An outstanding contribution of structural membranes to efficiency and sustainability is their tensile behaviour that prevents bending. Bending is expensive as it was already clear in the 50s pioneering experiences of Frei Otto and his team. But many designs do not take it into account to the point that membrane structures frequently end up being conventional steel structures.

Two completely different structural conceptions based on flexibility and lightness avoiding/reducing bending and compression (left) or rigidity and massiveness (right).

However, progress is being made in the understanding of the appropriateness of membrane structures, led by lightweight large-scale sport stadium roofs. They expand all over the world imposing the tensile bicycle wheel as a much more efficient structure than bending solutions based on trusses and cantilevers.

According to M.Birchall (1) various research into the weight of a stadium roof primary structure has concluded that a tensile bicycle wheel design is lighter than an equivalent bending solution and cheaper if the following conditions are met:

• the stadium is at least medium sized $\geq 40,000$ spectators.
• curvature in plan and vertical depth are convenient.
• the roof cladding is a lightweight fabric membrane.

Small and medium-size tensile structures have also proved to be efficient avoiding bending, stiffness and massiveness and limiting buckling by using circular hollow steel sections improved by tapering, trussing, tying or coupling.
gmp with sbp and Maffeis Engineering, 2018: Nizhny Novgorod Stadium

sbp and Maffeis Engineering, 2018: Volgograd Arena

10 x 10 m Span structure limiting the bending to the perimeter. Observe the application of flying masts

20 m Span structure based on tensegrity principles

References