Dendritic Web (WEB) production and the Ribbon Growth on Substrate (RGS) technique are moving to pilot demonstration phases. A summary of the changes in the status of leading ribbon/foil technologies over the past decade and projections for manufacturing capacities are given in Table 6.3. It is anticipated that the ribbon production will contribute in excess of 30 MW of wafers to world solar energy markets by the end of 2001.

Development has not been continuous for most of the methods listed above. The R&D has been interrupted and then restarted in several cases when the technological status changed to generate new opportunities for cost-effective production. EFG development has the longest continuous history. After initial technology development on EFG started at Tyco Laboratories in 1971, it was subsequently augmented with funding from Mobil Oil, starting in 1974. In the time span from 1971 to the present, pilot lines using five different variations of the EFG process have been evaluated, starting with single ribbons in 1971 to the octagonal crystal tube now being commercialised. Ownership transferred to ASE Americas in 1994, at which time the transition to manufacturing was initiated. After periods of decreased activity, WEB, STR and RGS have all been strengthened with R&D in the past several years subsequent to being revitalised by new owners. WEB development was initiated with funding from Westinghouse in the 1970s, but now is being carried out by EBARA Solar. STR technology underwent an R&D phase in the early 1980s under the name of Edge-Stabilised Ribbon (ESR) and Edge-Supported Pulling (ESP) at the National Renewable Energy Laboratory and at Arthur D. Little, respectively, before being taken up in 1994 by Evergreen Solar. RGS development was initiated at Bayer, but is currently continuing with ECN of the Netherlands. If successful, a future commercialisation is anticipated by Deutsche Solar in Germany and Sunergy in the Netherlands.

Ribbon and foil technologies must meet the challenges of the photovoltaic marketplace and overcome a number of existing technical barriers if they are to continue to expand manufacturing and to position themselves to remain competitive in the next decade. Challenges to be met are productivity increases on a per furnace basis to drive down labour and overhead (capital) costs, improved mechanical and electronic quality of ribbon wafers together with the development of low-cost solar cell designs that will raise efficiencies to 18 to 20% and reduction of wafer thickness while maintaining high yields in order to reduce demand on silicon feedstock. Achievement of these goals in the next decade can lead to cost decreases, which will drive additional volume expansion for

Table 6.3 Historic record on R&D and manufacturing status of leading ribbon/foil technologies of the past decade

Wafer process/ year started	1990 status level		2000	2001	Schematic
WEB/1967	R&D	<0.1 MW	R&D <0.2 MW	Pilot −0–1 MW	Figure 6.20
EFG/1971 (Ribbon); 1988 (Octagon)	Pilot	1.5 MW	Production −12 MW	Production −20 MW	Figure 6.21
ESP (STR)/1980	R&D	–	Pilot <0.5 MW	Production <5 MW	Figure 6.23
SF/1983	–	–	Pilot −1–2 MW	Production >5 MW	–
RGS/1983	R&D	–	R&D	Pilot <1 MW	Figure 6.24