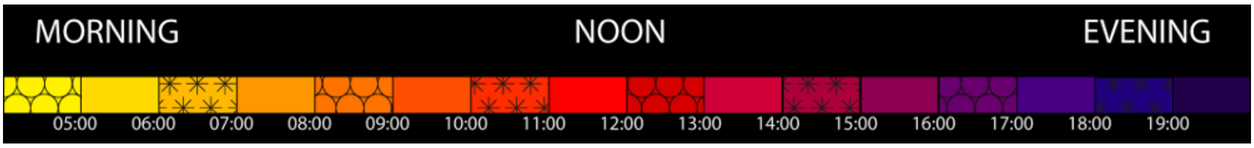



Fig. 14: Solar reflections



## 60° FIELD OF VIEW: SEASON
## VIEWPOINT N1A

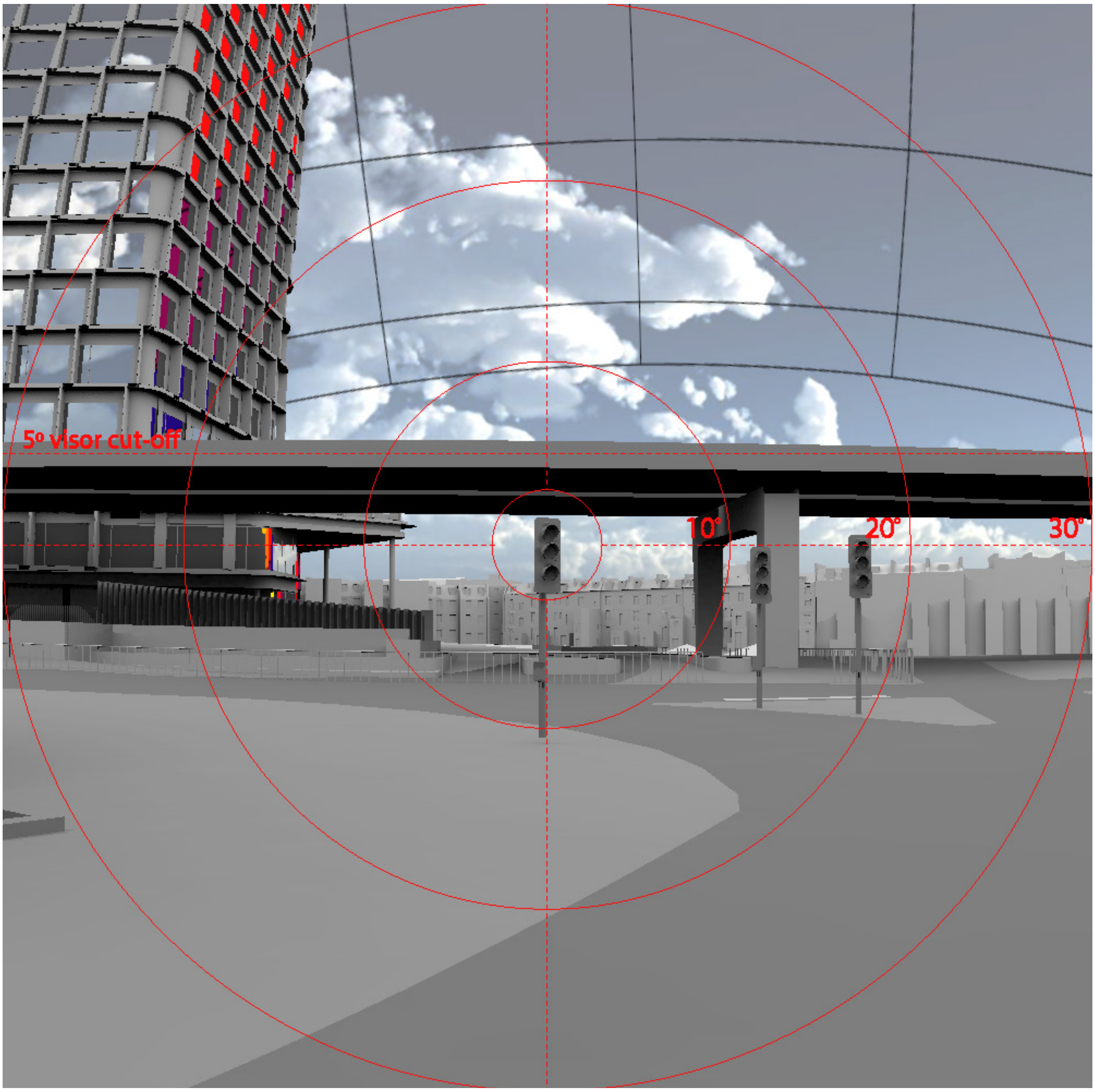



Fig. 15: Solar reflections

## 60° FIELD OF VIEW: TIME OF DAY
**VIEWPOINT N1B**

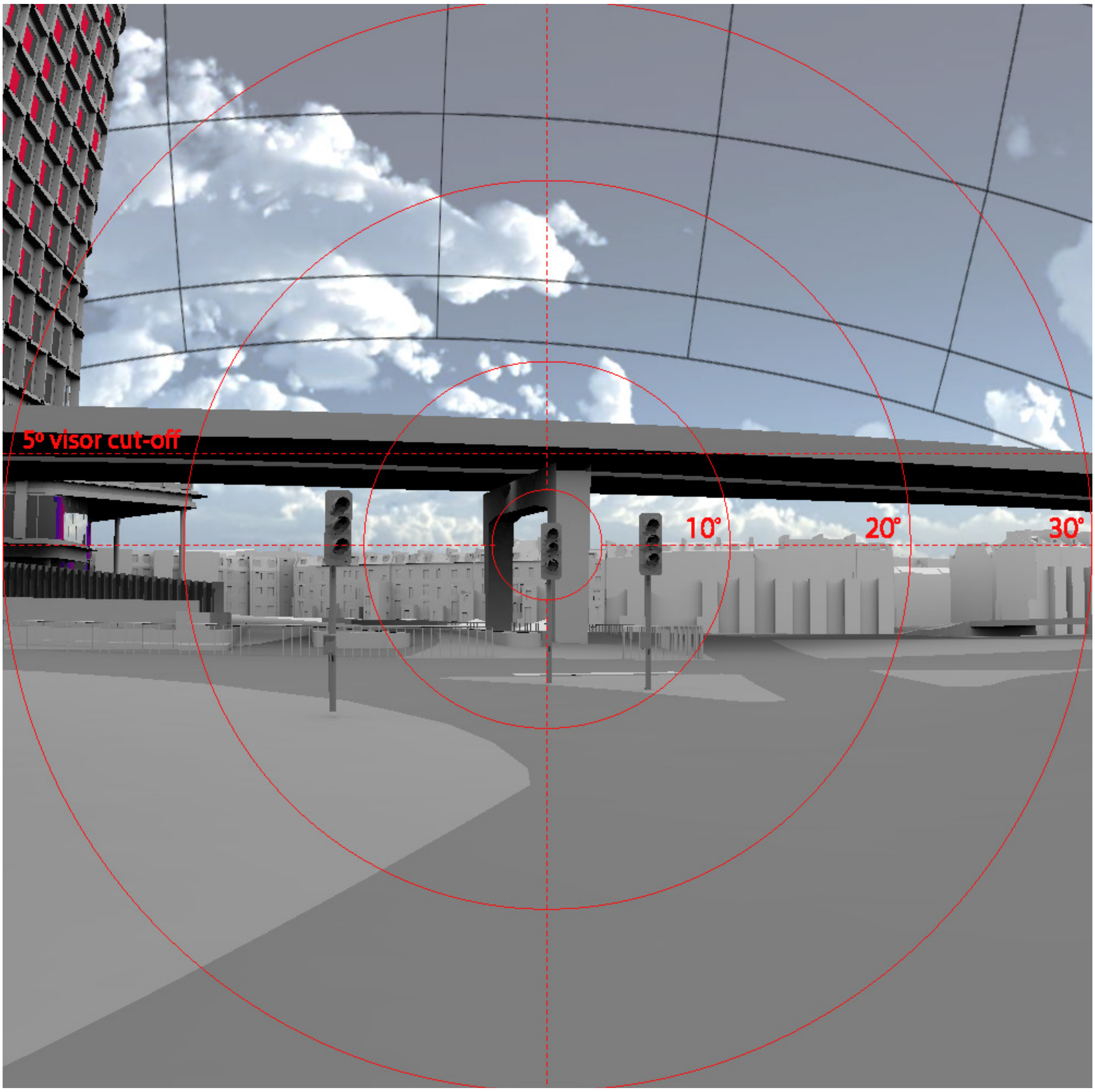
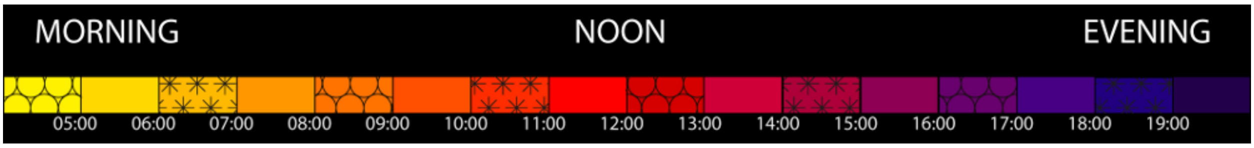



Fig. 16: Solar reflections



## 60° FIELD OF VIEW: SEASON
**VIEWPOINT N1B**

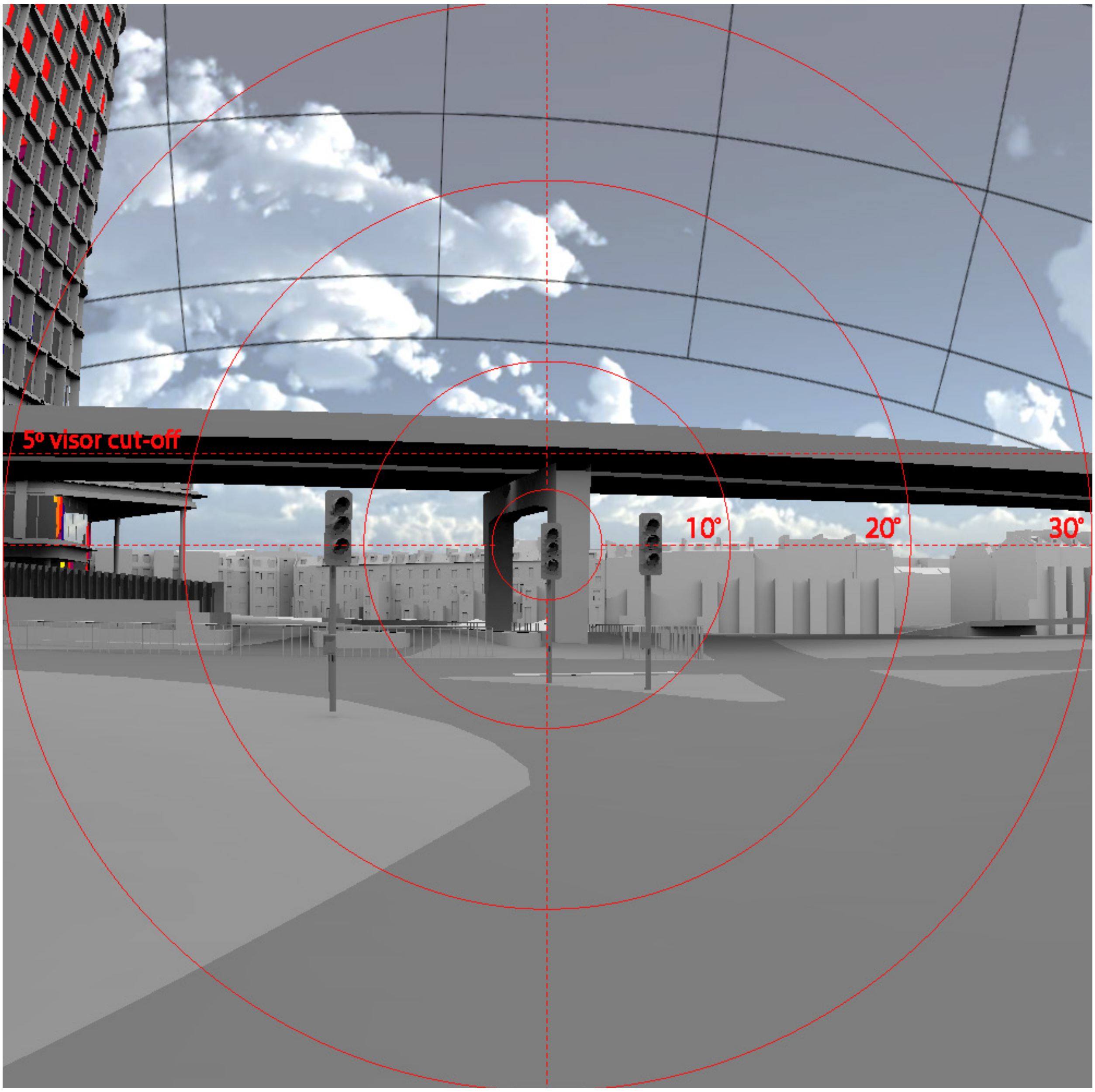



Fig. 17: Solar reflections

## 60° FIELD OF VIEW: TIME OF DAY
## VIEWPOINT SE1A

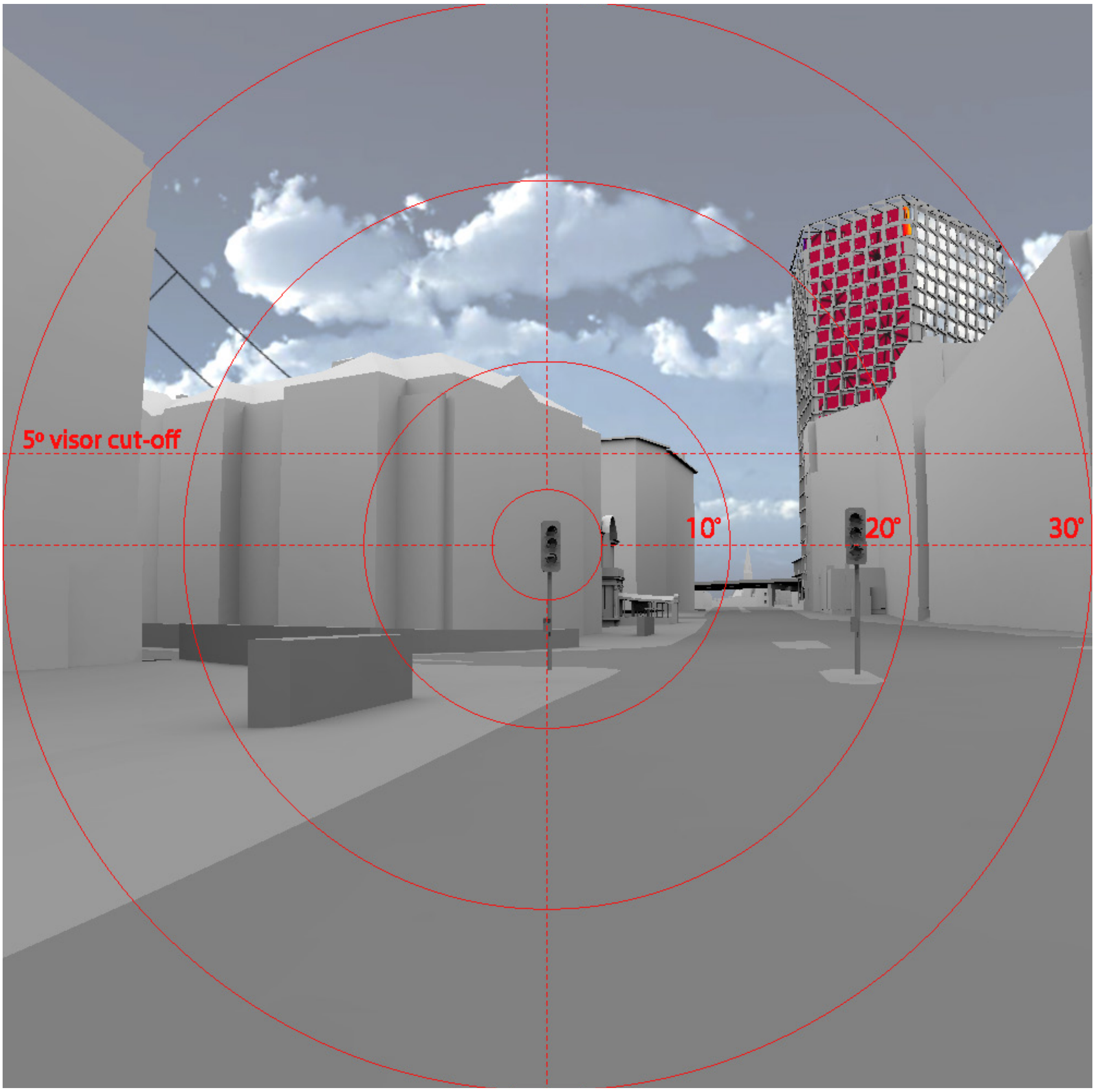
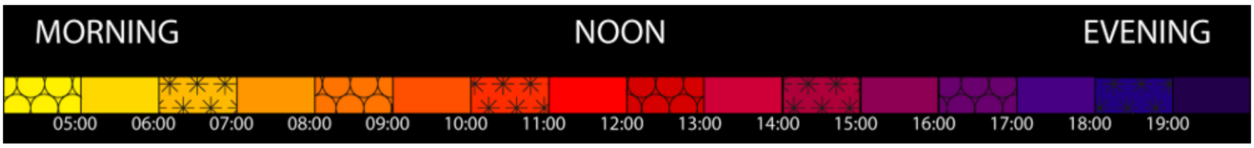



Fig. 18: Solar reflections



## 60° FIELD OF VIEW: SEASON
### VIEWPOINT SE1A

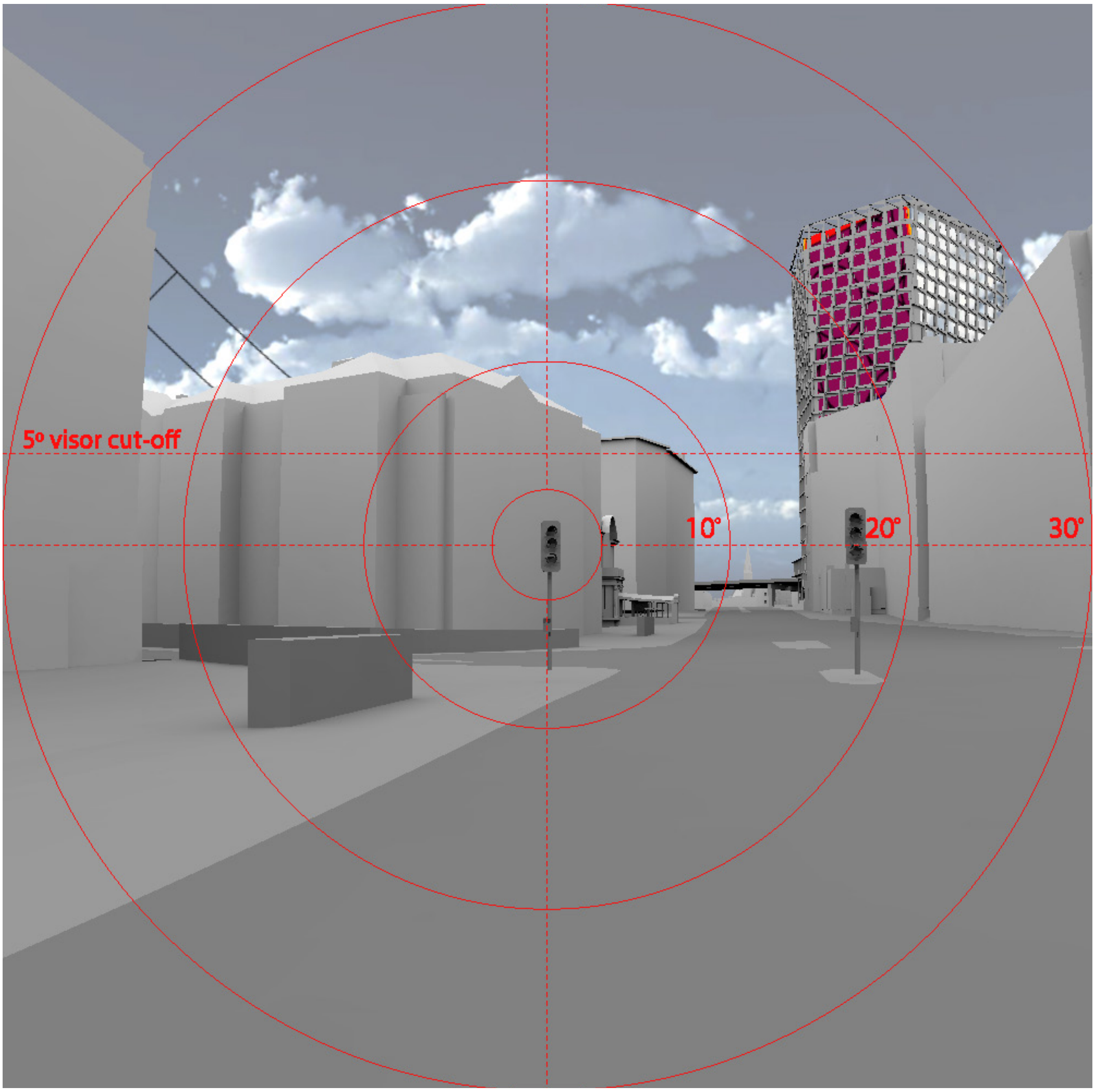



Fig. 19: Solar reflections

## 60° FIELD OF VIEW: TIME OF DAY
## VIEWPOINT SE1B

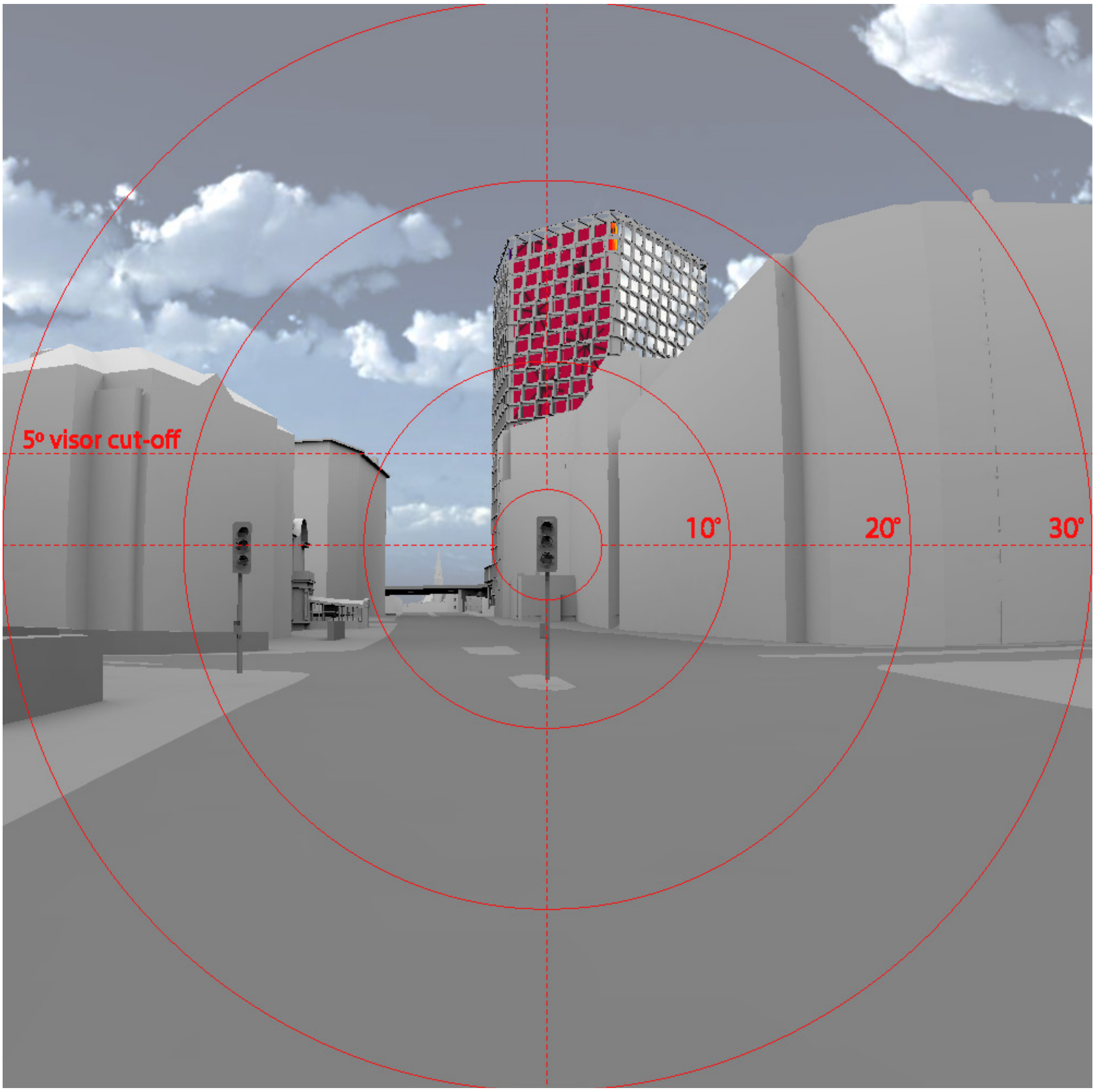
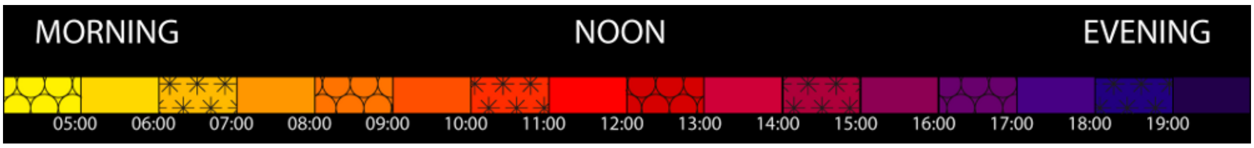



Fig. 20: Solar reflections



## 60° FIELD OF VIEW: SEASON
## VIEWPOINT SE1B

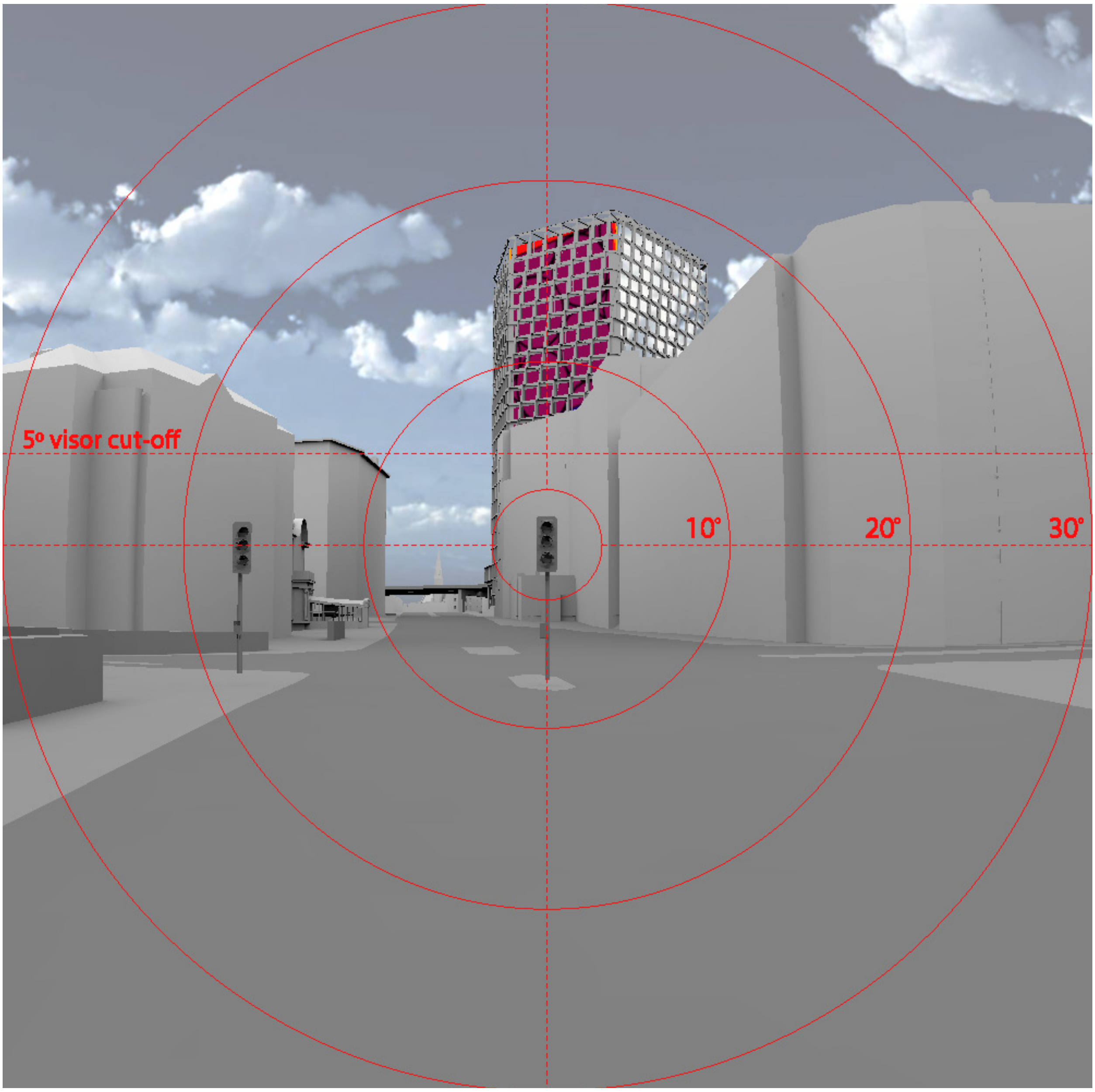



Fig. 21: Solar reflections

## 60° FIELD OF VIEW: TIME OF DAY
### VIEWPOINT SE2

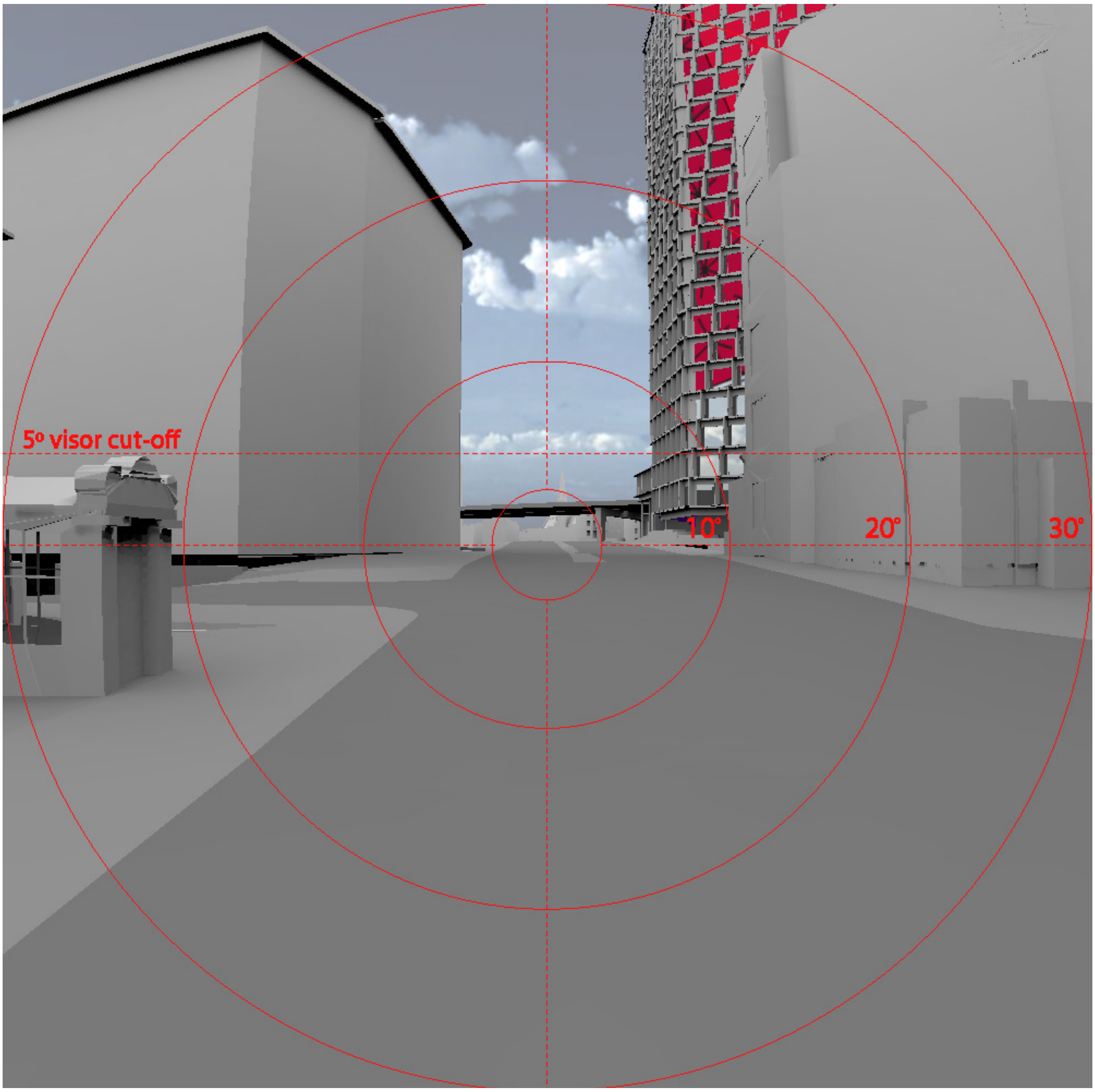
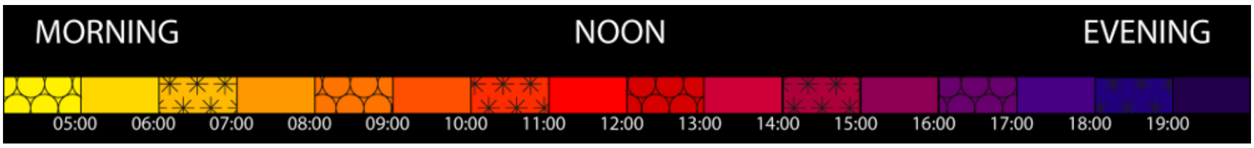



Fig. 22: Solar reflections



## 60° FIELD OF VIEW: SEASON
### VIEWPOINT SE2

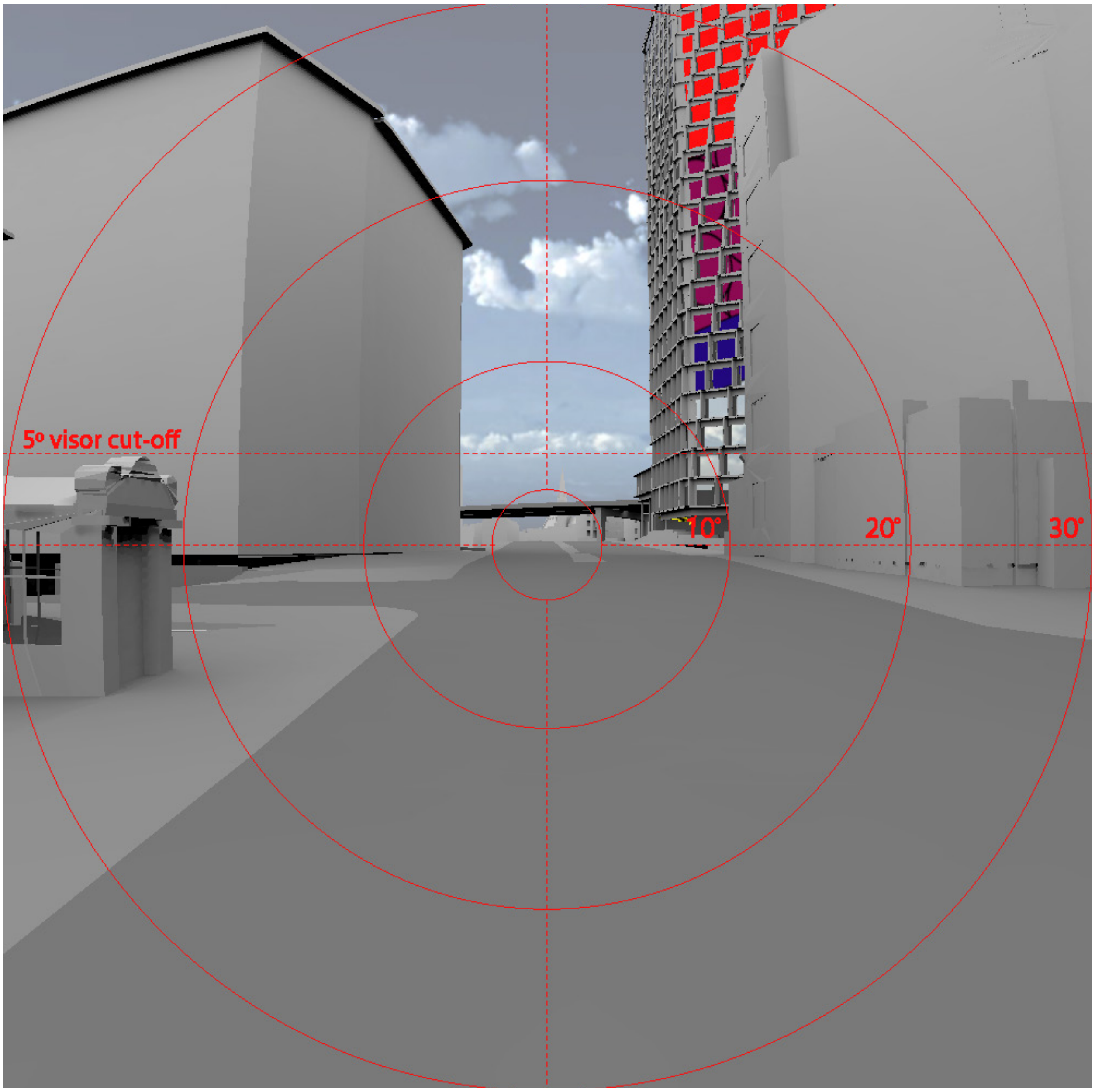



Fig. 23: Solar reflections

## 60° FIELD OF VIEW: TIME OF DAY
### VIEWPOINT SW1

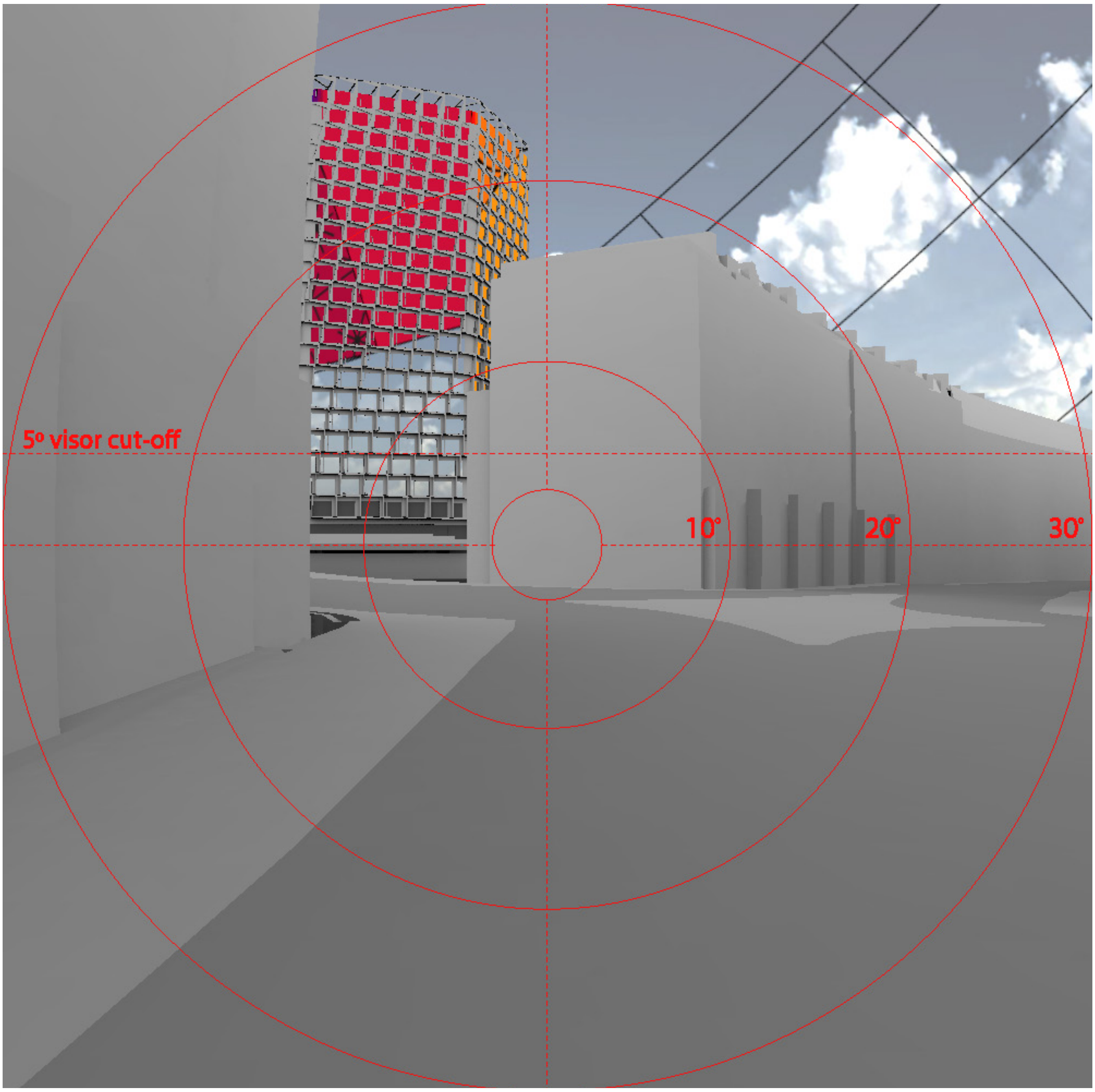
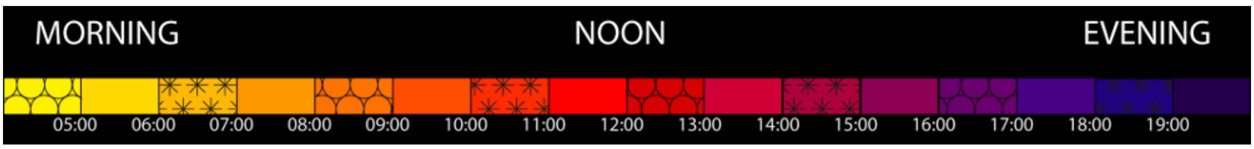



Fig. 24: Solar reflections



## 60° FIELD OF VIEW: SEASON
### VIEWPOINT SW1

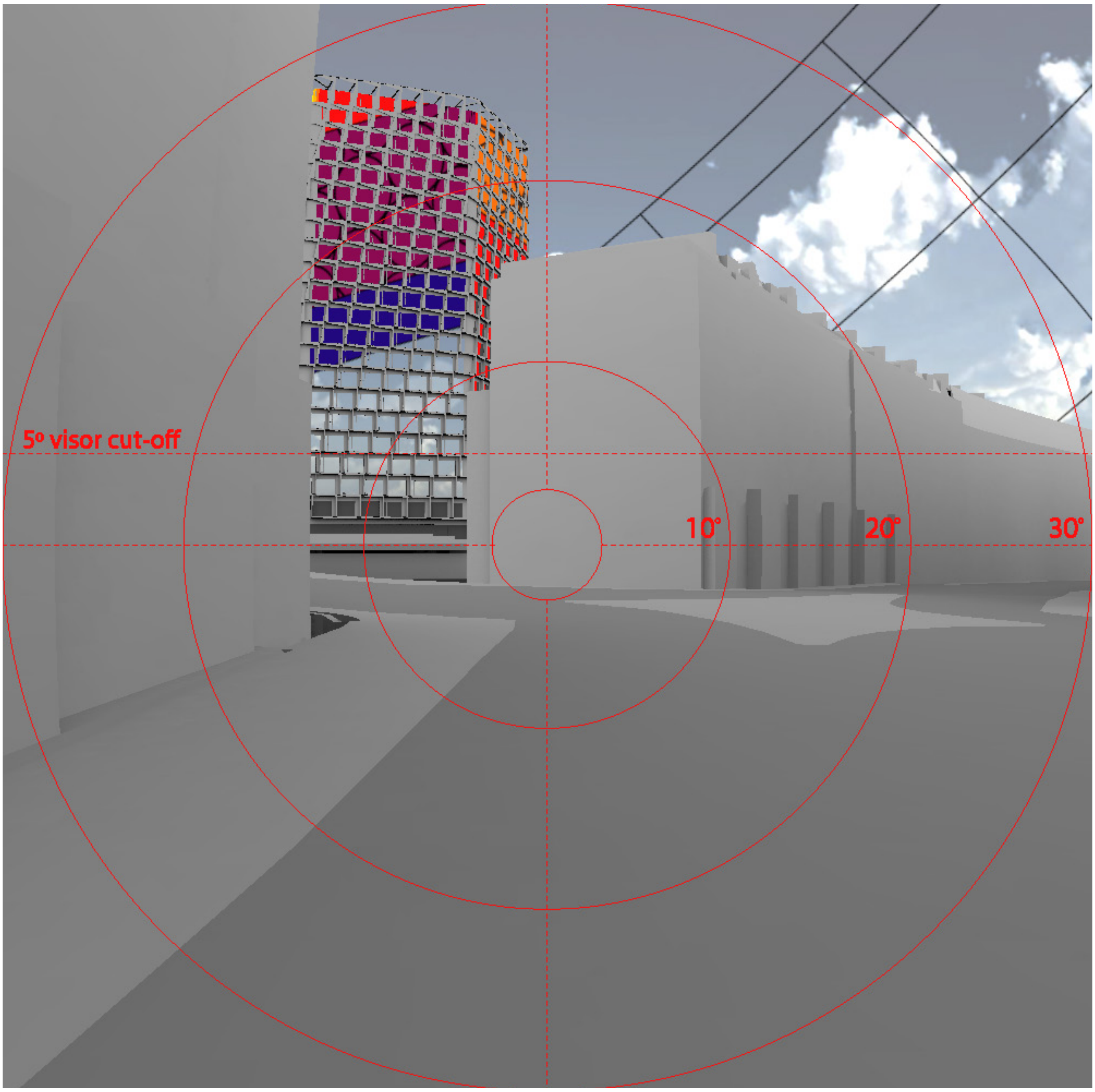



Fig. 25: Solar reflections

## 60° FIELD OF VIEW: TIME OF DAY
### VIEWPOINT W1

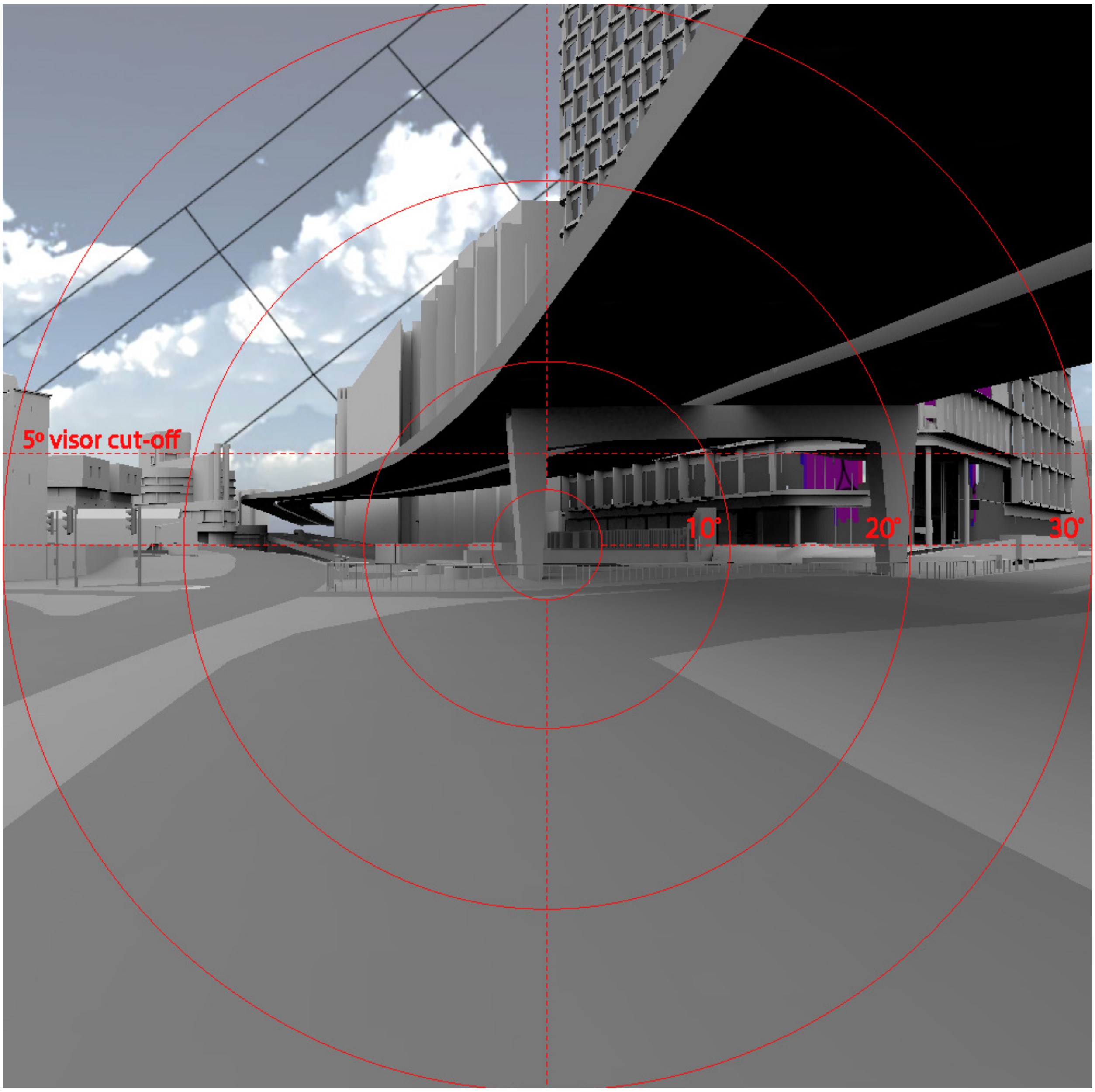
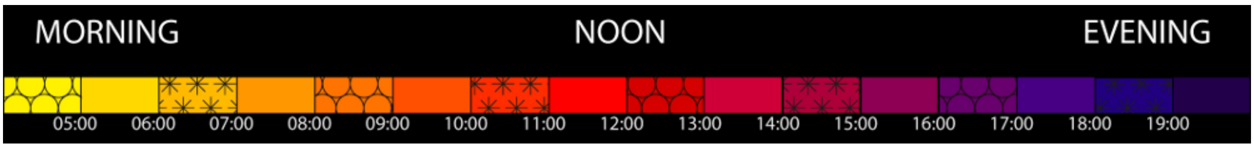



Fig. 26: Solar reflections



## 60° FIELD OF VIEW: SEASON
### VIEWPOINT W1

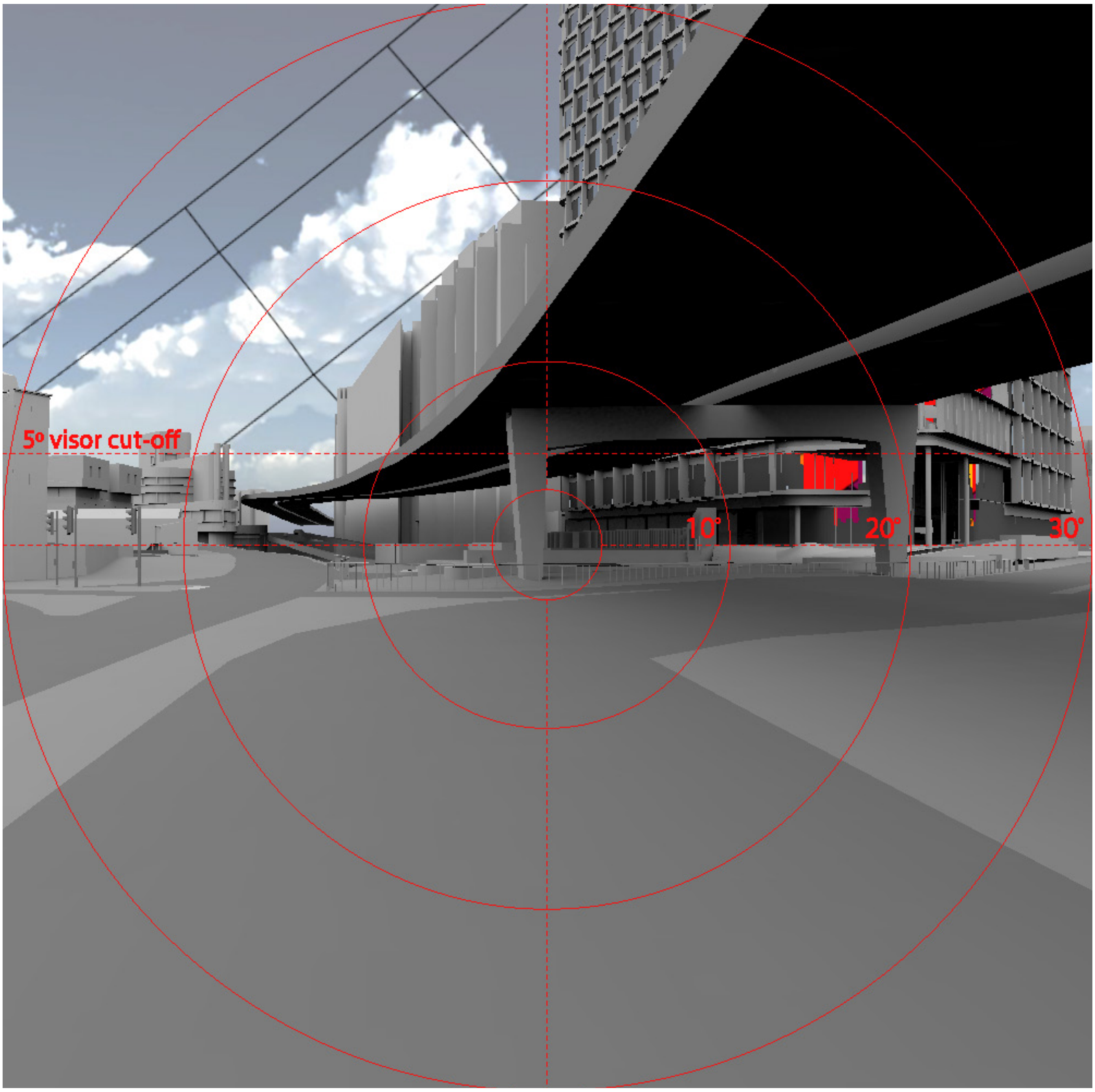



Fig. 27: Solar reflections

## 60° FIELD OF VIEW: TIME OF DAY
## VIEWPOINT W2

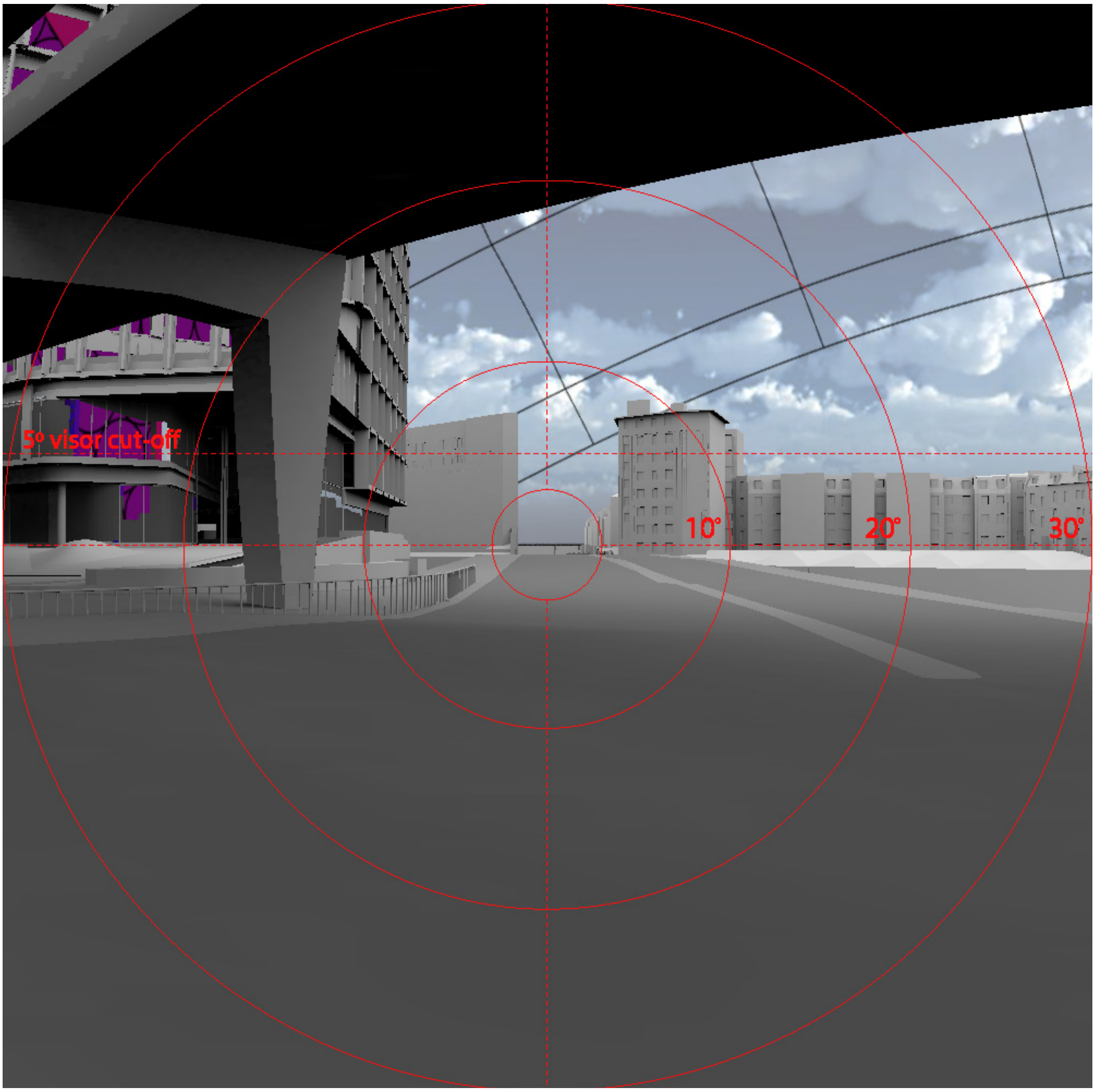
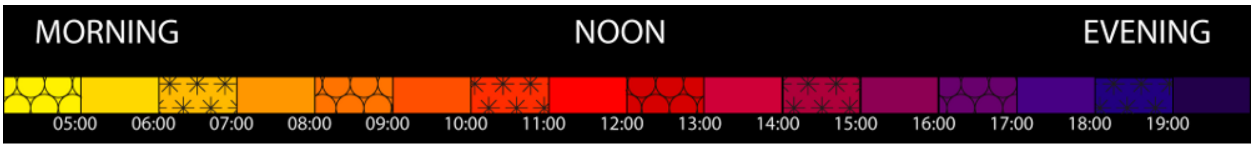



Fig. 28: Solar reflections



## 60° FIELD OF VIEW: SEASON
### VIEWPOINT W2

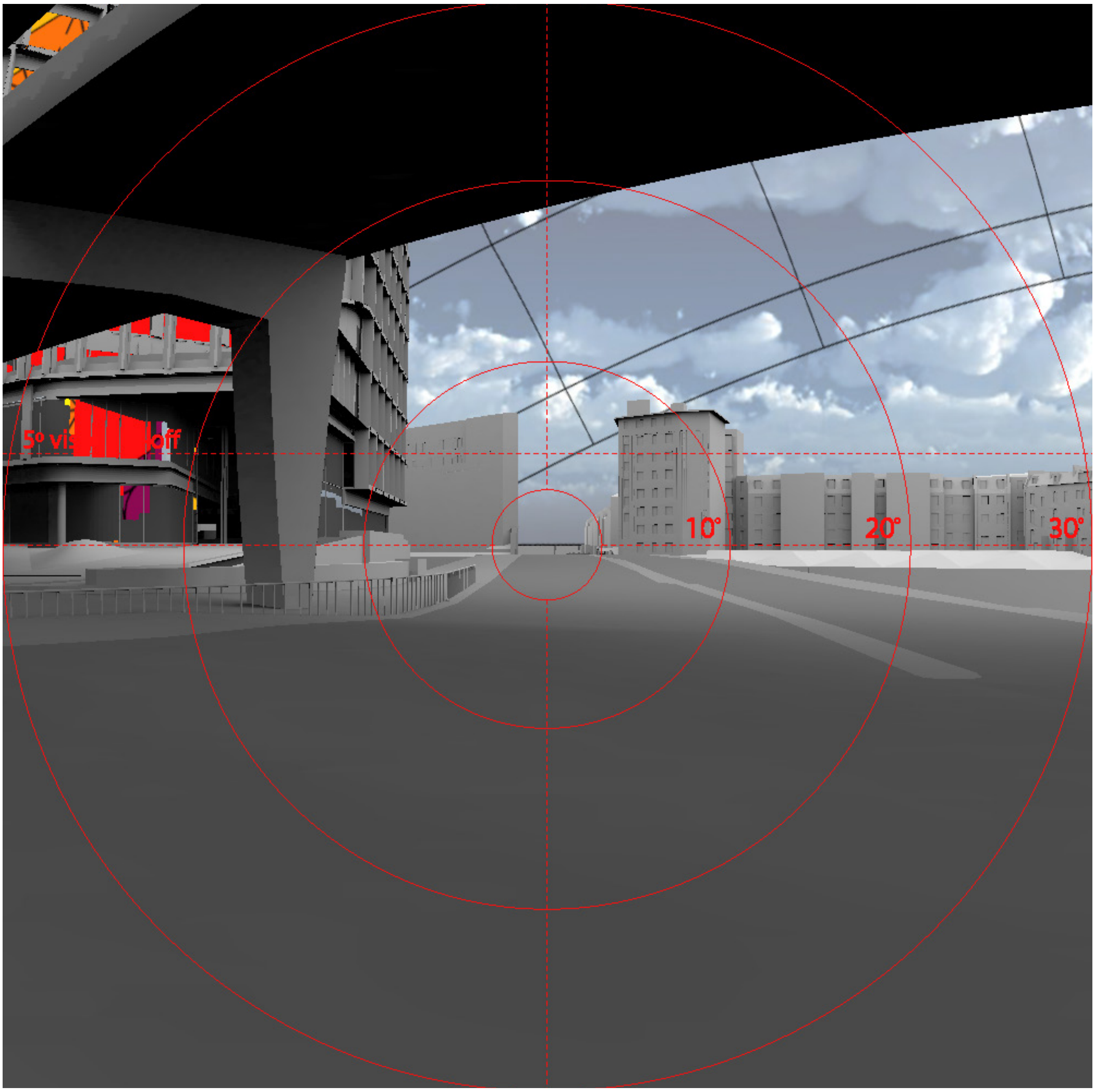



Fig. 29: Solar reflections

**60° FIELD OF VIEW: TIME OF DAY**
**VIEWPOINT W3**

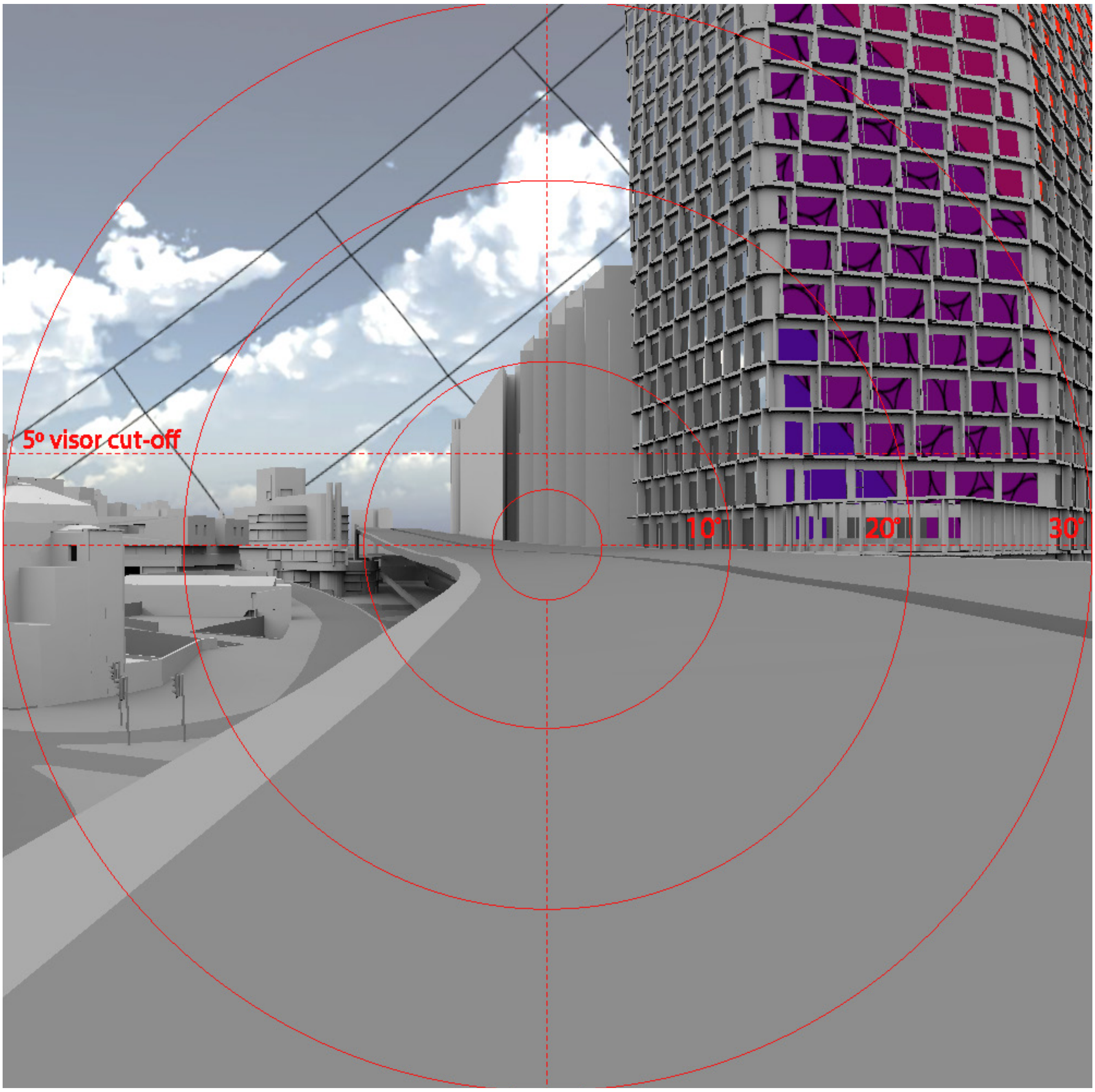
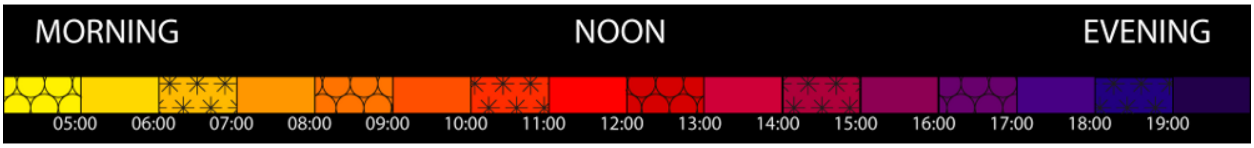



Fig. 30: Solar reflections



## 60° FIELD OF VIEW: SEASON
## VIEWPOINT W3

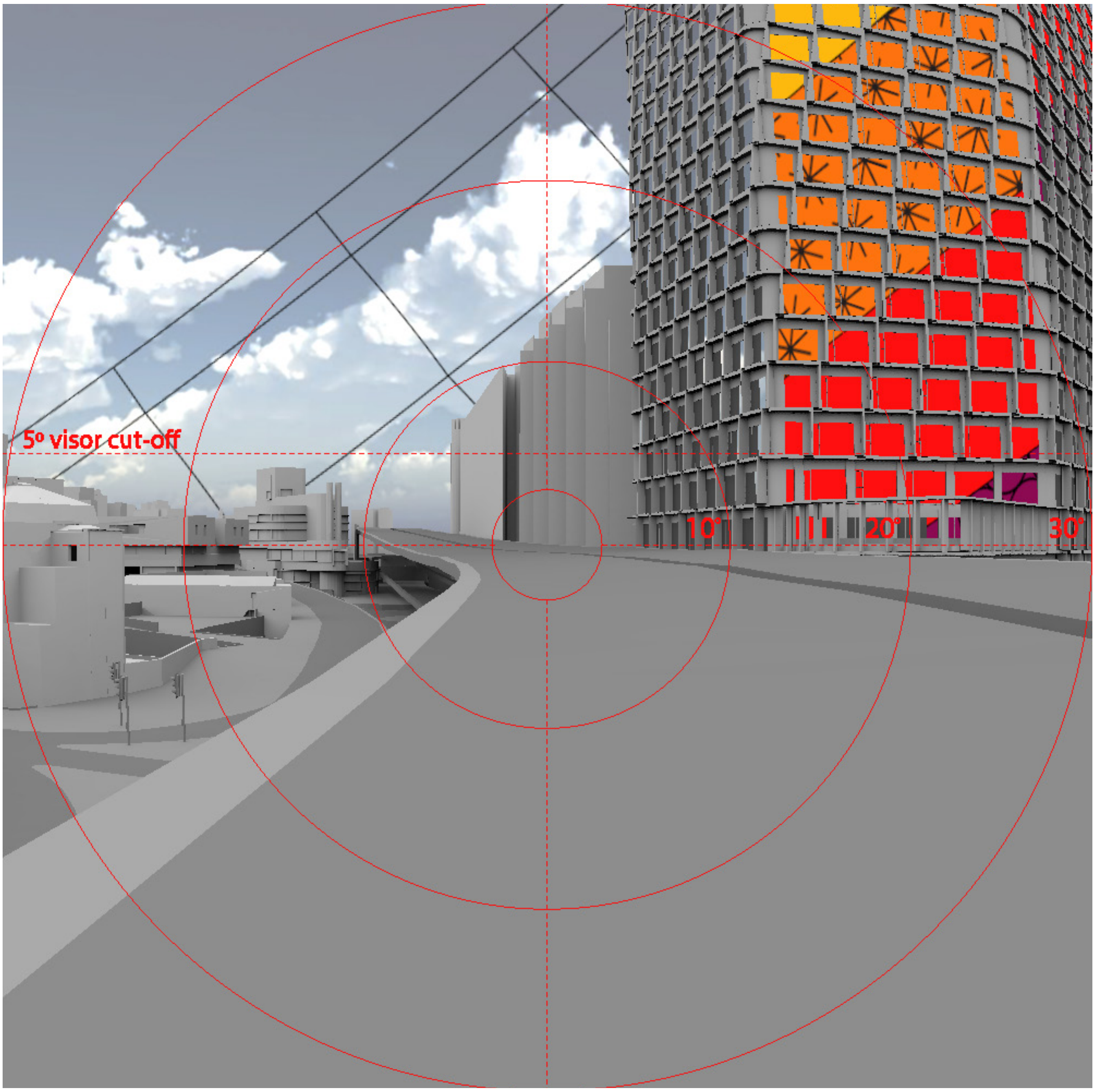



Fig. 31: Solar reflections

## 60° FIELD OF VIEW: TIME OF DAY
### VIEWPOINT TW1

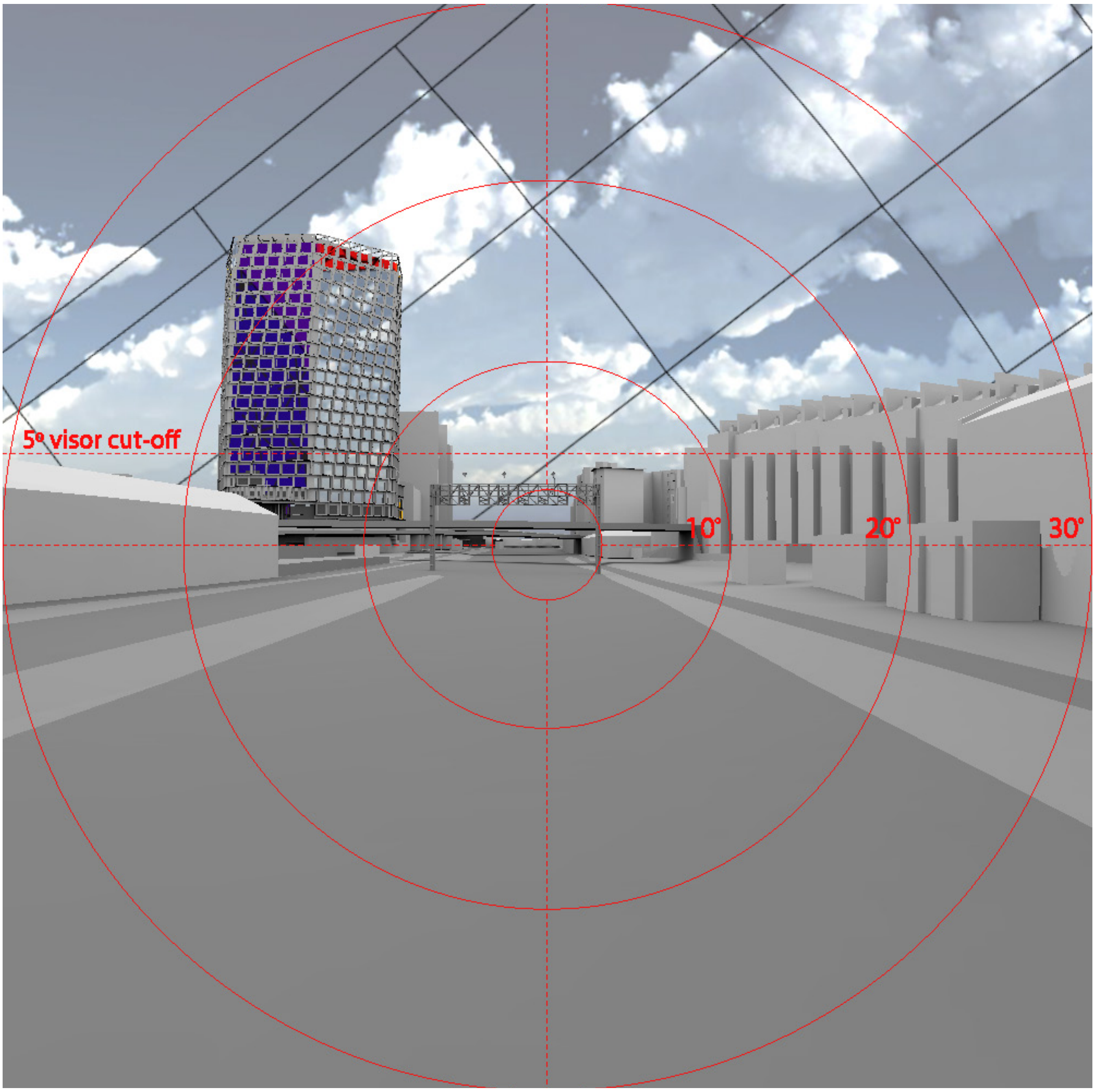
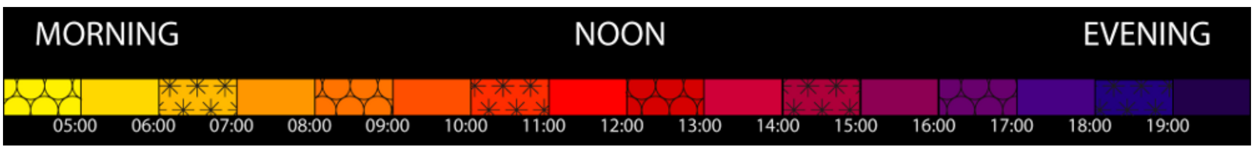



Fig. 32: Solar reflections



## 60° FIELD OF VIEW: SEASON
### VIEWPOINT TW1

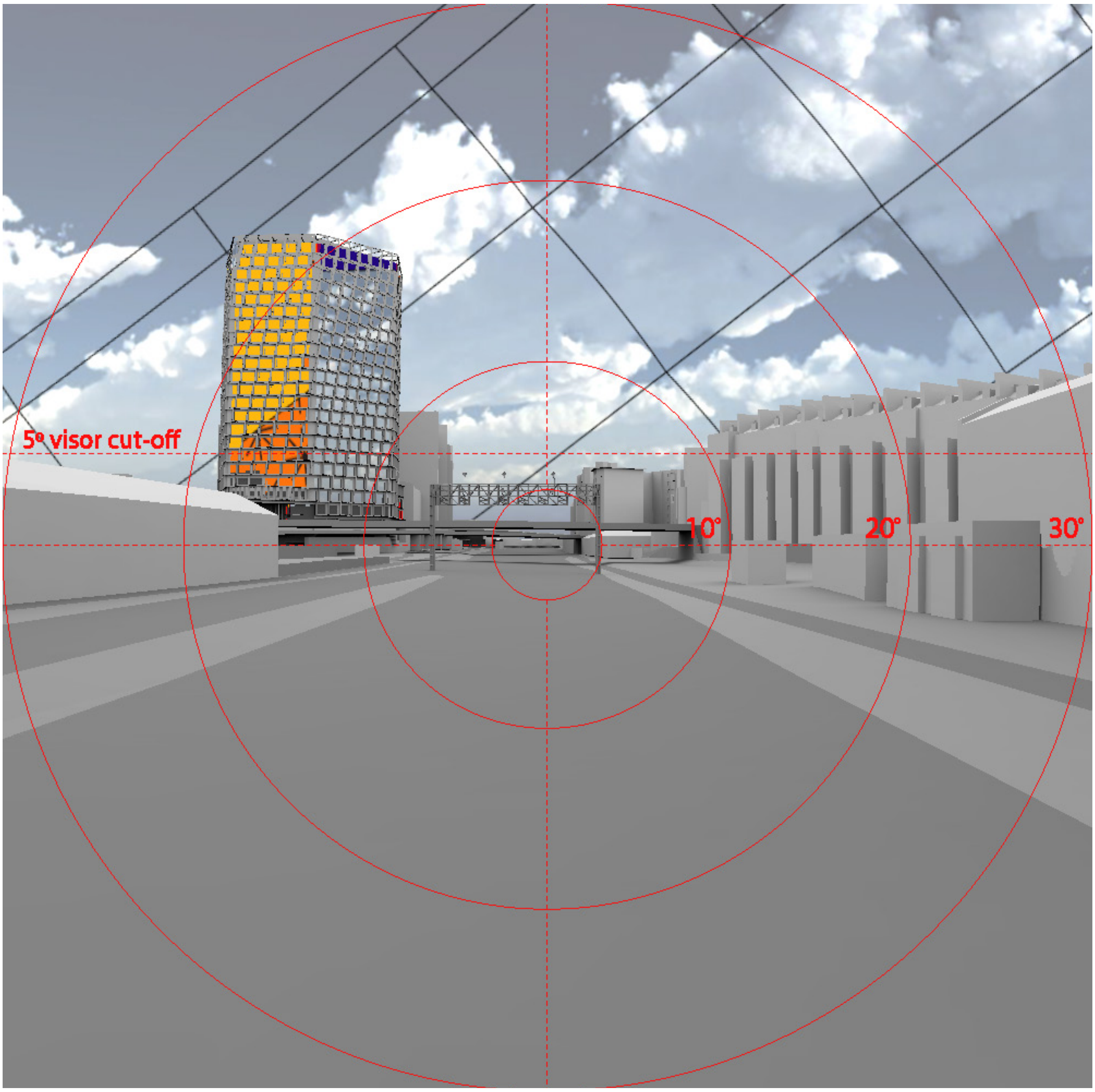



Fig. 33: Solar reflections

## 60° FIELD OF VIEW: TIME OF DAY
## VIEWPOINT TW2

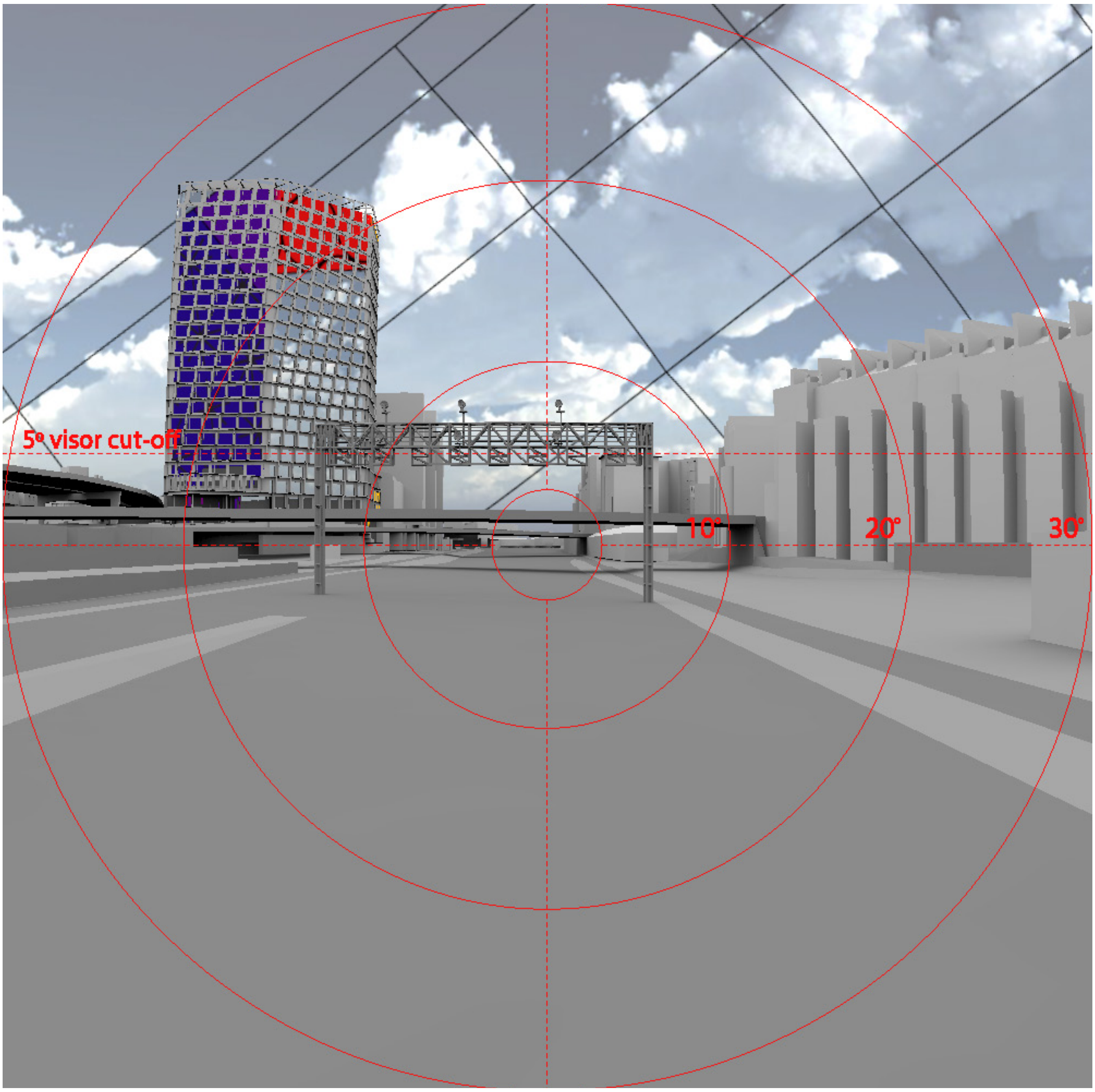
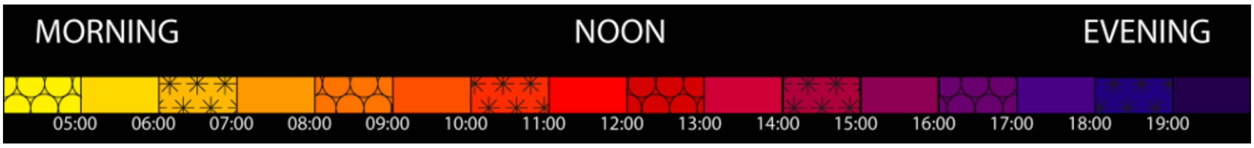



Fig. 34: Solar reflections



## 60° FIELD OF VIEW: SEASON
### VIEWPOINT TW2

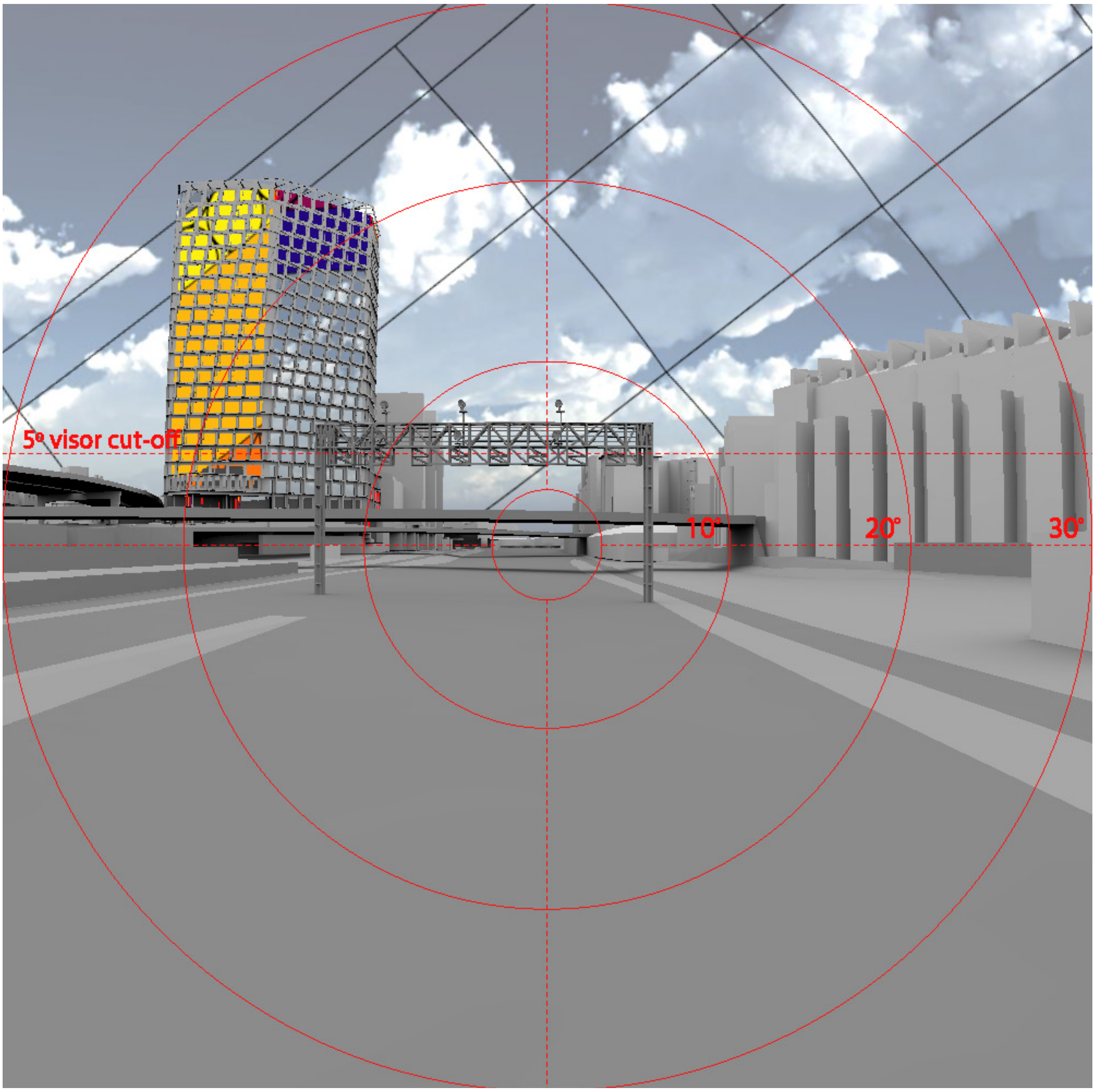



Fig. 35: Solar reflections

## 60° FIELD OF VIEW: TIME OF DAY
## VIEWPOINT TW3

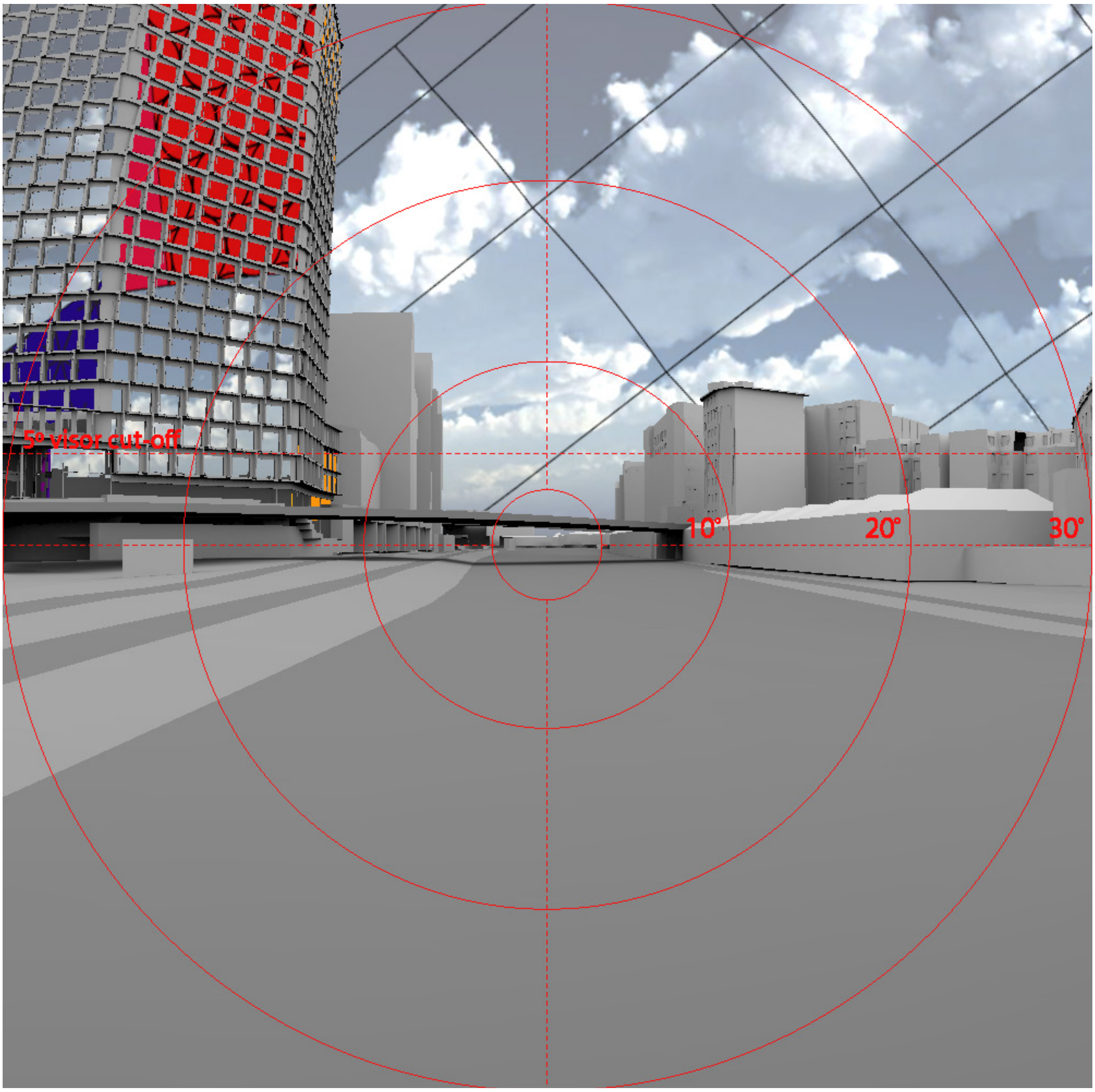
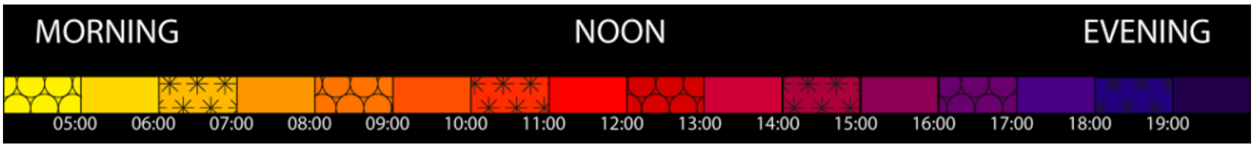



Fig. 36: Solar reflections



## 60° FIELD OF VIEW: SEASON
## VIEWPOINT TW3

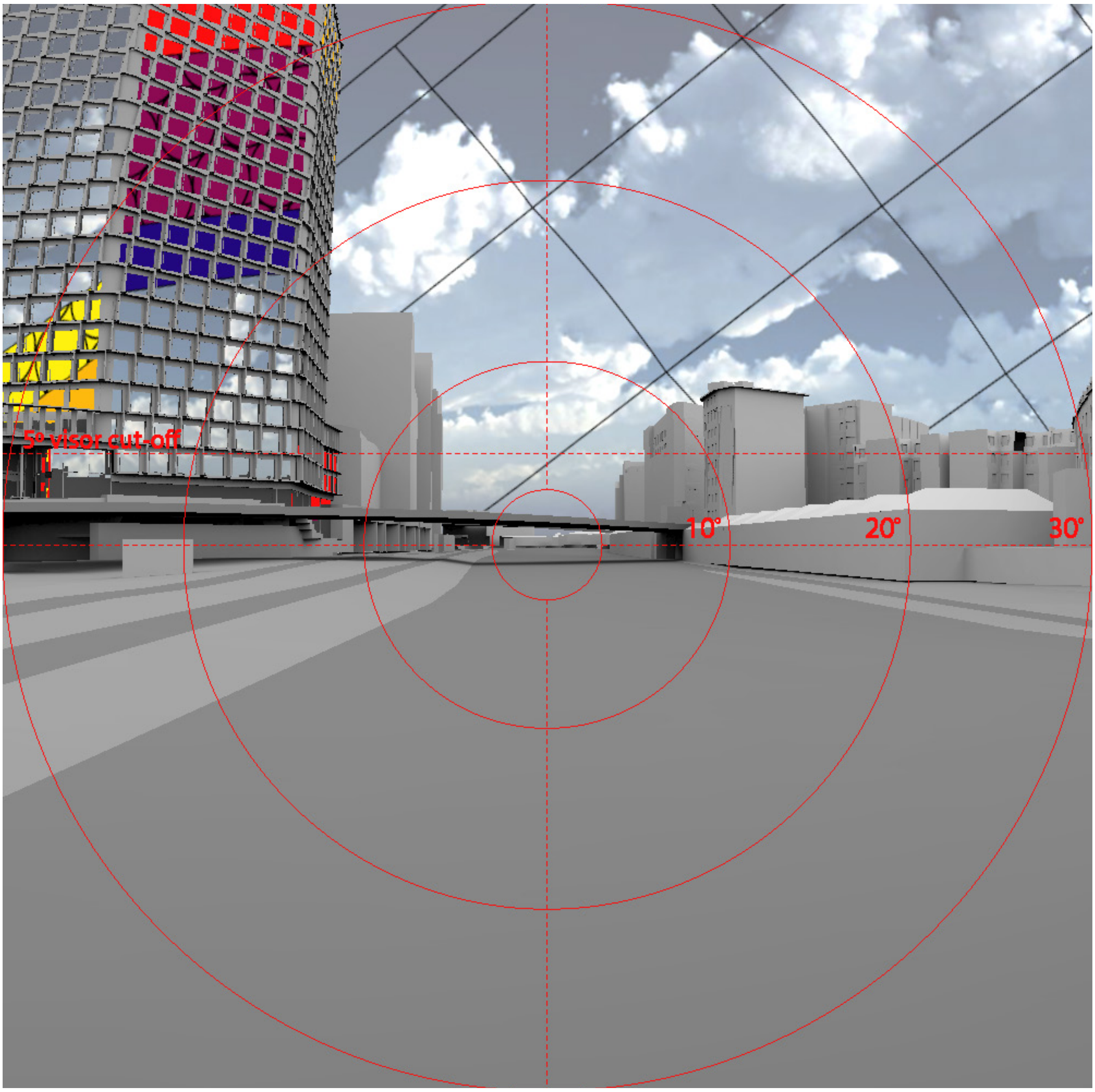



Fig. 37: Solar reflections

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